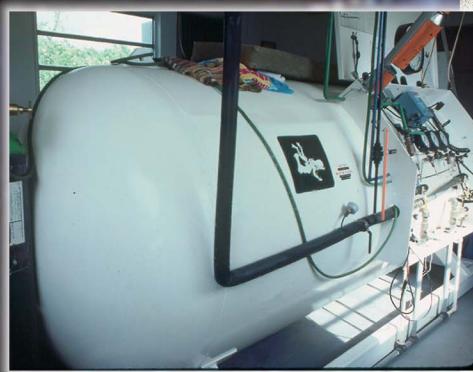


Management of Mild or Marginal Decompression Illness in Remote Locations



Workshop Proceedings





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May 24-25, 2004

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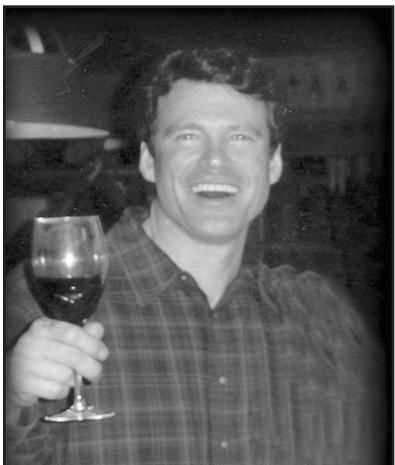
Dedication



Anthony Slark, M.D.

Surgeon Commodore Anthony George Slark RNZN died after a short illness on 24 May 2004 at Auckland. Tony was born in the United Kingdom and joined the Royal New Zealand Navy from London in 1956. It is said that his involvement in diving medicine began in 1957 when his Surgeon Captain handed him a posting order and proclaimed "read this my boy, you are to be the doctor to the divers". From this time, to his retirement in May 1988 Tony diligently served New Zealand's exuberant diving population. Few diving physicians would have seen more sick divers in the course of their careers, and his credibility was all the greater for his own active participation in the sport. In addition to his clinical work, Tony mentored many young diving physicians including

one of this workshop's co-chairs (SJM), and was considered by all with whom he came into contact as an invariably charming and approachable man. Indeed, Tony has rightly come to be known as the "father figure" of diving medicine in New Zealand. This was officially acknowledged when New Zealand's premiere diving medicine unit at the Royal New Zealand Navy Hospital was named after him in 1990. Tony would have reveled in the groundbreaking discussions that took place at this 2004 UHMS Workshop, and it is with a true sense of honor that we make this dedication. Vale Tony Slark.



William Turbeville, J.D.

Bill Turbeville passed away in January 2004 from an inoperable brain tumor. He had been scheduled to provide legal opinion at this conference and was deeply disappointed that his illness prevented him from attending. Bill had dedicated the majority of his legal practice to improving diving safety, the sport he loved, and he was considered one of the best in the field of diving risk management and defense. Because Bill was an experienced technical diver, his advice was highly valued by diving industry leaders across its many disciplines. His guidance helped shape many training programs and industry workshops, and he was respected equally by his defense legal peers and by opposing counsel. Diving has lost a great colleague and friend who will be remembered fondly for his honesty, directness, wit, and warm personality.

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The presenters for their time and effort in preparing and delivering this excellent series of papers.

The invited discussants and workshop attendees for taking the time out of busy schedules to attend and provide commentary.

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Dr. Mike Bennett and the Organizing Committee of the UHMS Annual Scientific Meeting for their facilitation of this event.

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FINAL CONSENSUS STATEMENTS

*Discussant Group
Consensus Session
Sydney*

Consensus Statement 1

With respect to decompression illness (DCI), the workshop defines "mild" symptoms and signs as follows:

- limb pain^{1,2}
- constitutional symptoms
- some cutaneous sensory changes³
- rash

where these manifestations are static or remitting^{4,5} and associated objective neurological dysfunction has been excluded by medical examination.

Footnotes

1. The workshop agrees that severity of pain has little prognostic significance, but acknowledges that severity of pain may influence management decisions independent of the classification of pain as a "mild" symptom.
2. Classical girdle pain syndromes are suggestive of spinal involvement and do not fall under the classification of "limb pain."
3. The intent of "some cutaneous sensory changes" is to embrace subjective cutaneous sensory phenomena such as paraesthesiae that are present in patchy or non-dermatomal distributions suggestive of non-spinal, non-specific, and benign processes. Subjective sensory changes in clear dermatomal distributions or in certain characteristic patterns such as in both feet, may predict evolution of spinal symptoms and should not be considered "mild."
4. The proclamation of "mild" cannot be made where symptoms are progressive. If the presentation initially qualifies as mild and then begins to progress, it is no longer classified as "mild" (see also Footnote 5).
5. The possibility of delayed progression is recognised, such that the "mild" designation must be repeatedly reviewed over at least the first 24 hours following diving or the most recent decompression, the latter applying if there has been an ascent to altitude. Management plans should include provisions for such progression.

Consensus Statement 2

The workshop accepts that untreated mild symptoms and signs¹ due to DCI are unlikely to progress after 24 hours from the end of diving.²

Footnote

1. Mild symptoms and signs are strictly limited to those defined in Statement 1 and its footnotes.
2. This statement does not hold where there is a further decompression, such as further diving or ascent to altitude, in the presence of mild symptoms.

Consensus Statement 3

Level B epidemiological¹ evidence indicates that a delay prior to recompression for a patient with mild DCI² is unlikely to be associated with any worsening of long term outcome.

Footnotes

1. Levels of evidence in American Family Physician [Internet]. [Leawood(KS)]: American Academy of Family Physicians; c2004 [Cited 2004 Dec 6]. Available at: <http://www.aafp.org/x17444.xml>
2. "Mild DCI" is limited to those presentations exhibiting only "mild symptoms and signs" strictly as defined in Statement 1 and footnotes.

Consensus Statement 4

The workshop acknowledges that some patients with mild symptoms and signs after diving¹ can be treated adequately without recompression. For those with DCI, recovery may be slower in the absence of recompression.

Footnote

1. The non-specific reference to "mild symptoms and signs after diving" is intentional. It reflects the fact that the manifestations may or may not be the consequence of DCI. The statement suggests that even if they are the result of DCI, full recovery is anticipated irrespective of the use of recompression although resolution may take longer. Importantly, "mild symptoms and signs" are strictly limited to those defined in Statement 1 and footnotes. Where symptoms and signs fall outside the spectrum of manifestations herein defined as "mild," standard management and therapy is indicated.

Consensus Statement 5

The workshop acknowledges that some divers with mild symptoms or signs¹ after diving may be evacuated by commercial airliner to obtain treatment after a surface interval of at least 24 hours, and this is unlikely to be associated with worsening of outcome.^{2,3,4}

Footnotes

1. "Mild symptoms and signs" are strictly as defined in Statement 1 and footnotes.
2. It should be noted that most favourable experience with commercial airliner evacuations comes from short haul flights of between 1 and 2 hours duration. There is much less experience with longer flights.
3. It was agreed that provision of oxygen in as high an inspired fraction as possible is optimal practice for such evacuations. In addition, the risk of such evacuation will be reduced by pre-flight oxygen breathing.
4. It was emphasised that contact must be established with a receiving unit at the commercial flight destination before the evacuation is initiated.

Editorial Notes

Given the title of the workshop and proceedings, the reader who peruses these statements without a full appreciation of the discussion that led to their final wording may be confused by the absence of specific reference to *remote* locations. During the consensus discussion it became clear that ethical and legal concerns could be minimized if guidelines for important management decisions were applicable irrespective of the patient's location. Care was taken to make this so, and the consensus statements therefore do not specifically refer to DCI in remote locations. It is acknowledged, however, that the environmental and logistic characteristics of a remote location (such as weather, aircraft availability or material condition) may need to be considered in management decisions in the interests of patient safety, irrespective of the guidelines promulgated here.

The statements are self explanatory, but the reader should note that some of them are heavily qualified with footnotes. These qualifications are non-negotiable components of the meaning of each statement, and the statements should not be quoted without reference to these footnotes. Of particular importance is the strict definition of mild symptoms and signs in Statement 1 and footnotes. All references to "mild" in the subsequent statements are linked back to this definition. It follows that Statements 2–5 should not be quoted without reference to Statement 1.

Statement 4 is perhaps the pivotal outcome of the workshop. Its intent requires contextual explanation so that the concerns and commentary of the workshop participants are accurately reflected. The statement supports a decision not to recompress for mild symptoms and signs (as defined) after diving where, for example, there is suspicion the symptoms may not be caused by DCI, or where there are logistic or safety reasons to avoid evacuation, such as might exist in a remote location. Statement 4 also reflects the

workshop consensus that if the symptoms are due to DCI but they fit the "mild" criteria, then medium to long term disadvantage to the patient is very unlikely if they are not recompressed. This is clearly quite different from a directive that "henceforth, all cases of mild DCI do not require recompression." Statement 4 should not be interpreted in this way. Statement 4 merely notes that some patients are unlikely to be disadvantaged by not being recompressed and provides the treating clinician with options for sensible decision making according to the prevailing circumstances. The word "some" is used intentionally to indicate that it is the clinician's final decision whom to recompress or not. The statement cannot be generalised to allow treatment funding providers to make funding policy decisions about recompression for all mild DCI.

A statement acknowledging the practice of in-water recompression was discussed but not included in the proceedings. The rationale for this deletion was the primary workshop focus on mild DCI. In view of the earlier determinations, especially Statement 4, in-water recompression was not an option likely to be pursued for patients whose presentation met the criteria for "mild" DCI signs and symptoms. In-water recompression was endorsed as an option for severe remote DCI management during the evolving clinical problem evolution (see hypothetic problem discussion), but no policy statements were generated. Its deletion from the consensus statements should not be interpreted as rejection of its utility. The reader is referred to the proceedings of the UHMS in-water recompression workshop for more information (1).

Similarly, an attempt to provide a consensus statement describing an appropriate time interval between recompression for DCI and flying, usually for the purposes of returning home, was rejected due to insufficient data. There was general agreement that more work is needed in this area.

References

1. Kay E, Spencer MP, editors. In-Water Recompression. Proceedings of the 48th Workshop of the Undersea and Hyperbaric Medical Society; 1998 May 24; Seattle. Kensington (MD): Undersea and Hyperbaric Medicine Society; 1999. 108pp.

EXECUTIVE SUMMARY

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Decompression illness (DCI) results from the formation of bubbles in body tissues during reduction in ambient pressure. Bubbles can affect any organ system, and DCI may be diagnosed following the onset of one or more characteristic manifestations following a compressed gas dive. Severe manifestations of DCI typically develop rapidly following diving and include central neurological symptoms and signs, and more rarely, cardiopulmonary collapse. The nature and latency of mild symptoms of DCI are more variable. Typical symptoms are limb pain, constitutional symptoms, rash and sensory changes without central neurological manifestations. Since bubbles can be detected in the blood following most dives, and since divers frequently experience vague symptoms following diving, the boundary between "mild DCI" and "no disease" is indistinct.

First aid treatment for DCI centres on oxygen breathing to accelerate the washout of other gases from bubbles and tissues. Definitive treatment of DCI is recompression to reduce the size of bubbles, with hyperbaric oxygen breathing to accelerate the washout of other gases. Hyperbaric oxygen also has therapeutic actions independent of bubble resolution. Recompression therapy is particularly efficient when administered within minutes following diving; presumably early bubble dissolution limits pathophysiology. Even if recompression is not immediately available, it is self-evident that delay should be minimised for central nervous system DCI and additional decompression (such as by un-pressurised air flight) should be avoided during transport to recompression facilities. This viewpoint has guided the management of DCI of all severities for nearly a century.

The purpose of this workshop was to evaluate the precept of urgent, pressurised evacuation for recompression in the context of mild symptoms of DCI and recreational divers amongst whom delay to recompression is typically greater than 20 hours. This was motivated by the increasing popularity of recreational diving in remote locations where even emergency air evacuation to recompression facilities will take many hours. The only present source of data is from retrospective analysis of databases containing cases of mild DCI where treatment has been delayed. Analysis of such Level B (1) evidence (epidemiological data not derived from high quality randomised controlled trials or systematic reviews) risks biased estimates of prognosis or effect of interventions. Specific difficulties with these databases are that they are likely contaminated with non-cases owing to the diagnostic ambiguity for mild DCI and the only outcome measure is the presence or absence of residual symptoms following treatment.

Mild symptoms of DCI that are static or remitting at 24 hours after diving are unlikely to progress to serious symptoms. No incidents of such deterioration were found in databases from several large treatment centres and several recreational and naval databases. Also, divers often do not seek treatment for mild symptoms, and there is no evidence of consequent long-term health problems in the recreational diving population.

The existing literature is divided on whether delay to recompression for DCI influences the treatment outcome, and some of this ambiguity is due to an interaction of disease severity and urgency. However, for mild symptoms of DCI, delay does not appear to influence long-term outcome. Careful filtering to remove doubtful diagnosis from DAN data (1987-97) revealed that delays longer than 12 hours resulted in 5.9 percent incidence of residual symptoms at the end of all recompressions compared to 3.9 percent for shorter delays. Delay was a less potent predictor of outcome than other factors (e.g., age), and there was no difference in percentage of divers with complete relief at three, six, and nine months.

Aeromedical evacuation of a diver is costly, can be logistically difficult, may not result in a clinically relevant reduction in delay to recompression, and is not without risk. These might seem to outweigh any potential benefit in mild DCI. Such conventional cost-benefit analysis is dependent on the integrity of any diagnosis of mild DCI and is clouded due to cultural and social expectation of standard of medical care and because the cost is usually borne by a third party. Informed risk assessment by the diver in a remote location with mild DCI requires a strong doctor-patient relationship that is unlikely to exist, leaving the doctor to make this decision.

Private ground transportation, usually without supplemental oxygen or intravenous fluids and a typical delay to treatment of 42 hours, is the most common form of retrieval to the recompression facilities in Townsville that services the majority of the Great Barrier Reef. There was no difference in the incidence of residual symptoms at the end of all recompressions between 80 divers with mild symptoms of DCI retrieved by ground transport and 22 divers retrieved by air (typical delay 24 hours).

Where logistics determine the necessity, divers with mild symptoms of DCI can make short-haul flights aboard commercial airliners without any apparent influence on subsequent recompression treatment outcome. DAN data (1998-2002) contained 1,108 divers with pain or mild neurological symptoms of whom 95 flew with symptoms before recompression. There was no significant difference in the incidence of residual symptoms at the end of all recompressions between divers with mild neurological symptoms who did not fly and those who flew more than 24 hours after diving; however, there was a significantly higher incidence of residual symptoms in divers who flew sooner than 24 hours. There were no such differences for divers with pain as their only symptom.

Treatment options in remote locations include non-recompression therapies that should be employed as first aid during any delay to recompression and may be sufficient treatment alone for mild symptoms. Standard non-recompression therapies are based on known pathophysiology and include 100 percent oxygen breathing (see above), fluid replacement to reduce haemoconcentration, and drugs to reduce platelet activation. Inflammation is probably an important aetiology of mild symptoms, and more trials are needed of non-steroidal anti-inflammatory drugs, antihistamines, and possibly emerging anti-inflammatory therapies. Options for hyperbaric oxygen treatment that may exist in remote locations include recompression chambers not staffed by experienced diving medical officers or in-water recompression. Choice of these options would depend on evaluation of the patient, facilities and staff.

There is a perceived risk of relapse from flying soon after treatment. Current recommendations for delay before flying following treatment are not evidence based and range from three days to six weeks. Amongst 95 divers surveyed by DAN, there was no difference in the rate of relapse (9 percent) between divers who flew earlier or later than three days following treatment.

As a prelude to producing a consensus statement, two hypothetical cases, one of serious DCI and one of mild DCI, were used to stimulate discussion of workshop issues amongst a panel of experts. These discussions are supplemented by one subjective account of lessons learnt during 25 years of treating DCI in remote locations. The discussions illustrated that no standardised management algorithm could replace clinical judgement. However, there was unanimous support for hypothetical case management that did not require aeromedical evacuation or recompression therapy for a patient with mild symptoms after diving in whom the diagnosis of DCI was equivocal.

The workshop consensus statements generated in regard to these issues are presented at the beginning of the workshop proceedings.

References

1. Levels of evidence in American Family Physician [Internet]. [Leawood(KS)]: American Academy of Family Physicians; c2004 [Cited 2004 Dec 6]. Available at: <http://www.aafp.org/x17444.xml>

OPENING REMARKS

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Welcome to Sydney and to this workshop on the Management of Mild or Marginal Decompression Illness in Remote Locations. Some of you have made a very long journey to get here. For most of us Antipodeans at these events, we're the ones who are the jet-lag victims. For once, the roles are reversed, but everyone seems to be coping very well.

I have an unfortunate duty to perform at the start of this meeting. We've heard this morning that one of our diving medicine father figures from this part of the world, Dr. Tony Slark, previous Surgeon Commodore in charge of the Hyperbaric Unit at Auckland in New Zealand for many years, has died. Many of us started our careers under Tony's guidance, and we'd like to observe his passing this morning. I'm sure he would have been very happy to see an event like this taking place down in this part of the world.

I want to mention the role of DAN America in this workshop. DAN America was involved in the workshop's inception, and they also provided the Undersea and Hyperbaric Medical Society (UHMS) with a seed grant to ensure that it would happen. The UHMS placed the responsibility for the scientific component of this workshop, its content, with me and others not involved with DAN. I make this comment lest one construe a conflict of interest for DAN since one of their subsidiaries provides diving medical insurance for divers. The scientific content of this workshop and its management have been entirely in the hands of its conveners in Australia. I can also tell you that the involvement of an organization like DAN is necessary and appropriate because DAN maintains the only database in the world that is capable of even beginning to answer many of the questions that we will address this week.

To ensure that decisions at the conclusion of the workshop would have appropriate credibility, we invited a group of experts who we call the Discussants. These people are key to any decisions taken by vote. Many people who are in attendance in the general audience could qualify as Discussants and will undoubtedly contribute to the discussion, but logistics required that the voting Discussants be limited and defined in advance.

This meeting is being recorded and videoed and will be available as a CME package through National Baromedical Services (NBS). Thus, it is vital that every comment is addressed through a microphone and preceded by your name and where you come from.

MANAGEMENT OF MILD OR MARGINAL DECOMPRESSION ILLNESS IN REMOTE LOCATIONS: AN INTRODUCTION TO THE PROBLEM

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Introduction

Decompression illness (DCI) is a disease of divers, aviators and astronauts in which bubbles form in blood and / or tissues following a reduction in environmental pressure. Depending on their size, number, and location, these bubbles may cause sufficient ischemia, mechanical damage, or inflammatory derangements to provoke symptoms. The relevant pathophysiological processes are fully described in recent reviews (1,2). Since bubbles in the blood may be carried to a variety of organs, and since bubbles may form directly in many different tissues, the symptoms of DCI are qualitatively protean in nature (3). Moreover, there is an extraordinarily wide range of severity.

Severe DCI may present with disabling and permanent spinal syndromes of very short latency. Rarely, in fulminant disease, there may be cardiopulmonary collapse and death.

At the other end of the spectrum, "mild DCI" is harder to define. This is largely because bubbles form, and can be detected in the venous blood, following a significant proportion of dives that do not result in symptoms that would normally be labelled "DCI" (1). It is therefore hardly surprising that there can be a poorly defined boundary between wellness and mild DCI following diving.

Mild symptoms following diving that most diving physicians would be inclined to label DCI typically include musculoskeletal pain of relatively short latency with or without paraesthesiae, but there are many possible variations. It is not infrequent for divers to report highly non-specific and vague symptoms of variable latency, such as mild evanescent aches and pains, fatigue, demotivation and headache. Given that there are neither sensitive nor specific laboratory investigations for "clinically significant DCI," these "marginal" cases constitute a significant diagnostic conundrum; particularly given the implications of the diagnosis of DCI in our present treatment paradigms described below. The incidence of DCI among recreational divers is estimated at approximately 1:10,000 dives (4), and the vast majority of these cases lie at the mild and even marginal end of the severity range.

The definitive treatment for DCI is recompression and hyperbaric oxygen administration (5). Although there are regional and institutional variations in recompression protocols, common underlying principles influence the practice of most hyperbaric units. First, it has become standard practice, where possible, to offer recompression treatment to all divers diagnosed with decompression illness; and second, it is widely accepted that the best chance of complete recovery accrues from recompression as early as possible after diagnosis.

It is self-evident that expedient recompression is the correct approach for severely affected divers. However, recompression itself, let alone recompression delivered on an emergency basis, is an untested principle in divers with very mild or equivocal disease. Nevertheless, the conservative approach to mild DCI has persisted. One important reason for this is that the reported success of recompression therapy by Keays in 1909 (6) elevated the intervention to a "standard of care" almost overnight, and subsequently there has been little opportunity to observe the natural history of untreated cases at any level of severity. Although historical reports of mild cases suggest the disease is self-limiting (7-9), there has been reluctance to shift from the paradigm of "expedient recompression for all" for a number of reasons, including: occasional refractoriness of mild DCI even after treatment (10); the reporting of sub-clinical neurological injury in apparently mild cases (11); the possible link between mild DCI and dysbaric osteonecrosis (12); and in the modern context, for medico-legal reasons.

This paradigm of providing emergent recompression for all divers diagnosed with DCI has presented an increasingly troublesome logistical and financial challenge as more divers travel to remote locations where comprehensive hyperbaric chamber facilities are not available. It has inevitably resulted in the frequent use of helicopters and fixed wing air ambulances for evacuation of divers over long distances. The cost of these air ambulance evacuations from remote locations varies according to the circumstances, but figures in excess of \$US 30,000 are not uncommon. Such events are an increasing (and perhaps intolerable) burden on the insurance industry as evidenced by a recent decision by Divers Alert Network South East Asia-Pacific (DAN S.E.A.P.) to temporarily withdraw cover for divers visiting the Northern Islands of Vanuatu in the South Pacific. This decision, which was prompted by a rash of highly expensive evacuations by Lear Jet, has subsequently been reversed after the installation of a recompression chamber locally.

In addition to the costs, there are logistic considerations to medical evacuations from remote locations. The logistics are often complicated, the evacuations are sometimes hazardous, and the event may impose a significant inconvenience on dive operators and local authorities. Diving physicians would agree that none of these concerns should deter evacuation for moderate or severe DCI under usual circumstances. However, in the context of very mild DCI, it is far less certain that emergent recompression is more effective than delayed recompression, or even management with measures (such as surface oxygen and fluids) that are usually classified as first aid techniques. It is appropriate therefore, that in this modern age of health economics and attention to

the cost-efficacy of medical interventions, we question the principle of emergent recompression for all cases of DCI regardless of mild severity or uncertain diagnosis.

Cases

Three actual cases with characteristics relevant to the above issues are summarised briefly:

Case 1: A diver in an isolated Central Pacific location developed pain and paraesthesiae in the right arm during a period of multiday diving. No dives exceeded the limits prescribed by the dive computer used, and there was a background history of similar symptoms in relation to a chronic cervical spine problem. A doctor (not diving medicine trained) examined the diver at a local clinic. No objective neurological signs could be elicited. The diver was evacuated on an emergency basis (cost \$AUD24,000) to the nearest diving medicine unit. It was concluded that this was an exacerbation of a chronic neck problem, and the patient was not recompressed.

Case 2: A diver on a liveaboard dive boat developed migratory aches, intermittent paraesthesiae and constitutional symptoms over a period of several days diving but continued to dive. There was no consistent change in symptoms in relation to diving. The problem was reported several days after onset. No doctor was available to examine the patient. The diver was evacuated on an emergency basis (cost \$AUD32,000) to the nearest diving medicine unit. There were no objective neurological findings. One U.S. Navy Table 6 was administered with little change in symptoms. An envenomation, seafood toxicity, or a viral illness was suspected, and no further recompression was given.

Case 3: A diver in an isolated South China Sea location developed pain in the left forearm during a period of multiday diving. No diving exceeded the limits prescribed by the dive computer used. The diver felt slightly tired but otherwise well. Examination by a diving medicine trained doctor on the island revealed no objective neurological signs. The patient was counselled thoroughly on the uncertainty of the diagnosis, and did not want to be evacuated for recompression. He was further counselled on the possibility of exacerbation during the routine unpressurised flight off the island, and the uncertain links between musculoskeletal DCI and osteonecrosis. He was advised not to participate in further diving, and underwent a six-hour normobaric oxygen-breathing period. The symptoms settled over 10 hours, and the diver left the island some 48 hours after reporting symptoms with no recurrence or further complications.

Workshop on Remote Management of Mild or Marginal DCI

This workshop has been convened to systematically review the issue of management of all DCI in remote locations. For these purposes, a location is defined as "remote" if air evacuation would be required to access recompression as quickly as possible. Although management of severe DCI will be discussed, a special focus of the workshop will be on the management of mild or marginal cases. We have proposed a simple remote DCI management decision tree (Figure 1) from which the key issues for discussion (as indicated in the Figure) will be drawn as follows.

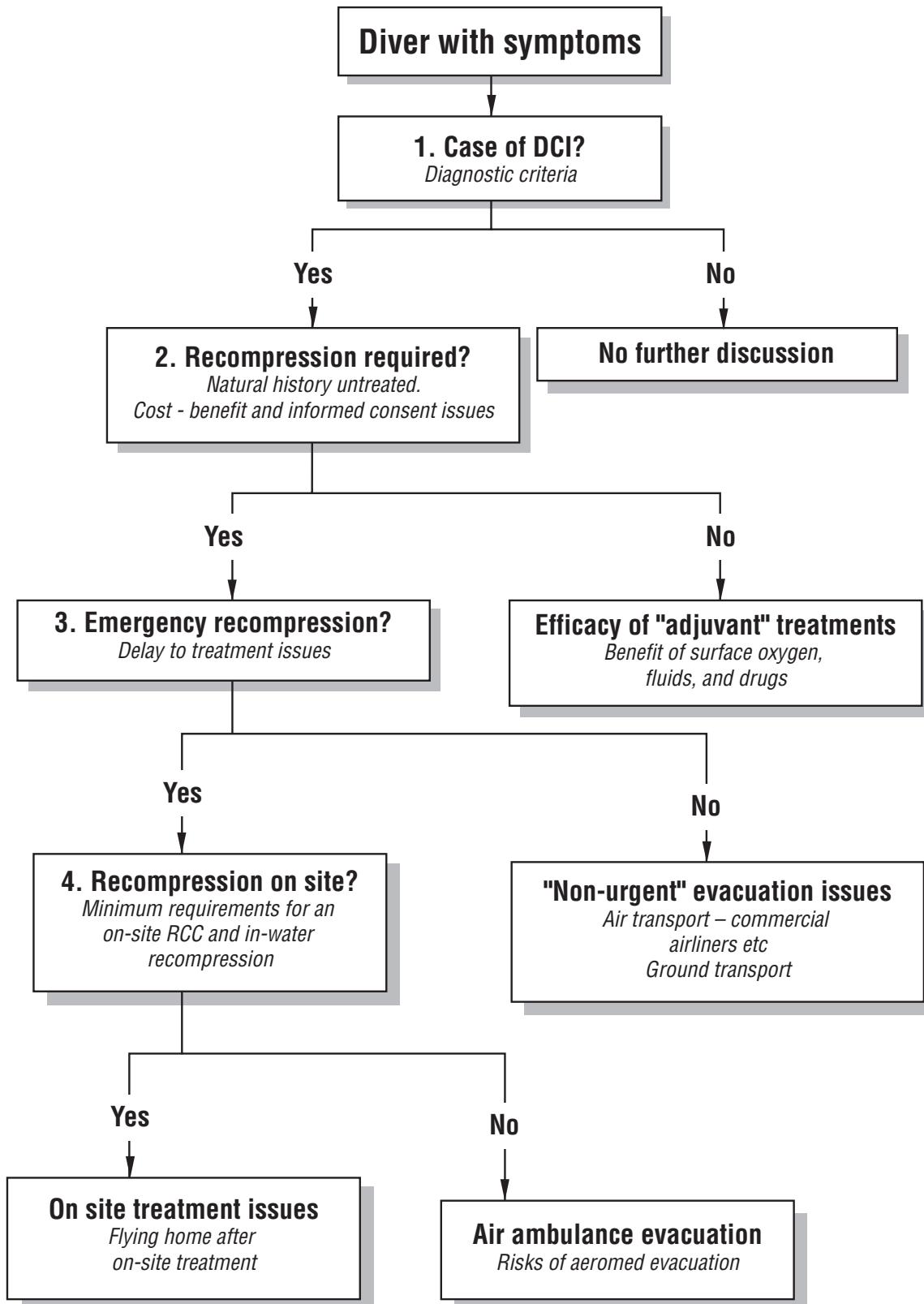


Figure 1. Schema for decision-making in management of a remote DCI patient

Diagnostic criteria for DCI.

It is acknowledged that there is often great difficulty diagnosing DCI, especially the milder forms. This is exacerbated in remote locations due to poor communication, inaccurate reporting, any tendency to downplay symptoms and the frequent lack of medical personnel to perform accurate examinations. Although there is no properly validated diagnostic schema, the workshop will review the optimal approach to diagnosing DCI. Cognisant of the inherent difficulties, the workshop will also be asked to evaluate the importance of distinguishing between symptoms of mild DCI and the non-specific symptoms of another mild malady. For example, if the workshop subsequently decides that some mild cases could be treated locally or evacuated by slower means, there will be less compulsion to distinguish them from other diving-related or non-diving problems.

The natural history of untreated DCI

For obvious reasons, the natural history of DCI is a critically important issue in the approach to mild disease. Clearly, if we could be confident that the natural history for mild cases was toward spontaneous and uncomplicated resolution in the vast majority of cases, then there would be less compulsion to recompress them at all. Similarly, if it could be demonstrated that early mild presentations rarely progress to serious disease after modest latent periods, and that the extra delays to treatment imposed by non-emergent evacuations do not significantly affect outcome, then the use of less expensive forms of evacuation might be justified.

Cost-benefit and informed risk acceptance

There are many situations in medicine where a medical intervention is feasible and possibly beneficial, but where it is withheld because the benefit does not justify the cost. Accordingly, the workshop should consider whether a \$30,000 air ambulance evacuation for recompression is always justified in mild or marginal DCI. In addition, modern medicine is practiced in a climate of active patient participation in management decisions. The issue of mild or marginal DCI patients participating in decision-making as informed risk acceptors as previously described in Case 3 (on page ??) will also be evaluated.

Benefit of surface oxygen, fluids and drugs

The administration of oxygen ($\text{FiO}_2 = 1$) at 1 atmosphere is the pivotal component of pre-hospital first aid for DCI. Adjuncts include intravenous or oral fluids, and possibly, certain drugs. Complete resolution of mild symptoms is sometimes associated with these interventions. Any decision to delay or even dispense with recompression therapy would, in most cases, be made in the context of concurrent use of these measures. The workshop will review current thinking on the appropriate nature and efficacy of "first aid" measures for DCI, and consider the issue of whether it is ever appropriate to utilise first aid measures alone.

The effect of delay to recompression

The effect of delay to recompression is another crucial issue in this context, since the workshop will consider the legitimacy of using slower non-emergency means of evacuation for mild or marginal cases. If there is little evidence for harm from clinically relevant delays to treatment in mild cases, then it justifies consideration of slower less expensive forms of patient transportation.

Air evacuation in commercial airliners

Some patients with symptoms of mild or marginal DCI are travelling on commercial airlines prior to recompression, sometimes under their own volition rather than on the advice of a diving physician. The workshop will utilise DAN reports and records to review the available experience of this highly controversial practice, and to determine under what (if any) circumstances we can consider this acceptable.

Ground transport

Ground transportation is often overlooked as an option for long distance "evacuation" of the DCI patient. Nevertheless, bus or train transport is potentially very useful for slower but less costly evacuations. The considerable experience of this modality at the Townsville General Hospital Diving Medicine Unit in Queensland, Australia will be reviewed by the workshop.

Remote location treatment options

Local treatment in a remote location to avoid evacuation and delay to treatment is a desirable option, especially for moderate to severe DCI. Not infrequently, diving physicians have to decide whether to use a local chamber facility of uncertain quality and capability. The workshop will review aspects of the minimum requirements for such a chamber to be acceptable for use. For example, the workshop might consider a minimum operational capability to be provision of a U.S. Navy Table 6 treatment.

In addition, the workshop will briefly review attitudes to the use of in-water recompression at all levels of DCI severity. In-water treatment is already prevalent in the technical diving community. This has always been a highly controversial practice, with many arguments both for and against. While most agree that it can be efficacious, there is often conflict over the circumstances (in terms of both logistics and disease characteristics) under which it is appropriate. The workshop will review attitudes to in-water recompression, and attempt to define the circumstances, if any, when it might be recommended by a consulting diving physician.

The risk of aeromedical evacuation

The issue of cost-benefit in emergency aeromedical evacuation of mild or marginal cases of DCI will have been considered, but the issue of risk-benefit also needs attention. It should not be assumed that aeromedical evacuation is an exercise without its own risk. Available data pertaining to aeromedical evacuation accidents will be reviewed. It seems unlikely that this would alter the approach to evacuation of a very sick diver, but it may influence the workshop's attitude to very mild or marginal DCI.

Flying home after remote treatment

If divers are recompressed locally either in a recompression chamber or in water, the issue of an appropriate delay prior to any flight home will arise. In a sense, this reduces to a discussion of flying after treatment for DCI, though it needs to be acknowledged that treatment in a remote location may not be as "complete" as it might be in a tertiary referral centre. It is not unknown for DCI patients to undergo an initial treatment locally and then fly home for more treatment.

Evolving clinical problems

After these presentations on day 1, day 2 will begin with discussion of two hypothetical evolving clinical problems based on remote locations: one describing an unequivocal case of serious DCI; and the other a case of marginal or very mild DCI. In both cases, and particularly the latter, there will be an emphasis on discussion of the various evacuation and treatment options. The rationale for this exercise is to encourage the application of some of the principles discussed on day 1 to an evolving clinical scenario. It is hoped that this will serve as a platform to argue out and defuse controversies over various management strategies prior to our attempt to draft a consensus statement.

Legal commentary

The legal implications of the strategies discussed will be assessed and commented on by a lawyer with experience in medico-legal cases pertaining to diving.

Consensus statement

A series of consensus statements will be drafted, debated and modified based on the outcome of the discussions. The aim is not to address the minutiae of assessment and treatment of remote DCI, but rather to provide broad statements of principle with respect to some of the potentially contentious issues.

Conclusion

By the end of this workshop, the participants will have a broader knowledge of the theoretical and practical issues pertaining to the management of DCI in remote locations. It is hoped that some consensus on the boundaries of sensible and acceptable practice can be achieved and documented. Such consensus from an august body of practitioners will be of immense utility and perhaps reassurance to the diving physician operating alone in a remote location, or advising remote divers from a distance.

The co-chairs and editors acknowledge that some very contentious issues will be discussed, and that consensus on some of these may not be possible. We anticipate vigorous debate which we hope will remain as objective as possible. We acknowledge the value of individual experience, but point out that every diving physician will be able to cite "a case" that proves the exception to almost any "rule" or theme the workshop is trying to develop. Such arguments must be kept in perspective if we are to progress. For such reasons, we have encouraged our speakers to, where possible, refer to that rarest of commodities in diving medicine (objective data), in making their arguments. We welcome the participants, thank the speakers for their efforts, and look forward to an enlightening two days.

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DIAGNOSING DECOMPRESSION ILLNESS IN REMOTE LOCATIONS

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Introduction

This paper addresses Block 1 in the decision tree of Fig. 1 in the Introduction to this workshop: is it or is it not a case of decompression illness?

Decompression illness (DCI) can be succinctly stated as the new onset of one or more of a series of characteristic manifestations, usually within 24 hours after a dive in which the diver has breathed compressed gas, WITHOUT ANY OTHER EXPLANATION. Characteristic manifestations are listed in Table 1. Actual reported manifestations in a series of 348 cases of DCI in recreational divers are shown in Fig. 1.

Recognition of DCI in Remote Locations

Making recommendations regarding the diagnosis and management of decompression illness in remote locations must often be made on the basis of incomplete information obtained and communicated by people with little or no specific training. An attempt must be made to differentiate DCI from other diseases, and to predict those cases of DCI that are likely to require advanced life support or to result in disability. Displayed in Table 2 is a series of 103 consecutive emergency cases referred to Divers Alert Network America from islands or offshore locations in which no hyperbaric facility exists. Evacuation was recommended in 32 cases. Nine cases were rated as severely ill. Only a minority (18 cases) were confirmed to have received hyperbaric oxygen therapy.

Most cases of DCI in recreational diving are mild, and have no significant permanent residual sequelae, often despite a long time from symptom onset to treatment (1). Some cases are severe, and require acute supportive medical management or may have long-term neurological impairment (2). Using clinical criteria, such cases can usually be predicted. Severe cases generally have short latency of onset after surfacing and symptoms progress rapidly (3). Onset laten-

cy was reported by Francis and colleagues in a series of 1,070 cases of neurological DCI (4). Their analysis revealed that in 467 cases reported in the medical literature prior to that time, 95 percent of cases had presented within six hours of surfacing; in 603 cases identified by the authors, 99 percent had presented within one hour of surfacing. In 69 cases of paralysis due to DCI analyzed by Dovenbarger (2), 95 percent had presented within 12 hours. Other indicators of impending severity include confusion, truncal or girdle pain and lower limb paresthesias and weakness.

Thus, mild DCI, could be defined as DCI in which, 12 hours after surfacing, the patient has normal blood pressure, is breathing normally and is alert, oriented and can walk and urinate voluntarily. Such an individual is unlikely to deteriorate, particularly if general supportive measures such as fluid resuscitation and surface oxygen are administered.

One issue is the concern that the patient may deteriorate after apparent improvement, possibly after a decision against rapid evacuation. Delayed or spontaneous deterioration was described by Pearson and Goad in 1982 in a series of 168 cases of cerebral arterial gas embolism (5). In that article, five cases were described in detail. All of the detailed cases exhibited major paresis or loss of consciousness. In one of these cases, a relapse occurred nine hours after symptom onset (four hours after completion of USN Treatment Table 6), and was described by the authors as "one of the more delayed relapses in the series." Major relapse is therefore unlikely in patients with minor initial symptoms within the first 12 hours (3).

Summary

Severe cases have: (a) short onset time after surfacing, (b) severe manifestations that occur within 12 hours, (c) rapid progression. Relapse to severe neurological symptoms can occur after spontaneous improvement or recompression therapy within 12 hours, but is unlikely in mild cases.

Table 1. Characteristic manifestations of decompression illness.

Pain

Peri-articular pain, rash (*cutis marmorata*)
Girdle pain

Skin/subcutaneous manifestations

Nonspecific macular eruption
"Cuttis marmorata" (*livedo reticularis*)
Lymphedema

Sensory abnormalities (paresthesias, hypesthesia)

Motor weakness

Nausea, vomiting, vertigo

Inability to perform tandem gait, walk unaided due to balance

Sensorineural hearing loss in the absence of inner ear barotrauma

Inability to empty bladder/requires a catheter

Shortness of breath, cough, sometimes with hypotension

Impaired consciousness (use Glasgow coma scale)

Confusion/disorder of mentation

Seizures

Table 2. Diagnoses and management of a consecutive series of 103 emergency calls referred to Divers Alert Network from islands or offshore locations in which no hyperbaric facility exists.

Diagnosis	N	Emergently Evacuated	Commercial Air Evacuated	Sea Level Evacuated	Severe	Confirmed HBO Treated
Cardiac, not dive related	3	1				
DCI or possible DCI	39	19	5	1	6	17
Dehydration	1					
Heat stroke	1					
Jellyfish sting	1					
Mask squeeze	3					
Mild stable symptom, possibly dive related	4					
Minor symptoms, not dive related	17	1	1			
Near drowning	1	1			1	
No symptom	1					1
Otic barotrauma	11	1				
Otitis externa	1					
Otitis media	2					
Pneumonia	1					
Pulmonary barotrauma, not AGE	2					
Sinus barotrauma	4					
Stroke	2	1			2	
Vertigo, unspecified	2					
Viral illness	7	1				
TOTALS	103	25	6	1	9	18

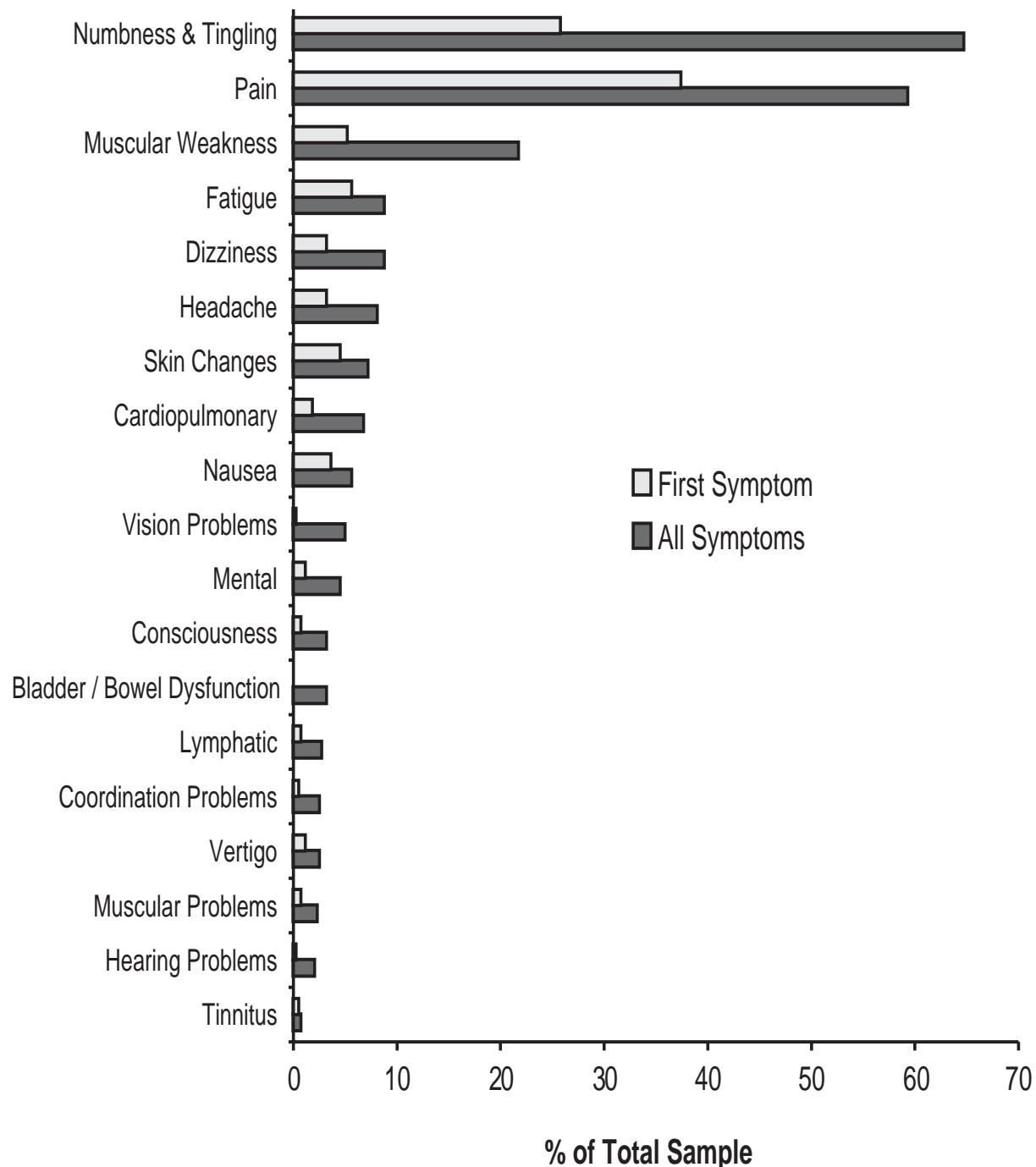


Figure 1. Symptoms in 348 cases of DCI in recreational divers (1).

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DISCUSSION

MAURICIO MORENO: Your first slide defined remote locations as those places where there was the absence of a recompression facility. Is that correct?

RICHARD MOON: Yes. The absence of a recompression facility within 24 hours.

MAURICIO MORENO: Within 24 hours of surface transportation, or may I ask how you define 24 hours?

RICHARD MOON: Well, there are places within North Carolina where I live that one could argue would fall within this category, but shall we say it's within 24 hours of easy transport – and I'll leave it to you to define "easy."

MAURICIO MORENO: All right. Now my follow-up question is, when we say diagnosing DCI in remote locations, what we see, for instance, on this particular slide, does that still apply, or is there a double standard? Where there is a recompression facility onsite or in a big urban center, would one diagnose exactly the same as with those remote locations where there's the absence of a facility within 24 hours?

RICHARD MOON: Yes. No, I was not trying to imply a double standard. This would apply to diagnosing DCI anywhere, of course. What I was trying to do was come up with some simple principles that could be used when dealing with something over the phone or in a situation where one cannot get one's hands on the patient to do a fine-tune examination.

ED MILLER: As you talked, Richard, it struck me that one issue that may arise with the mild cases in terms of our knowledge of signs and symptoms is a very significant reporting and recognition by selection bias in that I think we can be fairly sure that serious cases of decompression illness have turned up and, therefore, the rating of signs and symptoms that is probably fairly reliable. But, given very different diagnostic thresholds for decompression illness when you're working at the lower end, the data that we have got may be substantially biased.

RICHARD MOON: Yes, I agree with you. The cases that I showed you, the 348 cases, have been at least filtered by somebody knowledgeable in decompression illness; and it's almost impossible, because we don't have a gold standard to be sure that all these cases are indeed decompression illness, but these are cases which were recompressed which had some clinical response to recompression and which otherwise appear to knowledgeable people to be due to the disease.

ED MILLER: So I guess my point, though, is that these are the cases that were selected because they were treated. We don't have any data on the cases that may have been decompression illness, might have had some elements of the disease but which weren't treated and maybe did resolve spontaneously. That's a big unknown sitting out there.

RICHARD MOON: Yes, that's exactly correct.

KLAUS TORP: I think one of the problems with defining mild and moderate or severe decompression illness to date leaves out the patient's perception. The numbness or tingling for a piano player or an electronic engineer may be much worse than for somebody who operates a jackhammer. I had a few patients where the main complaint was their arm weakness was interfering with their ability to lift a bottle of beer. Or the one patient was not concerned about his arm weakness because the instructor could actually show what the students needed to do with the left hand, and so he didn't need the right hand. So I think it's very difficult to generalize what mild decompression illness for one is than for the other. Do you have any idea how we could include the patient's perception into the definition?

RICHARD MOON: Yes. Well, Klaus, I think you raise some important points. The real bottom line I think is going to be the long-term outcome, and Jake Freiberger has some information on that, so I think that issue will be addressed later on in the conference.

JAMES FRANCIS: Richard, I'd like to congratulate you on a model of clarity on how to identify decompression illness, but follow it up by saying that in remote locations, you may not just be 24 hours away from a recompression facility; you may be a long way away from anybody who's skilled to elicit these signs and symptoms. What gets reported to you from a remote location may have a considerable amount of the fog of war overlaid on top of it that makes actually using such a simple paradigm rather more difficult in practice.

RICHARD MOON: Yes, I totally agree.

DAVID ELLIOTT: This is a probability game. If a case doesn't meet the criteria, it does not mean it is not decompression sickness. Also, this conference is devoted to air diving range. We're not interested too much in the people that go deeper than that. But, of course, there are many divers who are not recreational divers and all your data is recreational diving and, therefore, the interpretations apply to that particular population.

DAVID GRIFFITHS: Richard, the situation that you describe here I presume is for single or a limited number of dives. In particular, I draw your attention to the fact that in Australia there have been a number of reports of relatively shallow dives, particularly from fish farmers but also from some of the occupational divers collecting produce who dive to shallower depths but repeatedly perform "hundreds" of ascents. There's well-documented decompression illness in that group from depths of approximately even half the 40 feet that you're talking about.

RICHARD MOON: Yes, I agree with you, David. We've had experience in the United States with the divers at Epcot Center in Florida where the fish tank was deliberately designed to be 29 feet deep because decompression sickness is thought not to occur at depths shallower than 33 feet. When these divers who spend hours and hours in the water feeding fish after several days or weeks of doing it came up with symptoms, we were called by some very mystified physicians who didn't know what was going on. But I totally agree with what you just said.

DAVID DOOLETTE: We're at our second point now in the decision tree, which is looking at the natural history of decompression illness if it's untreated. This topic will be reviewed by Professor David Elliott.

THE NATURAL HISTORY OF UNTREATED DCI

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Introduction

The first objective of this review is broader than just mild or marginal decompression illness (DCI), and my instruction from the organising committee was to examine the following question:

"What will happen to those with acute decompression manifestations who are not recompressed?"

Possibly because that we think we already know the answer, it is a question that few of us bother to consider. As with tourniquets for traumatic amputations, the established need for urgency after a decompression incident has overtaken the academic desire to collect controlled evidence. So,

- If very sick, without recompression the diver may die.
- If lucky, the diver may later recover but probably with neurological residua.
- If mild, the diver should make a functional recovery quite soon.
- And for each, the outcome without treatment is largely a matter of luck.

That's it.

In fact, we know surprisingly few facts about the natural progression of any of the decompression injuries, perhaps because there are many different starting points and thereafter so many possible pathways for the development of the pathology.

From several studies we know that the prediction of outcome for an individual case is far from precise, and occasionally it will then appear to have been wildly wrong. So for the purposes of this workshop, the second objective of this review is to

"Examine the point in the evolution of mild or marginal disease when it is reasonable to assume that it is unlikely to progress to a more serious form."

A supplementary question to that is

"Can serious neurological deterioration begin more than 24 hours after the onset of mild or marginal manifestations?"

The only source of accurate answers is from actual cases that have not been recompressed, but they are not easy to find. This review has considered two sources for such information:

- The diver for whom recompression was not an option.
These are mostly historical cases in which critical information may be missing.

- The diver who was recompressed but only after a delay of more than 24 hours (and with no altitude exposure in that time).

Some Conclusions First

Because our time is limited, this review begins with some thoughts that could be on tomorrow's agenda as potential conclusions. This means that, while we now go through what little evidence there is, we can add positive or negative weightings to each unproven preconception:

- Limb pains may be the most common presenting manifestation, but some 20-60 percent of the cases also have neurological manifestations. Some of these may be potentially severe, and others may be local and trivial. In the absence of any neurological manifestation elsewhere, it may be possible to suggest that a diver does NOT have neurological DCI even if there are mild sensory manifestations, but only in the vicinity of the painful joint, and / or if there is some weakness of movement, but only in those muscle groups that are associated with a distinctly painful joint.
- Until a person with any decompression manifestation has been competently examined neurologically, there can be no confident prediction that they have only mild manifestations at that stage and do not need an urgent recompression;
- A diver is not likely to develop serious neurological manifestations later if it is certain that he / she has no neurological DCI manifestations 24 hours after their onset.

However, as will be discussed, the same may not be true of some of the more marginal symptoms in cases with delayed or slow progressive neurological illness. Some cases have emerged of individuals with a delayed onset, a very slow progression of serious neurological manifestations and no non-DCI causes found.

Effects of Altitude

Intentionally, this brief review does not include the effects of flying after diving. Exposure to altitude is certainly a confounding factor in the development of decompression manifestations but, to be pragmatic, the focus of this workshop is on the triage of remote cases *that are still on the beach*.

Of course, advice might be needed for a diver who has landed at some remote airport after the onset of symptoms during a commercial flight or who has traveled over a mountain pass. These cases can be complex, and they deserve their own separate workshop. The potential for unusually severe manifestations to be associated with altitude can be illustrated by just one cautionary tale.

A novice completed a two-week training course overseas using a computer though all were no-stop dives. Her final dives on a Wednesday were at 12:00 (max 30m, T.D.T. 39 min) and at 14:00 (max 20m, T.D.T. 56 min). On Thursday at 18:30 she flew home (2 h) and noticed weakness in her R. arm during the flight. At 22:30 an emergency physician noted that she was neu-

rolologically normal and said that she had "Slept awkwardly." On Friday and Saturday she became progressively worse, developed nausea and vomiting and by Sunday she had a speech impediment and found walking impossible. On Monday she went to her family doctor and was given an appointment to attend hospital the next morning. On Tuesday she was seen by consultant who noted a "history of scuba." Referred to a neurologist with "severe flaccid R. hemiparalysis progressive over several days." Investigated for tumour or MS, but nothing found. On the Wednesday, a week since her dive, a friend alerted a diving doctor. She was recompressed but remains disabled. With hindsight, she later realised that on waking on the previous Thursday she had noticed an "odd feeling down the right side."

Whatever the underlying pathology was that followed her dive, it should be generally recognised that flying can change the clinical picture in an unpredictable manner. Diagnostic and management decisions should be made accordingly.

Decompression Disorders

The use of the all-inclusive title of "decompression disorders" covers every possible underlying pathology, known and unknown. It has been used for more than 25 years and probably was not original even then (1). In special circumstances, such as submarine escape training or slow decompression from saturation diving, one can be reasonably confident about the underlying pathology but often there is no certainty. For example, in 1843, in one of the first cases of neurological DCI ever to be reported in a diver, Pasley described a history of overexertion and of staying too long at depth (2). That would make one concerned about bubbles from dissolved gas. Pasley then described the diver's manifestation of hemiparesis that would suggest that he had a gas embolism. In such a case today, deciding on the clinical management and assessing the urgency for recompression would seem more important than the semantics of possible pathological causations.

Nevertheless, selected manifestations are grouped by association and attributed to a specific causation among which the commonest are pulmonary barotrauma, arterial gas embolism, decompression sickness, and right-to-left shunts of venous emboli. An individual case can have more than one cause and may also have some coincidental illness or injury that influences decompression pathogenesis and prognosis. Even if the circumstances tend to point an experienced doctor firmly towards a gas embolism or towards a classic decompression sickness (DCS), the contribution made to an individual's prognosis by, for example, a coexistent but undetected patent foramen ovale (PFO) remains completely unknown. Nor does the physician always know the proportions in which the two basic processes of bubbling, alveolar gas intravasation and dissolved gas evolution, are active concurrently in an individual or, in a biphasic presentation, consecutively.

We would be wise when interpreting clinical data also to consider that some features of DCI may be related to the type of diving. "Chokes" and "staggers" after rapid deep dives are historical examples of this, but even this impression does not seem to have been examined in detail. Nevertheless, it does seem that the characteristic presentations of DCI following a single deep dive may not be the same as those occurring towards the end of a multiday scuba-diving vacation.

The hotline doctor to whom the case is referred must decide on necessary action even if the decompression history does not suggest an obvious cause. As many of us have found, management as though it is DCI may be appropriate even for a diver in whom some other pathology may be suspected or even probable (3).

In assessing untreated symptoms, the hotline doctor can never be sure of the reporting threshold of the individual seeking help. This could vary from the anxious diver who may report everything unusual, to the overconfident diver who may deny a genuine problem. Hagberg and Ornhagen recently confirmed that many symptoms are not reported and that the threshold for reporting symptoms appears to differ between individuals (4). The operator must also consider the differential diagnosis of similar symptoms arising post-dive from inner ear barotrauma or coincidental illness.

The principal symptoms and signs of decompression illness have been listed by some naval and other authorities as not including those symptoms, such as vertigo and vomiting, that may be due to compression or other diving pathology and which therefore are less specific for decompression sickness. In contrast some, but not all, authorities include in their lists headache, which is probably even less specific. Some diving manuals influence diagnostic discretion and state that headache must be considered as a serious neurological symptom. This review does not attempt to clarify the issues of specificity or sensitivity, but merely emphasizes in passing the need for the training and experience by the hotline doctor to generate the ability to sort out diagnostic probabilities competently.

Data or Just Anecdote?

For our purposes today, the natural history of decompression disorders should become evident from cases that occurred before the introduction of recompression, but such historic case histories are usually incomplete. Nevertheless, they do contain some observations that test today's hypotheses or may lead to new thoughts. So for this review, many early reports have been re-examined for material that may be relevant to our workshop and the development of delayed severity.

The start for this review has been the 1948 annotated bibliography by Hoff (5). When one then retrieves the original papers of more than a hundred or so years ago, one finds, as expected, that many of the cases are described only superficially. One is rarely told about the timing and progression of physical signs. Nevertheless, one does get a glimpse of the way that the illness progressed when there was no recompression.

Musculoskeletal "Pain-Only" Manifestations

Since Triger's report in 1845 of "... rather keen pains in the articulations half an hour after leaving the shaft," many historic papers have described limb pain in or close by the joints (6). On the severity of this symptom Wainwright said, "I know of no condition which produces a greater degree of physical agony ... as if the joints were being twisted off ... as if a dog were gnawing the bone" (7). But these case descriptions tell us only a little about the time course of untreated decompression sickness. For example:

- Bouhy reported that joint pains could keep a worker awake due to pain for some 48 hours and they could last for some eight days (8).
- The sponge divers of Greece suffered joint pains that never lasted more than two days and generally they disappeared after a few hours. Gal wrote: "*I have not listed any observations on this subject, because these disorders ... showed nothing abnormal either in their course or in their ending*" (9).
- Snell stated that limb pain does not last longer than six weeks (10).
- The pains as a rule pass off spontaneously, usually in a few hours according to Parkin, but may last for weeks (11).

Musculoskeletal and Associated Neurological Manifestations

A practical problem in diagnosis can be that the pain may dominate the clinical picture and so the diver does not notice or report some other more serious deficit. Van der Aue reported pain in 107 of 113 military cases of decompression sickness, and of these, just 77 had pain as their only symptom (12). Of the 46 others (30 with pain but who were not "pain-only," and the 16 who did not have pain), nine had a rash, 10 had weakness, and 10 had numbness, but the exact distribution of these and other symptoms among the divers is not stated.

The observation that many cases with limb pain have a more serious neurological manifestation at the same time has been made many times, for example in 30 percent by Slark and 15 percent by How, West & Edmonds (13,14). In 935 cases of military divers with decompression sickness studied by Rivera, the presenting manifestation in 79.6 percent of cases was "bends" (15). He does not provide a figure for the percentage overlap of manifestations, but the separate totals of each manifestation certainly imply an overlap between limb pain and serious neurological illness.

Could some of this neurological involvement merely represent a local response to the joint manifestation? Or do the abnormal findings always signify a more widespread involvement of the central nervous system (CNS)? Some weakness found could be simply a reflex response to severe local pain. The role played by peripheral nerves in some of the localized manifestations of joint pain has long been postulated. A case report by Edmonds of arthralgia (neuralgic pain in one or more joints) with peripheral nerve involvement may be an example of that (16). Goad also distinguished the patchy peripheral sensory deficit from the manifestations of more serious spinal cord lesion (17). The reported association of limb pain with localized neurological impairment is not easily resolved, but when joint pain is associated with numbness or tingling, this occurs in the region of pain and weakness may also be described in association with joint pain (18).

If such peripheral neurological deficits occur in an individual who has no other neurological manifestations in any other location, perhaps the individual should not be classified as CNS decompression sickness, even though it may be wise at the time to manage the case as though it were.

In an examination of 225 cases of decompression sickness held on a diving accident database, the combinations of different manifestations in an individual were examined (19). Of the 115 cases with limb pain, 63 percent also had neurological manifestations that were mostly sensory changes (50 percent), but weakness was also present in 21 percent of cases of limb pain. In 72 cases reporting pain, 39 percent were progressive or relapsing, 49 percent were static, and 16 percent were improving or resolved. Similar data were provided from the Institute of Naval Medicine database, 1990-1999 (20). This showed that 77.2 percent of 1,170 cases had neurological manifestations and 48.7 percent had limb pain, a self-evident overlap of manifestations.

It has often been said that a diver may report pain but has failed to report his neurological deficits because pain is the dominant and obvious complaint. The latency of onset for neurological manifestations is generally shorter than that for limb pain (21). In these studies, the relative times of onset for neurological manifestations and for limb pain in an individual were not provided.

Some DAN data are presented in the form of summary statistics that are not easy to interrogate for more detail. Denoble has said that of 118 cases reported to DAN in 2002 as having pain as the presenting symptom, only 45 percent were finally classified as pain (22). Of the rest, 2.6 percent became cardiopulmonary and 52.2 percent became neurological. There were 31.9 percent of the original limb bends who were classified as mild neurological (parasthesias, numbness, tingling, etc.), and 20.3 percent who were classified as serious neurological. No timelines were available.

Abdominal Pain and Vomiting

Acute abdominal pain, nausea and vomiting were reported in several cases of decompression sickness in 1873 (23). Wainwright reported that 10 percent of his cases had epigastric pain and vomiting (7). These symptoms feature regularly in the reports of 80-140 years ago, but without more detail and not knowing what divers and tunnel workers would be expected to report, the clinical significance of these presentations is uncertain. In a 1941 review, Shilling again described this feature of decompression sickness (24). The concept of a gastrointestinal decompression sickness has been suggested as part of the DCI syndrome (25).

In a number of reports on compressed air workers, the principal manifestation was that of pain, and this included "abdominal bends" which was associated with "shock, collapse and prostration" (26). The presence of cutaneous mottling and blotching in them were considered to be a prodromal (precursory) sign of coma. Erdman's description in 1916 seems different and, as had been observed previously, was of an abdominal pain associated with "spinal" paralysis (27). Abdominal pain, if presenting as a girdle pain, is now recognized as characteristic of the onset of serious neurological illness. In a series of 225 cases, there were 17 with girdle pain, and each one was associated with neurological manifestations (19).

Latency and Progression

A review of more than 1,000 cases of neurological decompression sickness studied the latency of the onset of the first symptom after surfacing (21). This study did not review the other manifestations of decompression sickness. Although the majority of cases presented early (some 84 percent within the first hour after surfacing), we should remind ourselves that 34 cases (3 percent) in that study had their onset 24 hours or longer after surfacing.

In another study, of 90 neurological cases 34 percent were progressive or relapsing, 33 percent were static, and 22 percent were improving or resolved just prior to treatment (19). The remaining 9 percent had several manifestations with different rates of evolution. In the same study of 72 cases reporting pain, 39 percent were progressive or relapsing, 49 percent were static, and 16 percent were improving or resolved. The median time to onset was 30 minutes for all neurological manifestations but more than one hour for limb pain. Nevertheless this study shows that at 16 hours after surfacing, some 15 percent of neurological and limb pain cases had not yet presented. These data are a useful reminder that while the majority follow a predictable and relatively quick time course, there are many who are slower in onset. Unless it can be shown that they follow a different time course, these cases should also be assessed urgently.

The onset of peripheral sensory symptoms in a diver a day after an air dive that had been close to the no-stop limits is itself unremarkable, but the slow development of ulnar palsy over the next 20 days deserves review (28). There was an incomplete response to a series of recompression treatments, and a number of investigations excluded evidence of other possible causes. There was then resolution over the next two months. This was an unusual case in which a decompression cause could not be eliminated, and it again demonstrates the unpredictable variety of presentations that may need to be assessed. However, as decompression illness, it was a peripheral neurological deficit and, as such, does not contradict the view that CNS deterioration does not usually start more than 24 hours after the onset of musculoskeletal symptoms.

Predictions

Severity scoring in decompression illness was comprehensively reviewed in a previous UHMS workshop (29). For the analysis of initial severity and for the prediction of treatment outcome, some models do not allow for possible deterioration during a delay before recompression. Obviously, the nature and effectiveness of the treatment is an important variable that will affect outcome.

For relative importance, the RNZN system uses a weighting scale (0-5). One of these weightings was related to the natural history of the symptom if the diver was untreated, ranging from 0 (= *almost certain to resolve spontaneously*) to 5 (= *almost certain to persist*). These weightings include an allowance for codependent symptoms such as subjective and objective sensory changes. The output of the system for assessing change from the time of admission to the time of discharge has since been tested retrospective-

ly and its broad prognostic capability has been confirmed (30). The application of the scoring system to the patient's condition when first reported may add useful guidance for triage in spite of the difficulties in a remote assessment (31).

Spontaneous Neurological Recovery

In the 19th century, many severe spinal cord lesions led to decubitus ulcers, urinary infections and an early death. Yet surprisingly in the absence of recompression, a number of persons with serious neurological decompression illness are reported to have made a full spontaneous recovery, and some returned to work. One example in the 1860s is from the Londonderry Bridge (32). With pains in his legs and thighs, a caisson worker was completely prostrated and unable to walk. His legs were cold and without sensation. He was "...seated with his feet in the fire, so that several of his toes were burned without him feeling the heat. Two days later he was cured except for his burns."

Rapid recovery from neurological decompression was also described by Blavier in a caisson worker who experienced complete paralysis of arms and legs for just 12 hrs (33). Thompson described three cases of paraparesis that recovered in four days to three weeks, and Baske one case within six days (34,35). "*The paralysis is sometimes recovered from, even in a few hours*" (11). A similar natural progression was also observed with other neurological presentations, for instance, after a four-hour loss of consciousness within an hour of leaving the shaft, "*in 3 days he was cured*," but alas the clinical details are absent (36). More recently, spontaneous recovery was reported in eight of 187 cases of neurological decompression sickness (37). They were not treated, and two subsequently relapsed.

Spontaneous recovery may indeed occur in around 3 percent of neurological cases, but there are no records to show that those who had apparently recovered without recompression had been fully neurologically assessed. Current experience is that after an apparently successful recompression, significant neural scarring and various abnormal signs can be found (37-39). Thus, it seems that those who do make a spontaneous recovery probably have some demyelination in the cord (a process where the protective and insulating myelin substance covering the nerves is destroyed), and their recovery seen should be considered as only functional.

Evidence from Native Fishermen

Another source for data concerning the natural history of untreated DCI would be the unregulated diving performed by indigenous fishermen around the world. The lack of safe diving procedures and the introduction of recompression facilities for the Miskito Indian divers have been well described (40-42). A retrospective study has been made of those who were not recompressed in that region, mostly from the time before the chamber became operational (43). This study suggests that the majority of divers who were treated with steroids but not recompressed did have considerable improvement but were left with residual motor deficits. The recompressed group had more serious deficits, did better but had a not very dissimilar percentage of residua on discharge. However, the limited data is not sufficiently robust for making detailed comparisons (42).

The amount of omitted decompression accumulated daily by these fishermen seems so provocative when compared with the diving done by recreational and military divers that any conclusions about treatments which have a median of 48 hours delay, and their outcome might not be directly relevant to decompression illness in other diving populations. Nevertheless, a parallel study of those indigenous fishermen divers who are recompressed and those who are unable to get to a treatment centre could answer questions concerning natural history and the efficacy of delayed treatment.

Evidence from Current Data Banks

Data banks of many diving accident and recompression centers around the world were asked to review for this meeting by examining their cases that had an interval of 24 hours or longer, from onset up to the time of flying or recompression. As the progress of only mild or marginal cases was to be considered at this workshop, divers developing serious manifestations within the first 24 hours after onset were not included. Because most diving accident and recompression data banks were set up as summaries for other purposes and not necessarily to record all the available data, many of them do not have the data needed to answer the specific questions asked by this workshop. Another example of their limitation is the lack of suitable cases in Europe, because lengthy delays with no air travel are uncommon before recompression.

For example, one difficulty has been with the inconsistent classification of physical signs, particularly those of early onset. Problems of retrospective interpretation were met when examining the original medical records that had been identified from clinical information provided in a data bank's computerized files, e.g., the interpretation of peripheral sensory deficits. In some divers, these were the sole neurological manifestation and seemed relatively mild and, indeed, could be compatible with a definition of "marginal." The final diagnosis in the data bank was "Type 2 DCS." In other cases, written up in same data bank but by other doctors, very similar symptoms were mentioned but subsequently ignored in the diagnosis and summary. It would be necessary to retrieve many hundreds of medical records on which the data bank is based in order to sort out this boundary.

A further limitation to any study of clinical progression is the lack of suitable cases in military and commercial diving. This is because there is usually a chamber close by and lengthy delays with no air evacuation before recompression are uncommon.

DAN Europe and DAN Southern Africa report 35 cases over some eight years with mild symptoms (pain only or tingling without weakness) that were delayed more than 24 hours, and none deteriorated significantly. Denial, rather than difficulty with evacuation, was the usual cause of the delay. This suggests that there may be a clinical threshold for mild or marginal cases above which early reporting becomes more common.

Only very few data banks hold copies of the original medical records. From some of these sources, important information could be reviewed that was not available just from the computer records. In the Royal Navy's data bank at Alverstoke, there are

summaries of many hundreds of recompressions among which one case was found that might have challenged a proposal that "mild or marginal DCS does not need immediate evacuation to a chamber." In this case, the computer records showed that joint pain had been followed in 24 hours by objective neurological manifestations. The later retrieval of the original paper records showed that he had noticed some relevant neurological symptoms from about the time of onset of his pain. So, had this diver reported without delay, the early neurological condition should have been revealed. A competent neurological examination, and the means to record it, is the starting line for the management of mild or marginal cases.

The U.S. Navy has records of a wealth of cases that received recompression. There is a research archive with descriptions of the manifestations of several hundreds of DCS cases, and uniquely each of these cases has been related to the profile of its causative dive. These include many mild cases that appear to have made a spontaneous recovery and none that later went on to severe deterioration. Outside that archive, many incidents are recorded at the Navy Safety Center, but the time of onset of symptoms is not always available. Among less than 20 cases found in the period 1990-2003 as having had a delay of more than 24 hours before being recompressed, just one case has been selected for the benefit of this workshop, because it stresses the importance of the neurological examination in reaching the diagnosis:

After a 82 fsw dive for 11 minutes, a 26-year-old Navy diver made an uneventful no-stop decompression. Twenty-one hours later, he experienced an unusual level of fatigue but did not report this. Fifty-six hours after the onset of that fatigue, he reported to a recompression facility. Besides fatigue, he was found to have a right-sided facial palsy and unequal pupils. He responded completely to TT-6 at 60 feet. There is no record to show the time of onset of these signs.

At the university chamber in Sydney, data was collected for a clinical trial that included all grades of decompression illness and of which some 80 percent were of low severity grades (44). Bennett has since stated that in the 75 cases with a delay of greater than 24 hours before recompression, there was no marked deterioration (45).

The experience of the DDRC, Plymouth, includes a few cases with extensive delay, but in several, this delay was largely due to denial, so one does not know how much sooner, given the opportunity, a diving doctor would have sent them for recompression.

A 46-year-old man had pain in the left shoulder one hour after surfacing. The next day on waking, he also had a vague feeling in his left arm and he seemed a bit "punch-drunk." Simply because he denied that he had a problem, he was then referred to the recompression centre by his wife. The DDRC reported that they had no cases of late neurological deterioration in what were known to be only mild cases of DCI.

The North Sea Medical Centre had 25 cases, both mild and serious, with a delay of at least 24 hours before recompression, but in no case with only joint pain was there late neurological deterioration. There were also other cases with time courses that confirm

that a textbook concept of time scale and progression is not always followed. There was no post-dive flying and no non-decompression factors were found to challenge the primary diagnosis or to account for the deviation from the usual history of a decompression disorder.

One followed a fairly typical working offshore working dive: Surface decompression with one wet stop based on EAD was used following a 90 fsw nitrox dive (max pO₂=1.5 bar) for 90 minutes and using hot-water suit. In retrospect, he had some unreported mild discomfort in the muscles of his lower right abdomen in decompression and overnight in his bunk where sleep was poor because of a rough sea. This had disappeared before he returned home some 24 hours after surfacing. The next day, he developed some malaise in the evening, with cervical and lumbar stiffness and pain with transient pins and needles across the shoulders. Serious neurological manifestations including girdle pain at T4 with sensory and motor deficits, and bladder difficulties began progressively some 72 hours after surfacing. Extended and repeated recompressions were effective in spite of some relapses. Five days after the delayed onset, a neurologist familiar with serious DCI could find no residual deficits, and an MRI was normal. He also concluded that the original abdominal pain had been truly muscular and not girdle pain.

In contrast, evidence from Scotland where all the recompressions in medical chambers are subjected to audit suggested that the condition of all patients on referral, regardless of delay since onset, did not necessarily match their condition on admission to the recompression unit (46). This may be evidence of natural clinical progression, or of incorrect neurological assessments, or of both factors concurrently. Regardless of delay, in all referrals, upper limb weakness, ataxia (inability to coordinate voluntary muscular movements due to a nervous system disorder) and cerebral problems would seem to have been routinely missed by referring doctors. Nevertheless, the severity at the time of presentation is the only useful predictor of severity on admission, and this correlation is extremely strong.

Among these patients in Scotland, there were 73 (12.3 percent of 593 consecutive cases) with complete data who had presented more than 24 hours after the onset of decompression manifestations. All cases had enough data to do this analysis, and two divers with a "pain-only" presentation and three with a sensory presentation were found to have a motor problem on admission. Two more with a sensory presentation were found to be ataxic. Thus, around 10 percent of those referred with mild symptoms were found on admission to have a more serious condition. A mild presentation at 24 hours did not preclude the presence on admission of serious illness that was amenable to treatment.

Of possibly greater relevance in this series from Scotland are the uncertainties of reliable but early diagnosis demonstrated by the case of "*a diver with erythematous [abnormal skin redness due to capillary constriction]'skin bends' of two-hour duration who was assessed by the chamber doctor as not needing a recompression. The following day he needed recompression for cerebral symptoms and ataxia.*"

Discussion

This brief review of the various decompression injuries confirms the wide variety of manifestations, but following the progress of decompression disorders is usually interrupted by the ethical need to treat by recompression. What happens to those who are not recompressed might be determined from historical reports when there was no recompression or from studying today's indigenous diving fishermen who have no access to recompression. Conclusions are limited because so too is the underlying data. Most accounts omit or are unable to retrieve the details of examination, timing and residua.

Records of cases that have had 24 or more hours delay before being recompressed in an established treatment centre have been more helpful. This pilot study revealed no cases of serious neurological deterioration that began more than 24 hours after the onset of musculoskeletal decompression illness. However, outside our conventional understanding, several cases were found in whom symptoms, maybe only constitutional, very slowly progressed to serious neurological deficits. These may be exceptional, but they deserve further study.

Any retrospective review is subject to many confounders caused by the wide variety of diving procedures and environmental circumstances, the range of symptoms, of observers, of reporting, and of academic definitions and record-keeping. Retrospective analysis is also hampered by the difficulties of validating what is secondhand data. Any future attempt to evaluate the significance of marginal neurological manifestations should be based on precise definitions and meticulous examinations and must be prospective.

A final cautionary reminder is that acute decompression illness may lead to scars associated with cerebro-spinal residua, a diminished capacity for future functional repair in the cord and an increased risk of bone necrosis (38,39,47,48). Thus, any changes in established recompression management need to be accompanied by a prospective study to monitor any long-term consequences of change.

Summary of Conclusions

In the absence of any neurological manifestation elsewhere, it may be that a patient does not have neurological DCI even if there are mild sensory symptoms only in the vicinity of a painful joint, or if there is some weakness of movement that is associated only with guarding a distinctly painful joint.

Until a person, in whom there is a possibility of a decompression manifestation, has been competently examined, there can be no confident prediction that they do not need urgent treatment.

A diver is not likely to develop serious neurological manifestations later if it is certain that he/she has no neurological manifestations 24 hours after the onset of mild DCI (but one must acknowledge that it could happen, and so the diver should remain under medical surveillance).

Some cases have emerged of individuals with a delayed onset of DCI, a very slow progression of serious neurological manifestations and with no non-DCI causes found. In some, these followed an earlier presence of "marginal manifestations" that would not necessarily be recognized as DCI and that are not indications for recompression. Indeed, many manifestations that may be thought to be marginal DCI may not even be so. This possible type of presentation is rare and must be brought to wider awareness so that it can be recognized by sensitive epidemiology and further assessed.

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DISCUSSION

CARL EDMONDS: David, as you know, one of the rationalizations for medevac for mild DCS is long-term syndromes that may develop. I would love this to be so, because there's good argument for in-water treatment early, but I have no evidence. Now I notice in your paper, but not in your presentation, you have stated that a delay in treatment may increase the likelihood of dysbaric osteonecrosis. You were kind enough to give a reference, which I went to, and could find no evidence. Is there any evidence – anecdotal or otherwise – that delay in treatment of mild DCS will produce increased instance of dysbaric osteonecrosis?

DAVID ELLIOTT: It's a loose association. Any diver, regardless of whether or not they have had DCI, can get bone necrosis. As far as in-water recompression is concerned, I think that is still a valid area of research. One or two papers have been published. So the argument, therefore, for an in-water recompression, although unproven, I would support. Does that help? Not at all? OK.

SIMON MITCHELL: I'm having a problem getting my head around the definition of mild symptoms. We need a definition that we can all live with.

ALF BRUBAKK: Data from some indigenous diving populations clearly show there is a relationship between symptoms and signs of decompression sickness and osteonecrosis. However, I think that for diving in the industrial world, there isn't much of a problem. There is strong evidence that mild symptoms, or even more severe symptoms, but not clear neurological symptoms, have little effect on subsequent health. Many symptoms are not reported. The point is that we have a gigantic experiment going on where a lot of divers never tell anybody about their symptoms. What you presented are those who have reported symptoms. Various studies have shown that experienced divers, on the order of 70 percent in our work, have had quite severe symptoms that were never reported. We found that all of them were still working and felt reasonably healthy. We used a questionnaire to that assessed mild head injury and found a statistical significant relationship between signs of mild head injury although they said they felt perfectly normal. I would say that untreated mild decompression sickness will have little effect on further health.

DAVID ELLIOTT: This is a question of boundaries: one thing merges gently into the next. If we're too specific, we may make mistakes in future data collection. We should collect data and then investigate specific questions, such as the association of bone necrosis and early manifestations.

Simon has raised the question of mild DCI that nobody would disagree about being decompression illness. The question is, if you have one marginal symptom, say pins and needles, it could develop into mild musculoskeletal. Feeling spacey or off-color is the marginal warning sign of somebody who may develop something more severe, maybe neurological. I'm quite happy to say that sensory changes are mild DCI, if that's all a person has. However, urticarial rash or cutis marmorata have been associated by Peter Wilmshurst with the PFO syndrome.

ALF BRUBAKK: The other component to the definition of mild decompression illness is the period of time within which we can't make the diagnosis to allow for progression. Our diagnosis would be only made after 12 or 24 hours, these numbers are debatable, after diving, where only mild symptoms as we defined them on that previous slide are present.

DAVID ELLIOTT: I think that's great. Everything's serious until at least 24 hours after diving.

ALF BRUBAKK: Correct.

CUAUHTEMOC SANCHEZ: We have to address the history of the dive, not only the symptoms. I think we should incorporate gas load (as Dr. Francis pointed out several years ago) because mild decompression sickness with a very low gas load will very probably not become severe decompression sickness. That is a hypothesis. If you had mild decompression sickness within 12 hours, it would be more probable to progress to more severe symptoms if it has a large gas load.

DAVID ELLIOTT: No, not really. I think that's supported by one of the cases I presented which occurred in somebody who'd done what recreational divers would never do, and that was a deep, long, working dive. So there's certainly an element of truth. But how you arrive at a specific point, you say it's just one of these waiting factors. I think in your own assessment of severity you dealt with that mathematically very well. So it is something which we need to consider, and how we apply it is another question.

CUAUHTEMOC SANCHEZ: On the other hand, sport divers do things that commercial divers don't do, like multilevel, multiple days, multi dives a day. That's another physiological point of view instead of just doing square dives and long dives, etc.

RICHARD MOON: David, regarding your comment about bone necrosis, recreational divers typically have delayed treatment. The median time from symptom onset to recompression in our database is roughly 24 hours, which I would argue is delayed, and there's no evidence of increased incidence of bone necrosis either in those who have DCI or not.

Did you mean that objectively confirmed sensory changes (with nothing else) are serious? In other words, you have to have a normal physical examination for mild DCI to be diagnosed?

DAVID ELLIOTT: Correct. Simon and I agreed on that.

Going back to bone necrosis, there are very few records of bone necrosis in recreational divers. When we're defining bone necrosis, I mean the conventional, accepted, dysbaric osteonecrosis, not the early Type 0/Type 1 phase of avascular necrosis as seen in femoral head dysplasias. This is the silent manifestation that is not discovered until the patient has a collapsed and painful joint or it's discovered by coincidental X-ray or MRI. The conventional bone necrosis I speak of is in divers with exposures (as in the old MRC work) that are four hours or regularly deeper than 30 meters. One wouldn't expect this type of bone necrosis in recreational divers. I think Peter Wilmshurst is the only person who has published a case that meets the conventional criteria for bone necrosis after shallow or mild diving with no history of decompression illness. Conventional bone necrosis is extremely rare in recreational divers.

RICHARD MOON: Could I go back to that point about sensory abnormalities? Why are we considering objective sensory changes as severe?

DAVID ELLIOTT: I'm not considering them severe. I'm just being cautious and say if there are no objective changes, I'm much happier.

SIMON MITCHELL: I can't really give you a better answer than that either, Richard, except to say that in my experience, I've rarely seen true measurable, objective sensory changes in sick divers who don't also have other manifestations that would make me concerned about their condition. For the purposes of a definition of mild DCI for this workshop, I want a fairly robust definition of "mild" that everyone can live with. Our ultimate application of this definition (after the consensus discussion tomorrow) might be that these patients don't need to be evacuated urgently and / or can be evacuated on a commercial airliner. These are interpretations that might be considered a little "radical," so we don't want to get too close to a marginal definition that the people at this meeting won't be happy with. We want a definition that's robust for the purposes that we're going to apply it to.

UNIDENTIFIED: Is it worth having an evolution term for someone who is progressing but not mild?

SIMON MITCHELL: I want to relate things back to the decision tree in Figure 1 of the Introductory paper to stay in context. The first decision in approaching a putative case of DCI in a remote location is to decide whether it is DCI. We've talked about diagnostic criteria and have tried to make a start towards defining a mild case of DCI. If we decide that a case is not DCI, that's easy. If we decide it is DCI, the next decision is whether or not recompression is required with all the implications for a remote location. David Elliott has reviewed the natural history of mild DCI if we don't do anything.

Another important consideration is the issue of cost-benefit. We do many things in modern medicine because we **can** do them and don't always insist that the benefit be weighed against cost. This is very true of the approach to divers with DCI in remote locations. In the modern setting, we cannot and should not dismiss the importance of cost-benefit analyses. There is also the related and equally important issue of whether or not to involve patients as informed risk acceptors in decisions about evacuation.

This is a difficult topic for obvious reasons. To address it properly, I've asked Surgeon Commander Alison Drewry from the Royal New Zealand Naval Hospital in Auckland to have a go. Alison is an occupational physician and a very experienced diving physician, but, above all, she's a fearless iconoclast with no hesitation in speaking her mind about controversial issues.

COST-BENEFIT ANALYSIS AND RISK ASSESSMENT IN THE MANAGEMENT OF EQUIVOCAL DCI IN REMOTE LOCATIONS

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Taken at face value, the cost-benefit analysis of the treatment of mild or marginal DCI in remote locations is straightforward. Given that "remote location" has already been defined as requiring evacuation by air, and if the result of not treating mild DCI results in no or only minor residual health effects, then the cost of evacuation and therapy would always exceed the benefit. However, this apparently simple conundrum is actually more complex when subjected to more in-depth scrutiny.

The Context of the Cost-Benefit Argument

When considering "cost-benefit" arguments, it must be acknowledged that clinical practice is usually biased, and recommendations to treat are always influenced by who is paying. If clinical probability and chance were the only "facts" worthy of consideration, treatment decisions would be based purely on statistical evidence, and it would be inevitable that some individuals would have an adverse outcome, although the group would achieve an acceptable outcome (for the cost). The objectivity of treatment providers cannot be guaranteed, particularly where there is some personal gain (including professional prestige) from recommending treatment (regardless of the cost-benefit equation). These biases are most obvious when the "cost" is borne by a third party (typically either a public or private insurer) and the service provider is guaranteed payment: the threshold for recommending treatment is lowered. Few providers would advocate a \$20,000 treatment for a non-disabling symptom if they knew the patient was directly liable for payment: similarly, few patients would opt for such a therapy.

Consequently, cost-benefit arguments are specific to consumer groups, and the analyses are dependent on the wealth of the society involved, rituals, custom and the prevalent expectations for health care interventions (1). It would be inappropriate to apply the same cost-benefit analysis to an underwater logger in the Malaysian highlands as an American tourist diving the Great Barrier Reef (perversely, the latter would be more likely to get treatment), but it is pertinent to this workshop to consider the climate within which we make clinical decisions, and examine those dynamics that would favour intervention (evacuation and recompression) rather than "supportive observation."

Currently, the drivers for treatment include the separation of the cost of treatment from the patient (most are funded indirectly through insurance); the vested interest of most diving medicine practitioners in treatment facilities (with high standing costs and a

requirement to maximize patient throughput); and the requirement to service an affluent recreational diving population with high expectations for health care interventions in a litigious environment. These drivers cannot be easily negated, but they should be acknowledged in any discussion that purports to be based on rational clinical decision-making.

The Analysis

While costs can usually be identified (although allocating costs to specific interventions is often contentious), there is always debate about what should be regarded as "benefit," and how this should be rated in different situations (2). Many analyses are reduced to comparisons of the cost of different interventions that achieve relatively similar outcomes, using gross measures such as QALY (quality of life-years); but these are crude tools, applicable to populations, and have little relevance to the consideration of mild DCI.

The "cost" of recompression treatment is anticipated to be relatively "high" in the given context: the assumed tenet is that anyone diagnosed with a decompression-related illness must not be exposed to further decompression stress, so evacuation can only be made at an equivalent altitude of less than 1,000 feet (approx 300 meters). If it is also accepted that to be effective, treatment must be delivered as early as possible, evacuation will be by air, and therefore require either rotary wing (subject to contour, distance, weather and visibility constraints) or fixed-wing (subject to runway access and pressurized aircraft availability) transport. Either option involves the dedication of escort and pilot personnel, and may be subject to significant risks if an adverse (weather, terrain) situation exists. In most cases, the cost of air evacuation will be in the range of tens of thousands of dollars. If, however, the costs of transport and therapy could be separated, and it was agreed that in some cases the requirement for low-altitude, rapid evacuation could be waived, then the overall cost of treatment could be reduced and a more acceptable cost-benefit equation reached.

Even if the costs can be established, "benefit" remains difficult to define and measure. An obvious benefit would be an improvement in health status after treatment, and a reduction in symptom severity score would provide an objective measure of this (3), but since there is a paucity of published data about the outcomes for patients with a presumptive diagnosis of mild DCI but no treatment, it is difficult to assess the relative "benefit" of recompression.

However, it is possible to make some assessment of "treatment benefit" if it is accepted that most dives result in bubble evolution, but only a fraction have clinical manifestations, and only a subset of these actually present for treatment (4,5). Thus those divers that are included in our treatment databases represent a sub-population of divers. This assumption leads to two further possible conclusions. Firstly, since there does not appear to be a substantial diver population with any significant long-term health effects following mild DCI but no treatment, then the natural history of the condition is for spontaneous resolution, and treatment is unnecessary. Secondly, the DAN data from recompression facilities suggests that treatment for "mild DCI" is not particularly effec-

tive: up to 70 percent of patients categorized as suffering from mild DCI have residual symptoms after treatment (6). Both cases support the view that there is little "benefit" for recompression therapy in mild DCI, and the cost of treating a patient from a remote location could not therefore be justified.

Changing the Cost-Benefit Equation

An alternative approach to this issue would be to examine whether there are less expensive, but effective, treatment options. It was Voltaire who stated that "The art of medicine consists in amusing the patient while nature cures the disease," which should prompt us to reflect that when we quote "clinical experience" in advocating recompression for divers, we are usually referring to our biased practice where recompression has *inevitably* resulted in resolution of symptoms, unless we acknowledge the existence of a "control group" that consists of all the patients we never see.

There is a lack of published data relating to the outcome for divers who are assessed but not treated – it appears that we cling so closely to the tenet that decompression illness must be treated with recompression that these divers are usually labeled as not having decompression illness. Examples of erroneous treatment principles based on a presumed pathophysiological mechanism abound in medicine: stopping beta-blockers in those with heart failure and immobilizing scaphoid fractures are just two such principles. Similarly, the logic of recommending "recompression" for any expression of symptoms after diving, even when it is implausible that the diving exposure resulted in the generation of significant amounts of "bubbles," should be challenged through controlled trials of alternative therapies before it is regarded as the only treatment option. The recommendation that a therapy designed for catastrophic occupational disease (7) would be equally efficacious in a sport diver (with a relatively trivial exposure) should have been treated with a lot more skepticism. To date, pharmacologic agents have only been trialed as *adjunctive* therapies (8,9). Perhaps it is time for a controlled trial of alternatives to recompression.

Nevertheless, all arguments about the cost-benefit of treatment are contingent on the integrity of the diagnosis of "mild DCI," and it is in this area that the most significant uncertainty within the cost-benefit equation resides. However, many specialists in this field would agree that there are several criteria that could, in various combinations, allow such a diagnosis to be reached, but there is as yet no agreement on what constitutes "mild DCI." Most would also require that the diagnosis (of mild DCI) should only be made by an "expert" – there is anecdotal experience and published data that suggest a specialist assessment is required to determine the severity of DCI (10,11). Aside from the nature of the symptoms and signs, the elapsed time since diving or symptom onset would also appear to be a critical component of the diagnosis: few would attach a label of "mild DCI" and confidently predict a benign outcome for a patient within the first six to 12 hours, and many would be reluctant to assign a specific diagnosis within the first 24 hours. It is implicit to our diagnostic systems that sub-types of "decompression

"illness" include a time consideration, which allows for the evolution of symptoms and signs, and their response to treatment, to influence the final diagnosis. Pursuing this argument, it becomes impossible to estimate the treatment cost-benefit for a diver with symptoms of DCI within the first 24 hours.

Risk Assessment

Given that the data on outcome from mild decompression illness is confusing, and that there may be some danger involved in transfer to the treatment facility, is it more appropriate for the patient to be involved in assessing the risks and electing whether to opt for recompression therapy? The nature of risk assessment in medicine has been explored in several studies, which acknowledge the growing ascendance of the patient in determining medical management (12).

Risk assessment involves the consideration and manipulation of probabilities in making decisions. Intuitively, a structured approach to making treatment choices should be popular, but unfortunately in medicine, better decision-making processes do not necessarily guarantee a better outcome for the individual patient, and practitioners have also been reluctant to adopt formal risk assessment tools as they appear to reduce the doctor's "discretion" in giving clinical advice.

Medical risk assessment theory supports that meaningful risk assessment in the medical setting requires a relationship, trust and time (13). While there are several methods for improving risk communication (analogy, rating scales, graphical representations, etc.), these cannot substitute for the existence of a therapeutic alliance between the patient and the doctor. This is hardly applicable to the situation of a diver in a remote location, often negotiating by phone through a third party with an unknown practitioner. Similarly, the context in which risk communication and informed choice have been studied is invariably one in which there are days or weeks to negotiate a way forward, which is not relevant to a discussion about the need for emergency evacuation!

Other factors that do not favour patient primacy in the decompression illness conundrum include that the outcome data are not robust, the lack of consensus on limiting criteria, and the vulnerability of the distant practitioner to future medical litigation. This is a condition that can reportedly present with subtle symptoms but have long-term adverse effects on cognition, personality, sexual function and mobility (14-16), and the doctor who had not insisted on treatment could be held to be negligent, even if the patient had elected not to have therapy at the time. The arguments would presumably focus on the premise that there was insufficient communication, facts, or time for the patient to have made an "informed decision." If we appreciate that we do not practice in a rational world, then it is difficult to construct a case for decision sharing in the DCI situation. The ongoing liability for even a "minor" adverse outcome precludes a decision not to at least personally assess, and treat, if funding is available. That this will lead to the "medicalisation" of post-dive symptomatology, and result in unnecessary evacuations and treatment, with an inevitable cost to the insuring public, is regrettable but inevitable.

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DISCUSSION

JOHN ROSS: That was an extremely good presentation and brought out the fuzzy nature of what we're trying to talk about here. In Scotland, we see many divers with a mild condition when they present, and I can say that all those people did very well because we treated them. If we decided not to treat them, I wouldn't be able to say how well they did. We don't actually know what the outcome of mild, untreated decompression illness is or how it would figure in your cost-benefit analysis.

ALISON DREWRY: Well, as I alluded in my talk, I assume that there is an enormous control group of divers out there who have not been treated who have had exactly the symptoms that we call mild or marginal DCI. To me – and this is my bias – it stands to reason that that there are no significant long-term health outcomes for that pool of divers. But it's very difficult to sort of defend that scientifically. It's just my bias.

JOHN ROSS: That brings me on to my second point. We've looked at one and a half thousand commercial divers, and 80 percent of them complain of mild to moderate forgetfulness. Now, one factor in that complaint is that many have a history of treated decompression illness. Their problems include reduction in cognitive performance, memory tests and reduced quality of life. My feeling is that until you've got data for untreated mild decompression illness, we're all going to be hunting in the dark. If we do come up with a definition, when you get these people on the phone and say, "You don't need treatment" – I've no problem with that personally, but you've got to keep tabs on them to find out what happens.

ALISON DREWRY: I completely agree, but the best thing I could say is that maybe treatment's bad for you. I mean, if we're seeing the residual symptoms in the treated divers. (Editorial note: this comment was made somewhat jokingly).

JOHN ROSS: Yes, doctors cause 50 percent of the disease they treat.

ALISON DREWRY: That's right.

LANCE TODD: We accept that there are a few patients who need evacuation, but there are medical interventions that we don't do because of cost. I think it should be up to the patient to decide, "Well, if society doesn't bear the burden of paying for a medical intervention, I would like control that myself." If the actuaries assess the risk and determine the premium, I can say, "OK. The risk is very rare that I might have an adverse outcome, but I decide to pay an insurance premium to insure that risk." I think it's up to the insurance company either to say yes or no. We have several examples where some health insurance plans won't cover certain procedures while others will. People have choices. I'm not familiar with the healthcare system in New Zealand, but if it's close to the British system where society bears the cost, you can take out supplemental insurance. If it's insurance-driven, it's just a matter of cost.

ALISON DREWRY: These are the two conundrums of a cost-benefit analysis. The cost may be hidden, but it's still a cost. That cost will be passed on to the other members of the insured public; it doesn't negate it. The other aspect is the health benefit. One of my concerns – only one of them – is that if we are advocating recompression therapy for all symptoms after diving, we are inevitably going to "medicalise" people who don't have decompression illness.

BOB WEBB: One of the areas which hasn't been raised yet, and I'm not sure it falls under the definition of remote location, is the dive boat. A liveaboard can be six to eight hours from Cairns or Cooktown, the nearest place where the diver can get proper medical assessment. We get a number of calls from those boats, and we have to make a decision whether the boat needs to come in. There's a cost in that, because we've been told on a number of occasions that we've just cost the dive organization \$10,000, \$15,000, \$20,000 which they can't insure against because they'd have to reimburse all the other divers for the dive trip that they've had to cancel. It's another area we need to think about.

ALISON DREWRY: Absolutely. And how does it influence your decision to treat?

BOB WEBB: Yes. It's not so much the decision to treat, but we're trying to get the diver to somewhere where they can be properly assessed because it's difficult to do it over the phone.

ALISON DREWRY: But does the cost influence your advice?

BOB WEBB: It usually doesn't because it's not costing us anything, and it's not costing the healthcare system anything, but there's often vigorous discussion between us and the organization.

SIMON MITCHELL: Liveaboard dive boats actually do fit the definition of what we're talking about, Bob. This workshop is exactly about that kind of patient. Those are the difficult decisions for exactly the reasons you point out. What we decide over the next two days is very relevant to those patients.

KLAUS TORP: We had a similar situation where a doctor in an airplane who was summoned to help a passenger decided to recommend landing the plane. That's a huge cost to the airline, and I would submit this is the cost of doing business.

ROBYN WALKER: It's in the assumption that there's a large group of untreated divers out there with mild DCI who don't have sequelae. We don't know what makes them different from the group that ring up and request assistance. What is it about the people that don't report as opposed to the people with exactly the same symptoms who ring up and request assistance? It's difficult to make assumptions about treatment on data we don't have.

ALISON DREWRY: Absolutely. I agree, Robyn. It would be great if we could initiate some sort of a post-dive general health questionnaire and were able to gather data over hundreds of thousands of dives and introduce it as a routine part of recreational diving. Perhaps, then, we would be able to make some conclusions. I know that Dave Doolette's been involved in a health questionnaire for commercial divers which has been quite revealing and showed a definite difference between divers who probably don't have DCI, and other divers who have symptoms after diving.

GEOFF BAYLISS: I refer to the Rogers vs. Whitaker case which demonstrated that if the patient perceives that there is a risk, a material risk, to taking a line of action or not, that has to be taken into account. The level of undisclosed risk in that case was one in 40,000 or 14,000 – I forget which – for sympathetic ophthalmia in an eye surgery case. In New South Wales, the autonomy of the patient is a very serious issue, and one of the things that has to be taken into account is if the patient is *compos mentis* and can make up his or her mind, their decisions or their issues have to be taken into account. This is similar to the situation where you have a woman in labor who wants epidural anesthesia for pain relief, and the anesthetist has to explain all the side effects of epidurals, etc. Our anesthetic colleagues say it's much better to do that in the antenatal phase when you can go through the risks in slow time, take the time to talk through the issues, etc. It's far better to do that than it is to try and cover all the issues in acute labor when the woman is actually in severe pain. Our anesthetic and obstetric colleagues have quite a lot of issues about this. We should be looking at in this situation in the pre-dive phase explaining to the patient the ifs, buts, maybes, and so on, so they can make a rational decision or be tuned up so that when they do have pain, you're not then dealing with someone whose cognitive function is disturbed by the severe pain. That's an issue we certainly need to look at. Does that make sense?

ALISON DREWRY: I understand what you are driving at, but I was looking at this from the situation of talking to a patient in a remote location about the tingling in their left little finger 16 hours after diving. Probably nothing bad is going to happen, but a crucial factor is whether the patient thinks that he's got decompression illness and should be treated. I, as an objective observer, can say, "There are far more risks in your getting in the helicopter, having an IV inserted, and being escorted to my chamber than there are in you electing not to have treatment." The problem is that we're dealing with a condition that may result in cognitive problems, sexual dysfunction and psychiatric issues way down the track. So, you're opening yourself up to litigation. While there may not be an objective, rational basis for a decision to evacuate and treat, we don't have the luxury of saying no.

GEOFF BAYLISS: Yes. Getting back to the epidurals, there was a very interesting case recently where a lady doctor requested an epidural and the anesthetist said, "Yes, you know all the risks. You're happy with that, happy for an epidural, and so on." He knew the patient, knew her background, started to put in the epidural when her husband came in. He knew her husband, who is a lawyer, so he went through the full drill of explaining the risks and hazards. The point is that quite often the legal side of the house will come in and, regardless of what you do. It's not a very clear-cut issue. I wanted to raise the issue that there are very significant problems in this situation, particularly in this country.

BENEFIT OF SURFACE OXYGEN, FLUIDS AND DRUGS AS ALTERNATIVES TO RECOMPRESSION FOR MILD DCI NON-RECOMPRESSION THERAPY

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Background

The mainstay of therapy for decompression sickness (DCS) and arterial gas embolism (AGE) remains recompression therapy with addition of hyperbaric oxygen. However, since the work of Ferris and Engle (1), and the studies of Hallenbeck et al (2), the importance of non-mechanical bubble effects has been well documented. These non-mechanical effects continue to complicate the therapy of all decompression-related gas bubble illnesses (DCI), and are addressed in various adjunctive therapies. As knowledge improves regarding the role of inflammatory mediators in disease and the effects of various insults on inflammatory signaling and on endothelial function, there arises a compelling need to understand these processes to grasp the extend of gas bubble disease (DCS or AGE) and to develop strategies for therapy that provide an adjunctive repertoire to recompression therapy. To better develop adjunctive treatment strategies, it is important to review the current information on inflammation and injury in order to justify current therapies and propose new therapies based on developing concepts of injury and inflammation resulting from gas bubble disease. To start, the assumption that the clinical syndromes of DCS and AGE result from free gas in blood and tissue will not be challenged.

Inflammatory Mediators

The presence of free gas in the circulation, and tissue injury by autochthonous bubbles provoke a complex process called inflammation, characterized by a reaction of blood vessels, leading to the accumulation of fluid and leukocytes in extravascular tissues (3,4). Inflammation is a physiologic process that serves to destroy or isolate the injurious agent, and initiate events that lead to reconstitution of the damaged tissue. This mechanism operates in response to free gas in the body by attempting to surround bubbles with a protein layer, to activate inflammation via coagulation, kinin and complement pathways, and to activate endothelium. In the case of gas bubble disease, the usual actions that would kill or neutralize an invading organism are ineffective on the inert gas, and in some ways the inflammatory process may serve to prolong bubble presence by reducing gas diffusion from the bubble. The injury from gas bubbles is of relatively short duration, and can be considered an acute inflammatory response whose characteristics are the leakage of fluid and plasma proteins (edema) and the emigration of leukocytes (4).

The initial effect is an increase in blood flow due to mediator induced vasodilatation, and edema caused by increased vascular permeability. Although blood flow is initially increased, the circulation eventually slows due to the loss of plasma into the extravascular tissues (5). The plasma loss concentrates red cells in small vessels and increases blood viscosity. As stasis develops, leukocytes adhere to the endothelium and migrate through the vascular wall into the interstitial tissue.

Vascular leakage results from endothelial gaps in venules elicited by histamine, bradykinin, leukotrienes, substance P, and other chemical mediators. It occurs rapidly after exposure to the mediator and lasts 15 to 30 minutes. A second mechanism of reversible leakage, also resulting in endothelial gaps, is induced by hypoxia, and sub-lethal injury to endothelial cells, and by cytokines such as interleukin-1, tumor necrosis factor and interferon-gamma. This response is delayed four to six hours, often persists for 24 hours or more, and is the result of intracellular remodeling (6). Direct endothelial injury may also result, for example, from a severe burn. This mechanism may be present in DCI due to direct contact with endothelium by circulating free gas. Leakage usually starts immediately after injury and is sustained for several hours until the damaged vessels are thrombosed from platelet adhesion and activation of coagulation.

Leukocytes contribute to vascular injury as they adhere to endothelium early in inflammation, and release toxic oxygen species and proteolytic enzymes, which cause further endothelial injury and detachment resulting in increased permeability. Many of the endothelial receptors involved in the inflammatory process have been identified, and strategies to prevent their activation with inhibitor compounds are being developed.

To date, studies of inflammatory mediators related to DCS or AGE have concentrated on blood clotting and the complement system. Complement showed promise as an important mediator of gas bubble injury; however, promising animal and in-vitro studies have not been corroborated by consistent observations of complement activation in humans subjected to decompression stress (7) or in divers or aviators with demonstrated intravascular bubbles (8). Studies on newer inflammatory mediators related to DCI have yet to be done, and are likely to show some positive correlations with free gas volume in blood and tissue, and with clinical evidence of DCI-related injury. In particular, the use of monoclonal antibodies to the inflammatory mediators TNF-a, and IL-1, both of which are now clinically available, may provide newer opportunities for adjunctive therapy for DCI, but are yet to be tested.

Endogenous inflammatory mediators (Table 1) include components of the complement system, eicosanoids and cytokines. The kinin system also produces vasoactive peptides, particularly bradykinin, a potent vasodilator that increases vascular permeability and contracts respiratory smooth muscle.

Inflammation also activates the clotting system. We have demonstrated that free gas in blood and plasma induces clotting, and follows the usual pattern of an inflammatory process (9). The intrinsic clotting cascade is initiated by Hageman factor activation by gas bubble surfaces in the blood (10).

Table 1. Inflammatory mediators, their source and actions.

Adapted from Cotran et al (21).

Mediator	Source	Action		
		Vascular Leakage	Chemotaxis	Other
Histamine and serotonin	Mast cells, platelets	+	-	
Bradykinin	Plasma	+	-	Pain
Coomplement 5a	Macrophages	+	+	Leukocyte activation
Prostaglandins	Membrane phospholipids	+	-	Vasodilation, pain, fever
Leukotrienes	Leukocytes, mast cells	+	+	Leukocyte activation Bronchoconstriction, vasoconstriction
Oxygen free radicals	Leukocytes	+	-	Endothelial damage, tissue damage
IL-1 and TNF*	Macrophages, other	-	+	endothelial activation
Nitric oxide	Macrophages, endothelium	+	+	Vasodilation, cytotoxicity

IL-1 - Interleukin 1, TNF - Tumor Necrosing Factor

IL-1 and TNF (alpha and beta) are cytokines that mediate inflammation and can be activated by hyperbaric exposure (11). Their secretion can be stimulated by the physical injury resulting from tissue gas formation, contact of free gas with endothelium, and possibly by blood-bubble interface reactions. They induce synthesis of endothelial adhesion molecules, chemokines, growth factors, eicosanoids, nitric oxide (NO), and enzymes associated with matrix remodeling, and they increase surface thrombogenicity of the endothelium. TNF also causes aggregation of neutrophils. NO release causes vascular smooth muscle relaxation, and reduced platelet aggregation. Recent knowledge of these complex endothelial adhesion processes that are characteristic of inflammation suggests promising new therapies that would further inhibit the initial tissue injury caused by free gas in the body. In the case of DCI, the inflammatory response may be detrimental.

Current Therapy for Gas Bubble-Related Injury

Current practice dictates that a diver with gas bubble-related injury should be recompressed under any circumstance. However, in the absence of immediate availability of a recompression chamber, basic and clinical research and standard of practice indicate that oxygen, fluid therapy and an antiplatelet agent should be provided. These measures are based on clinical and experimental data indicating that oxygen can provide a gradient for nitrogen washout and thereby reduce free gas volume in the blood and tissues based on the oxygen window concept (12).

Fluid therapy is based on well-documented data that an important component of the inflammatory reaction is plasma loss, hemoconcentration, and stasis in capillaries and venules with subsequent tissue ischemia or death (5). These effects are due to the loss of plasma in the microcirculation, thus replacing intravascular fluid will reduce or ameliorate this detrimental effect of plasma leakage. Fluid replacement is best carried out with a crystalloid solution devoid of glucose. Some studies suggest that increased glucose supplied to injured brain or spinal cord tissue might augment tissue injury (13). The choice of crystalloid solution has not been studied. Normal saline or a balanced ringer's solution are likely to be equally efficacious.

We and others demonstrated that bubbles will activate platelets and augment the microcirculatory stasis (9, 14), thus an antiplatelet agent is recommended. However, the effect of agents such as aspirin or clopidogrel may be diminished by the already active process, and the greatest value of an antiplatelet agent is likely to be as a preventive measure before injury occurs.

Specific Therapies for Diving-Associated Injury

With the understanding that the current basis for adjunctive therapy involves oxygen, fluids, and antiplatelet agents in most cases of decompression sickness, and in many cases of arterial gas embolism, this section discusses unique treatments in addition to the aforementioned three, that may be needed for less common situations resulting from diving.

Cardiac Arrhythmias

The relations of ventricular fibrillation of the Torsades Des Pointes form with swimming by subjects with the Long QT syndrome is well documented (15). In this case, the healthy diver becomes suddenly unresponsive and pulseless. Therapy is cardiopulmonary resuscitation, but this disorder is quickly reversed by cardiac defibrillation. Since most evacuation services carry a defibrillator and Automatic External Defibrillators are becoming more available, early defibrillation should be considered if such a device is available. The victim's chest should be dry, and rescuers should be out of electrical contact during the shock. These devices contain computer-based algorithms to determine the cardiac rhythm and to decide if defibrillation is appropriate. Their availability would save a number of lives from diving when a cardiac arrhythmia is the cause. Other causes of sudden death should be considered. These include acute coronary syndrome and massive gas embolism with filling of the central circulation with air (16).

Less serious arrhythmias such as atrial fibrillation or supraventricular tachycardia can be managed emergently with fluids and supine position as the major difficulty is hypotension due to the rapid heart rate. Medical therapy for such rhythms is diverse, but in nearly all cases an oral beta-blocker will provide some slowing of heart rate and stabilize the victim.

Lung Injury

Although the most evident manifestation of pulmonary barotrauma is arterial gas embolism and cerebral dysfunction, lung injury may be evident and require some support. This injury can take the form of pulmonary edema with arterial desaturation, or frank pulmonary hemorrhage. In the case of arterial desaturation, oxygen by tight-fitting mask will provide increased arterial oxygenation during transport to definitive therapy. If significant blood loss is occurring from lung hemorrhage, fluid replacement with a crystalloid solution would be appropriate until definitive therapy can be established. If a diver is bleeding from the injured lung, careful monitoring of blood pressure and urine output is required. Supine position in addition to oxygen and IV fluids will provide support during transportation.

Immersion Pulmonary Edema

This response to diving is not considered to be a manifestation of gas bubble disease, but appears to be a non-cardiogenic pulmonary edema of unknown etiology (17). The pattern of onset, and rapidly reversible course is typical of negative pressure pulmonary edema (18), and this mechanism may contribute to the disorder. The diver develops dyspnea on the bottom, usually early in the dive, that worsens and is associated with a cough. Upon ascent, the diver is severely dyspneic, may show signs of pulmonary edema fluid and is cyanotic. Emergency treatment consists of oxygen and diuretics, but the usual tourniquet approach is not warranted, as this is not a cardiogenic process, but a primary pulmonary problem. Recompression therapy is not indicated in this disorder. The characteristic presentation is dyspnea while diving, before ascent, that persists after return to the surface.

Drowning

Many cases of lung barotrauma with cerebral air embolism result in both cerebral injury from gas embolism and aspiration of water with drowning (19). The victim is usually unconscious and cyanotic, may be apneic with or without a cardiac arrest, and water may be present in the mouth and airways. The victim requires positive pressure breathing for oxygenation, and this is best done at the scene with a bag and mask, but mouth-to-mouth respiratory support also will improve oxygenation. The victim requires immediate evacuation for definitive care that includes intubation and positive pressure ventilation. In caring for such victims, both the severe arterial desaturation and cerebral injury must be considered. In most cases, cardiopulmonary stability requires the first consideration, and circulatory stabilization should be the initial goal during transport to a chamber facility.

Marine Organism Injuries

Divers may also develop decompression-related disorders and have associated severe marine injuries that may obscure the correct diagnosis or may complicate therapy. Several reviews of these disorders and their treatment are available (20). These injuries will not be discussed in this review.

Treatment Based on Blocking Inflammatory Mediators

Based on early decompression studies of complement activation and from gas-blood interactions, anti-complement treatment has been evaluated in animals, but no effect has been observed on reduction of incidence or on outcome of decompression injury. Based on current studies, anti-complement treatment cannot be recommended as an adjunctive therapy.

Monoclonal antibodies for human use are available against TNF-a (Infliximab, Etanercept) and against IL-1 (Anakinra). These have been studied in treatment of chronic inflammatory disorders such as Crohn's disease and rheumatoid arthritis and have shown good results. However, no studies on DCI therapy have been done to date. If activation of inflammation occurs early in divers with intravascular or tissue free gas, then use of these acute inflammatory inhibitors would likely attenuate the injury process. This type of therapy provided as soon as possible after the injury, and as an ongoing adjunct to recompression with fluids and oxygen, might result in improved outcomes in severe cases.

Summary

Oxygen, fluid replacement and antiplatelet agents are common adjuncts to recompression therapy of decompression sickness and arterial gas embolism. Although this combination therapy has not been tested in randomized clinical trials, clinical experience, experimental studies and the benign nature of the therapy have led to its common use before recompression therapy is instituted, and as an adjunct during recompression therapy. Based on knowledge of the inflammatory process and its role in DCI, a case can be made for use of newer anti-inflammatory inhibitors that have well-established efficacy in treatment of disorders characterized by acute inflammation. Both TNF-a inhibition and IL-1 inhibition could be the next advance in treatment of severe decompression sickness and arterial gas embolism.

Many divers who suffer serious consequences of diving are amenable to non-recompression therapy either as temporizing treatment or as definitive therapy. When planning non-recompression therapy for a diver, disorders unrelated to gas bubble disease must be considered (Table 2). These include immersion pulmonary edema, cardiac arrhythmias, drowning and marine animal injury.

Table 2. Diving-related disorders amenable to non-recompression therapy.

- Decompression Sickness*
- Arterial Gas Embolism*
- Drowning♦
- Cardiac Arrhythmias♦
- Immersion Pulmonary Edema♦
- Marine Animal Injuries♦

* Initial pre-recompression treatment only; these disorders require recompression as part of therapy

♦ These disorders should not be treated with recompression therapy

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DISCUSSION

CARL EDMONDS: Fred, I really appreciate your comments about differential diagnosis. Can we get back to basics because I'm a simple doctor? If it's a gas bubble disease and you want to get rid of the bubbles, to get rid of the nitrogen – and you've said you do that by using oxygen, of course – why don't we use the other ways that we've known for the last 50 years about how to get rid of nitrogen, which is by leaving the patient supine, which increases your nitrogen washout about 50 percent, will give you negative pressure breathing? You can do both by sticking them in a warm tub or a lukewarm bath. Why don't we advise this for people in remote areas while we're waiting for transport?

FRED BOVE: It's a good question. I'm sort of interested in negative pressure breathing as a cause for pulmonary edema, so I guess I'd worry that you might cause another problem with the negative pressure breathing. But immersion in warm water to cause more rapid turnover of gas, supine position to move nitrogen and to shift fluids centrally, those are all things I don't think we've adhered to very much but, again, they're things that are worth doing if you're in a remote site, and particularly if you've made the diagnosis of gas bubble disease on very objective findings. I think then whatever is possible to help remove gas during the time that you're waiting for transportation would be worthwhile. I don't know if there's a good trial of warm water other than what I recall is warm water can aggravate gas release, so I guess those are some issues that I would raise. If you had oxygen, warm water, supine position combined, it might be a good therapy while you're waiting for transportation, and then you could add some of the medication therapy as well.

ROWAN SANDERSON: Just one question about correct diagnosis. In our chamber in Phuket Hospital in Bangkok, Thailand, I think around about 20 percent of cases that we

receive with mild symptoms prove to have a problem not related to DCI. A dive operator will usually call us from a dive boat in a remote location and demand an evacuation for the patient. (Editors note: lengthy commentary here on motivation of dive boat operators to want to get patients reviewed). So, about 20 percent that we had come in did not have DCI-related problems.

One other issue in regards to the medication that you mentioned. Of all the dive boat trips that we've had, I've only had maybe two, maybe three dive operators that have come to the hospital that have had staff that had been sufficiently trained to be able to administer the type of medication. One was a DMT. The other one was a dive boat that had a nurse on it as well. What sort of issues are involved regarding the type of people administering this type of medication if you are on a dive boat trip maybe six hours away from any type of hospital evacuation?

FRED BOVE: Thanks. These are good comments. We probably need to do something about training the divers in their expectations, because it's appropriate for a dive operator to be overly conservative and, if there's any kind of symptom, to get the patient off of his diving operation and moved to somewhere where there's medical care. But we need to get the patients to understand that that doesn't necessarily mean they're going to go get treated in a chamber; it's just that they need to be evaluated by a more authoritative medical person. It may turn out that they don't have DCI, and that's OK, but you've heard this morning that we set expectations a little inappropriately. If we could change the way we set up expectations, that might solve part of that problem

In terms of the medications you would bring, I don't think I would bring Remicaid or one of those, but you might bring antihistamines. You can bring NSAIDs. There are some anti-serotonin oral medications that you could bring, also. So there are some things that are relatively easy to administer and that are relatively harmless that would allow you to at least attack some of these early changes and might prevent some of this vascular process.

ROWAN SANDERSON: There's no real set qualification for a person to apply these medications. I'd get concerned in regards to the legal issues if you're on a dive boat trip, and a DMT or an instructor said for you to take this type of medication. If the person has an allergic reaction to it or something else, then that opens up that dive operator to litigation. I can sort of understand why they call us and say, "Take care of this problem for us," or at least talk to a doctor and get something sorted out, because they don't want to get too involved because they'd open themselves up to further problems.

FRED BOVE: Yes, it would really be nice with the number of places around the world that are seeing injured divers to set up some randomized multi-center trials to get enough patients to look at the medications that might fit the theory on inflammation, so when you go on a dive boat, at least you have some studies that say, "Look, this is an appropriate medication." But we don't have the studies that would justify use now.

ROWAN SANDERSON: I know that for a significant number of patients, we've used additional medication as part of their recompression treatment. Plus, we've usually used a lot of physical therapy for muscular problems or problems walking.

UNIDENTIFIED: Fred, I'd like to ask you to speculate on Alison Drewry's suggestion, I don't think entirely facetiously, that hyperbaric oxygen therapy might actually produce worse outcomes in late treatment of mild cases. In other inflammatory diseases, particularly of the central nervous system, the dosage of oxygen seems to be associated with variable results – sometimes improved, sometimes worse – perhaps because of enhanced lipid peroxidation of cell membranes. What's your thought?

FRED BOVE: Well, if you could be certain that there were gas bubbles in the brain or cord that you could treat, you wouldn't argue about negative responses. It's the other level of "mild" DCI that's a problem. If you're not treating gas bubble disease and you're in a chamber, one of the beauties of hyperbaric oxygen, for the most part, is it's a fairly benign therapy. You can get away with it most of the time. But you're right, if somebody has a seizure or some other reaction to oxygen, you could be in trouble. So I would argue that if there is a significant doubt of whether this is truly gas bubble disease and the symptoms are stable or resolve over time with other therapies, you may not argue for recompression.

WILLMA PADILLA: In your presentation, you do not treat if there was previous neuropathy. Obviously, the patient's history is very important, but if the patient's symptoms are worse after diving, it could be that both the pre-existing problem and DCI exist together. How could you say, "Do not treat?"

FRED BOVE: It's a very good question, because there are cases in the literature, for example, of people with well-documented carpal tunnel syndrome who get worse after a dive. It seems a little better – not completely – when they are recompressed, but their carpal tunnel persists. Is this gas bubble disease? Have we treated gas bubbles in the wrist? It's not a spinal cord disease. Do we know if gas bubbles in the tendons and the ligaments of the wrist aggravate carpal tunnel syndrome? We don't know. For the most part, if somebody has documented carpal tunnel, goes diving, and comes back with an aggravation, it's more likely to be physical trauma aggravating the carpal tunnel and not gas bubble disease. We can't sort out who's what, but I would say it's less likely to be DCI than musculoskeletal injury from wrist motion. But there is no answer. I don't even know if response to therapy is the answer. I don't know the right answer. If I elicited a history of recurrent symptoms from carpal tunnel, I would be less likely to be concerned and less likely to evacuate for treatment if the pain reoccurred in a remote site. Give that individual some non-steroidals.

GLEN HAWKINS: I was intrigued that you went into the pathophysiology of the inflammation but stated that simple steroids – I presume you meant hydrocortisone and prednisone – don't work. Then you advocated more specific immunomodulators. Is there any point in discussing these when they are hard to get in Sydney, Australia, let alone Truk Lagoon or somewhere similar?

FRED BOVE: I absolutely agree. If you wanted to take some pills with you on a dive trip, take an NSAID or antihistamine. There are anti-serotonin agents for hypertension that are easy to get. You might take also some Singulair, some IL-1 inhibitors.

More complex inhibitors are often intravenous, like monoclonal antibodies, and very expensive – one dose is \$15,000. You’re not going to throw that in your dive bag, but if you’re working in a chamber and have a patient who’s not recovering, that’s the place to use more complex therapies. However, I wouldn’t do it unless a randomized trial had first determined if it really worked.

GLEN HAWKINS: Sorry, but how can you say to throw Singulair in your bag? How are you going to say it’s going to work as opposed to prednisone that has been shown not to work?

FRED BOVE: Right. We can’t go beyond NSAIDs until there are clinical trials of immune inhibitors to see if they work. Clinical trials should be conducted where we have the opportunity to see injured patients.

JAMES FRANCIS: Fred, unless I’ve been asleep, I’ve got a feeling that we may be saying, "Let’s try and define mild decompression illness because if it’s mild, we won’t treat it." Now you’re saying that limb pain, traditionally classified as mild, should go into a chamber. I’d like to ask you why.

FRED BOVE: If I saw a patient with limb pain that was radicular in nature, if it was radiating down the arm and in one finger and clearly defined as dorsal root pain – and the patient had a history of cervical disease – I wouldn’t get real excited about treating it. If you were in a remote site, I wouldn’t think it would be necessary to treat that patient because it’s more likely that it’s not DCI.

JAMES FRANCIS: I should have said joint pain.

FRED BOVE: If it’s joint pain typical of DCI with the findings that you’d expect, there’s gas bubbles. If there’s gas bubbles in the bones – I guess they’re in the bones – I would opt to try to treat, because we don’t know how much that contributes to osteonecrosis.

SIMON MITCHELL: We’ll close the discussion here. Thank you very much, Fred. That was excellent.

Picking up on what you said, James, we should clear up the misunderstanding that we are trying to define mild DCI and say we don’t need to recompress it. We will define mild DCI and look at the implications of that definition, such as how to evacuate, how long to wait before evacuation, and possibly whether to recompress or not. It’s very important in deciding what you’ll accept in the definition of "mild" that you understand that we don’t have a preordained agenda not to recompress.

To recap where we've been this morning and put in perspective where we're going this afternoon, I'll remind you that we're working our way down the decision tree in Figure 1 of the Introductory paper. We have a diver with symptoms after diving. We first ask ourselves if it's decompression illness. Let's assume we decide it is. The next question is, do we recompress? In the event we say no, we've talked about adjuvant therapy. If we decide that recompression is required, our next question is, does the case require emergency recompression? Should we be seeking urgent access to a recompression chamber? A pivotal issue in that regard is the effect that delay to treatment has on therapeutic outcome.

For this workshop, we are interested in the effect of delay on mild or marginal DCI. We've asked Dr. Jake Freiberger of DAN to speak on this question. Jake is a critical care-trained anesthesiologist and a very active researcher within DAN and Duke University. His areas of interest include diving medicine and mechanisms of hyperbaric oxygen. He has a master of public health degree with training in epidemiology and is a perfect choice for this tricky subject. Jake, thank you very much.

IS THERE EVIDENCE FOR HARM FROM DELAYS TO RECOMPRESSION TREATMENT IN MILD CASES OF DCI?

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Introduction

There is perhaps no more important issue in the appropriate triage of DCI patients than the effect of delay to recompression on patient outcome. As recreational divers travel to more remote locations in search of unspoiled dive sites, they can easily outdistance the medical infrastructure available to assist them in the case of a diving accident. Because most recompression facilities available to recreational divers are in fixed locations often far from dive sites, the question of how, when, and with what urgency to evacuate a case of DCI in a recreational diver is an issue of growing practical importance.

It is the mild cases, not the cases at the extremes of the severity scale, which present the biggest triage decision challenge. Almost all practitioners agree that severely injured divers with life- or limb-threatening DCI should be evacuated and recompressed as rapidly as possible. However, the indication for high-risk, high-cost medical evacuation in mild cases is less obvious. The very definition of what constitutes a "mild case" is unclear, and when "mild" symptoms occur, is there a time following the decompression exposure after which it is safe to assume that new, more serious symptoms will not appear? What should our time limits for emergency medical transport be?

Although the assumption that delay is harmful drives the perceived need for rapid evacuation and treatment, there is very little data to support this clinically cogent and widely held notion. The morally appropriate course for a physician to follow is to always make decisions in favor of the patients in his or her charge. In the setting of an emergency evacuation, however, the risks of evacuation must be weighed against the risks and severity of the expected outcome from the disease. Whenever an emergency evacuation is contemplated, the overall morbidity and mortality risk to the patient and the flight crew should be less than the risks imposed upon the patient from a delay to treatment. Apart from the purely medical decisions in triage, the issue of appropriate resource allocation and expense depend on an understanding of the importance of delay as well.

This report will discuss the existing scientific literature on latency and present two well-documented data sets that show no severe symptoms presenting 12 hours after decompression. It will explore the complexities in studying the phenomenon of delay

to treatment in DCI. It will then review the available literature on delay to recompression and present data indicating there is a small effect of delay on immediate, but not long-term, outcome in mild cases. Finally, it will introduce a new survey instrument specifically designed to record the effect of time to treatment on DCI cases of all severity categories.

The Issue of Symptom Onset Time (Latency) in DCI

When a diver is seriously injured with life- or limb-threatening DCI, there is no question that evacuation and treatment is required as soon as possible. However, there may be a time after which it is safe to assume that serious symptoms will not arise if they are not already present. This has important implications for triage.

Literature

Latency or symptom onset time is related to severity of injury and outcome in DCS. Patients with more severe symptoms and shorter latency are at greater risk. This was first shown in animals by Sykes and Hallenback in 1986 (1) and then by Francis in 1988 (2). The latency and severity association was also suggested by observations in humans (3, 4). In Francis' 1988 meta-analysis of 1,070 human cases of DCS, a short latency was associated with a more severe presentation, the need for more treatments, and a worse outcome. Francis specifically found that in central nervous system (brain and spinal cord) DCS, only 15 percent of the cases had symptom onset times greater than one hour after the hyperbaric exposure. Only one out of 80 cerebral and two out of 235 spinal cases from his literature group occurred after six hours. His current treatment center group recorded 28 out of 385 spinal and one out of 110 cerebral cases with latencies longer than six hours. Francis stated that in some of these cases, however, the diagnosis was uncertain, and the symptoms may not have been related to decompression.

DAN Data on Latency and Outcome for Severe and Mild Cases

If short latency and severity are related, can we hypothesize that there is a specific time after which serious symptoms would not appear? Any confirmed finding of a severe case that had a long latency would instantly invalidate this hypothesis. However, in the following DAN studies, no incontrovertible cases with latencies greater than 12 hours were found. Symptoms in cases involving paralysis or motor weakness appeared within minutes of surfacing in all but five cases in the DARF 1990-1997 dataset and in two cases in the DIRF 1998-2002 dataset. Review of these seven outliers suggested that the presence of recording errors or misinterpretation of the definition of paralysis and/or motor weakness caused their misclassification.

Paralysis Cases in DARF 1990-1997

In 1999 Joel Dovenbarger studied the cases of paralysis in 3,960 DARF injury reports. He found that paralysis was reported in 174 (4.4 percent) of the cases. He and his staff successfully contacted and interviewed 69 of these divers. The interviews revealed that 6 percent of the cases were miscoded and, in fact, were never paralyzed in the first place. Of the cases that were correctly coded, the median latency was 10 minutes with a mean latency of 2.5 hours. Five cases were outliers with latencies of greater than 600 minutes. The paper records were examined on each of the outlier cases and problems

were noted with: (a) the definition of symptom onset (actual paralysis onset versus time of confirmation by a physician); (b) the definition of paralysis (motor weakness versus generalized fatigue); and (c) possible misdiagnosis that could explain the prolonged latency (dizziness, headache, generalized numbness, bilateral arm tingling with weakness 36 hours AFTER treatment). Additional information from this study indicated that delay to treatment did not affect outcome.

Motor weakness cases in DIRF 1998-2002

In the second study, all recorded injury cases from DIRF 1998-2002 were searched for motor weakness in the symptom fields. Out of 266 cases designated as having "severe neurological symptoms," 168 cases recorded motor symptoms. These individual records were examined, the report's narrative read, and 109 calls made to verify the actual symptom and its onset time. One hundred fifty-three cases remained with verified motor symptoms that were not ruled out by either the narrative or the call. The median latency was less than one hour, and there were no verified cases with latencies greater than 12 hours. Figure 1 summarizes the DAN data on latency in severe cases.

Paralysis Cases in DARF 1990-1997	Motor Weakness Cases DIRF 1998-2002
3960 reports	All serious neuro reviewed
All paralysis cases selected	266 cases
174 cases (4.4%)	153 cases verified
69 called	Median latency < 1h
Median latency = 10 min	
No verified cases with these severe symptoms occurring greater than 12 h after the dive.	

Figure 1. DAN data on latency.

Implications of the Data on Latency

If we are confident that severe symptoms do not have prolonged latency, we might be justified in using surface oxygen or watchful waiting to treat a mild case of DCI. This philosophy obviates a risky emergency evacuation for mild symptoms once a minimal time period has passed. This does not mean that the clinician should not be extremely cautious about prodromal symptoms that might herald the onset of serious complications. The prodromal abdominal pain that sometimes precedes spinal DCS is such a symptom, and all available means should be employed to provide recompression therapy.

The Effect of Delay to Recompression on Mild Cases

We know very little about the impact of delay in mild cases. Surrogates for delay have suggested that late treatment is less effective, and intuitively, we believe delay to be harmful. However, this assumption is not always based on data. There is no information in the literature about the effect of time on outcome in mild cases, and it is safe to say that even for serious cases, the data we possess does not have adequate resolution in the very early time periods.

Surrogates for Studies on the Effect of Delay to Treatment

Although no prospective studies have assessed the effect of delay to treatment on outcome, surrogates for delay have been used and analyzed. The dive site's distance from the treating chamber is an example of such a surrogate. In DAN's 2003 Diving Report, the delay time was plotted against percent relief by chamber distance (Figure 2). The figure suggests that the closer a diver is to a chamber, the better the outcome.

Unfortunately, this interpretation is subject to many valid methodological challenges, primarily based on non-equivalent diving conditions, diver practices and reporting motivation.

Location and Outcome (DAN 2001)

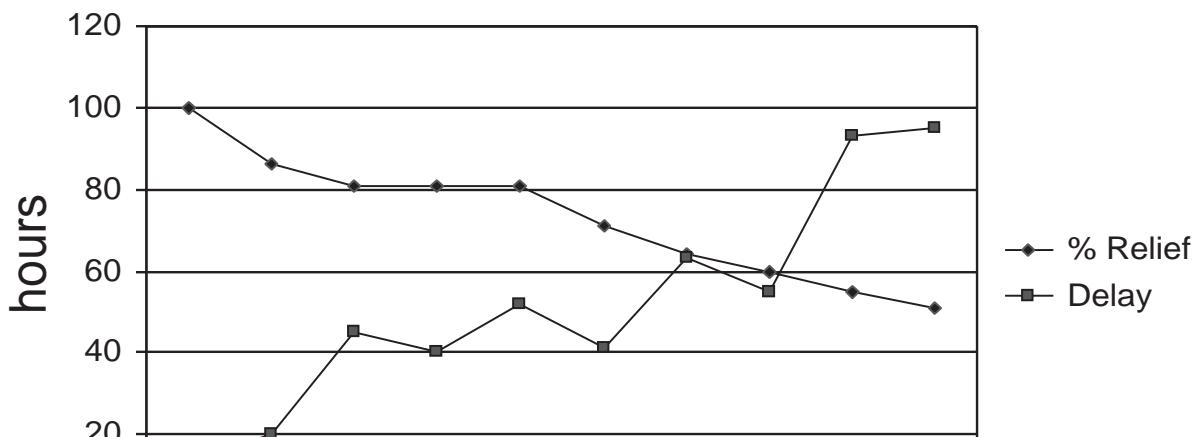


Figure 2. Dive location and outcome from 2001 data.

Literature

The scientific literature is not clear on the effect of delay to recompression on patient outcome. Authors attribute both high and low importance to its influence, and studies can be found that support both positions. Examples follow.

The Case for Delay as a Predictor of Outcome

It is commonly stated that prompt treatment for DCI is crucial for a good outcome. This position is intuitive, convenient and difficult to refute. In the abstract to his review article on the treatment of decompression illness, Moon states "the patient should be

recompressed as soon as possible" (5). Some studies supporting this view include: Goodman and Workman in 1965 (6), Workman in 1968 (7), Dick and Massey in 1985 (8), Lam in 1988 (9), Rudge in 1991 (10) and Ball in 1993 (11). In 1965, Goodman and Workman noted that in 1,088 cases of diver's DCS treated from 1946 to 1964, the initial treatment failure rate increased over the years. They postulated that this was a result of an increasing number of civilian divers who were treated with inadequate recompression and with significant delay. In 1968, Workman noted that the percentage of neurological cases was higher in civilian divers (85 percent) than in military divers (36 percent) and that the single treatment failure rate for civilians was 41 percent compared to 12 percent for military, implying that civilians with delayed cases had worse symptoms and outcomes. In 1985, Dick and Massey studied the neurologic presentation of decompression sickness and air embolism in sport divers and found that in a small series of 35 divers, recompression delays were associated with poor responses to therapy.

In 1989, Lam studied 793 cases of decompression sickness in a compressed air tunneling project in Hong Kong. Using the pressure required to relieve symptoms as a surrogate for severity, he found that the pressure required to relieve symptoms was more closely related to the interval between completion of decompression and commencement of treatment than to the delay between the onset of symptoms and treatment. In other words, surfacing to treatment time was important, not symptom onset to treatment time. In any case, the effect of delay to treatment was clearly measurable and adverse. In 1991, Rudge showed that in 233 cases of altitude-induced DCS, there was a direct relationship between length of delay to treatment and outcome. Patients successfully treated with recompression had an average delay to treatment of 10.6 hours, but in patients where a single treatment failed, the delay was 18.2 hours. The difference between these groups was significant ($p < 0.05$). Ball in 1993 stated that delay to treatment worsened outcome for 49 severely injured divers ($p = 0.008$). He also found that response to treatment was significantly different among initial severity groups ($p < 0.001$).

The Case Against Delay as a Predictor of Outcome

Studies that appear to challenge the importance of delay include: Kizer in 1982 (12), Meyers in 1985 (13), Hsu in 1992 (14), Boussages in 1996 (15), Desola in 1997 (16) and Smerz in 2003 (17). Kizer reviewed 50 cases of DCS where recompression was delayed 12 hours or longer after symptoms onset. Twenty-four patients (48 percent) had pain only and 26 (52 percent) had more serious decompression sickness. Ninety percent of the patients recovered either "completely" (66 percent) or "substantially" (24 percent) with recompression, implying that delay of greater than 12 hours was not reason to withhold treatment.

Meyers described three cases with residual DCS symptoms that responded well to recompression at three to seven days after the incident. In the same vein, Hsu presented a case of retinal artery occlusion treated with a delay of 14 days with a good outcome. In Hsu and Meyers, a good result was achieved even after an extended period without treatment, implying that delay to treatment was not harmful. Boussouges

examined delay as part of a study on severity and outcome. He showed that delay to treatment did not influence outcomes in this study population. Desola reviewed 466 cases over a 26-year period and found no relation between delay and outcome. Smerz, after reviewing his experience with the "Hawaiian deep treatment tables," stated that while the severity of injury and age of the diver were the most sensitive predictors, delay to treatment did not influence outcomes in his study population.

Why is the Literature Conflicted?

The discrepancies seen in the few studies above are a result of the difficulties inherent in any study of clinical outcomes after DCI treatment. The following section discusses where the data are ambiguous, or even misleading, and why.

The following issues frequently confound studies on the effect of delay to DCI treatment.

- (a) The severity of presentation influences both treatment outcome and the urgency for treatment (delay), and most studies fail to correct for either one or the other.
- (b) There is no "gold standard" for the diagnosis of DCI, and because diagnostic ambiguity contaminates many DCI databases, cases are inaccurately diagnosed and wrongly ascribed to DCI. Cases wrongly ascribed to DCI, as expected, do not respond to recompression and are counted as delay induced treatment failures.
- (c) The presence or absence of residual symptoms after DCI treatment is an inappropriate primary outcome measure because there is a wide range of residual symptoms encountered after DCI. Investigators who compare outcomes in patients using residuals without comparing the residual's severity or degree of improvement are not making equivalent comparisons.

Any analysis of DCI treatment procedures, surface O₂, recompression tables and specifically evacuation and delay must take these three issues into account, yet no large databases have ever done so. The following will explain this in more detail.

The Severity of Presentation Influences both Treatment Outcome and the Urgency for Treatment (Delay)

Severity of presentation strongly influences treatment outcome. Although intuitively obvious, this was first shown in animals by Sykes and Hallenback (1) who in 1986 regrouped animals into responders and non-responders to treatment. The non-responders were found to have presented with what clinically would be called more severe symptoms. They displayed more rapid onset, more severe insult and more adverse physiological effects than the responders. That effect has been confirmed in human divers in other studies including the previously mentioned studies by Francis (3), Ball (11) and DAN (18; see Figure 3). The data are clear that the probability of having a residual symptom after treatment is closely related to the severity of the symptoms at the time of the presentation.

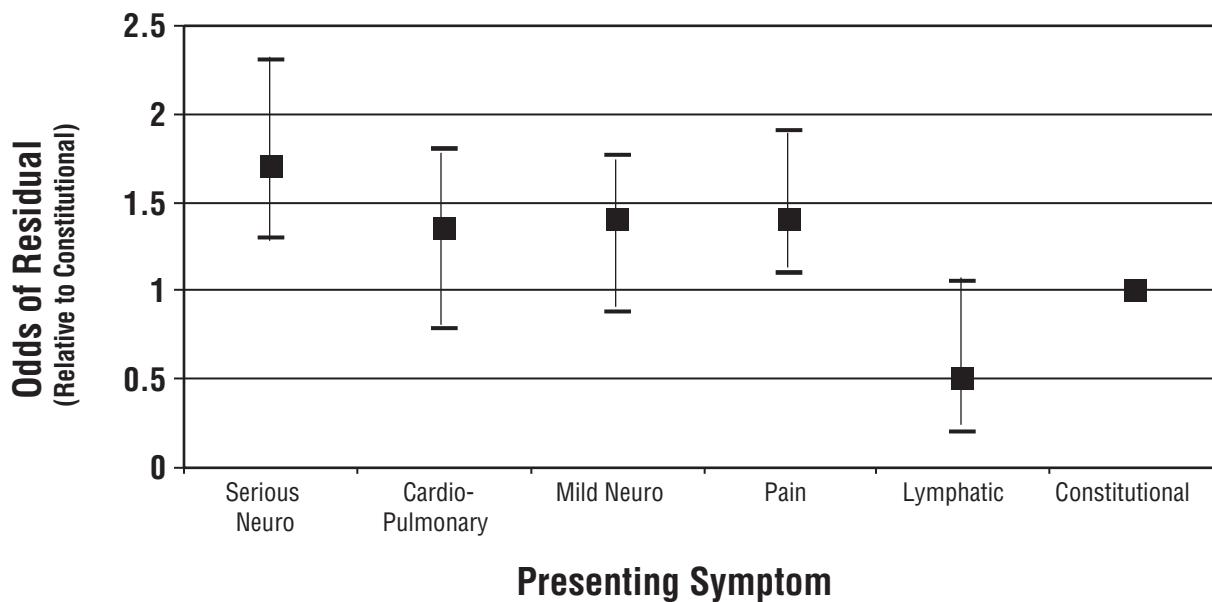


Figure 3. Relative odds of residuals by presenting symptoms.

The Severity and Latency Problem in Analysis

The problem with severity, latency and the analysis of delay arises because the delay to treatment is also influenced by the severity and latency of the presentation. Figures 4-6 were taken from an analysis of the 522 DAN cases from the 2001 DAN injury data in the "Doubt, no doubt" dataset to illustrate the following points (20). As described by Sykes and Francis (1-3), if symptoms have a delayed onset, they are less likely to be severe. Figure 4 shows how motor symptoms (a severe symptom group) have an earlier onset than the other symptom groups in this selection of the DAN injury data. It is intuitively logical that more urgency attends a severely injured diver with symptoms that come on immediately after a dive than one with mild and delayed symptoms. Figure 5 shows that the less severe symptoms (paresthesia, pain and constitutional symptoms) have a longer median delay to treatment. Finally, Figure 6 indicates that cases that are doubtful in terms of their diagnosis tend to present later for treatment.

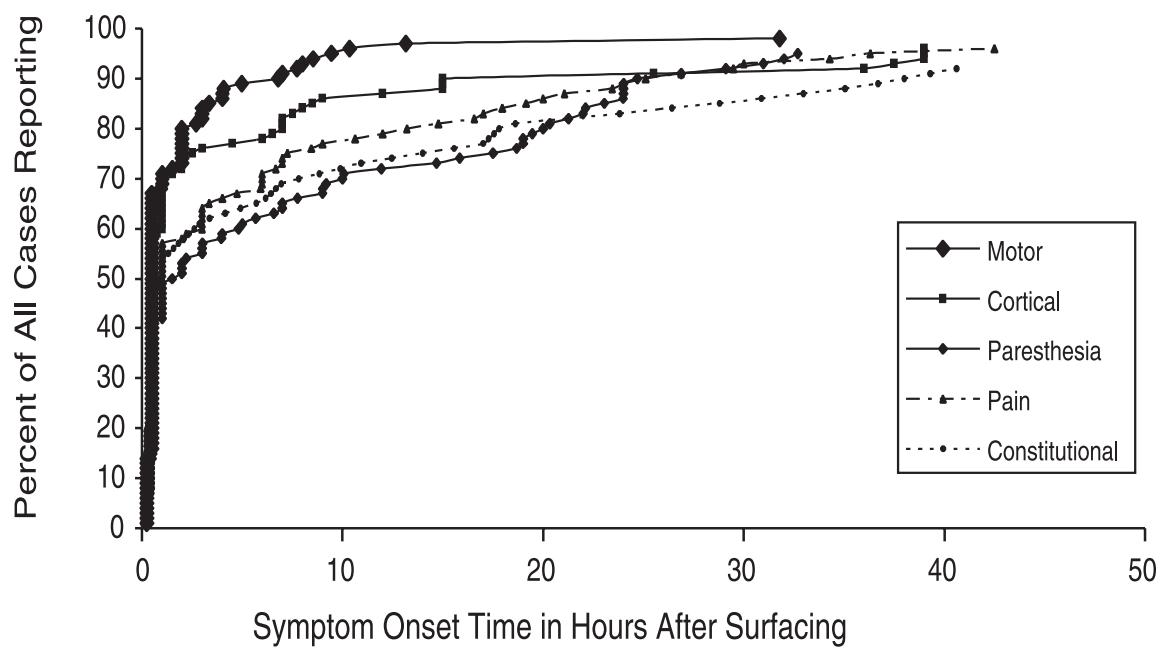


Figure 4. Onset time of first symptom by category.

Median Delay to Recompression by Symptom Category

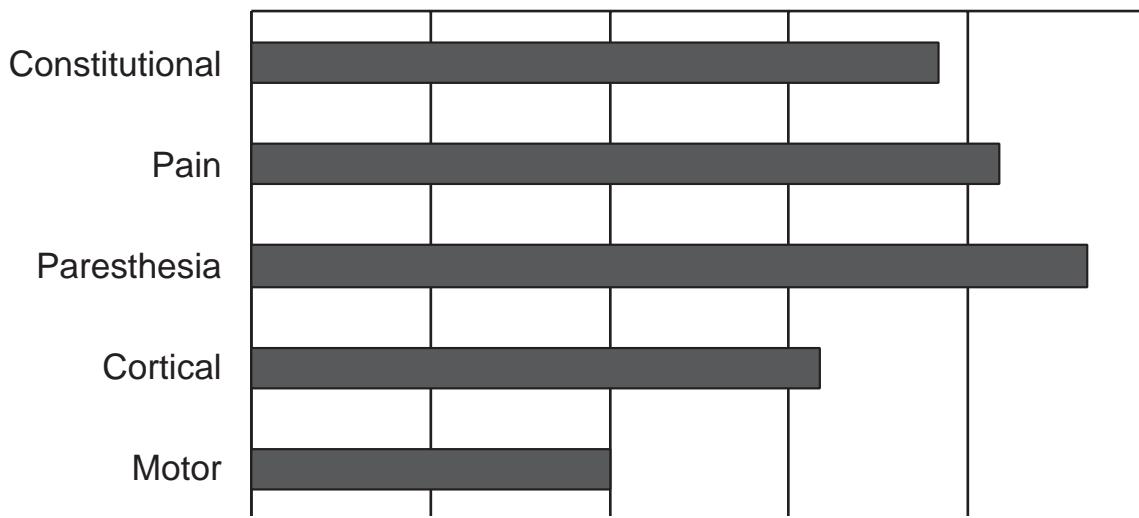


Figure 5. Median delay to recompression by symptom category.

Median Delay to Recompression

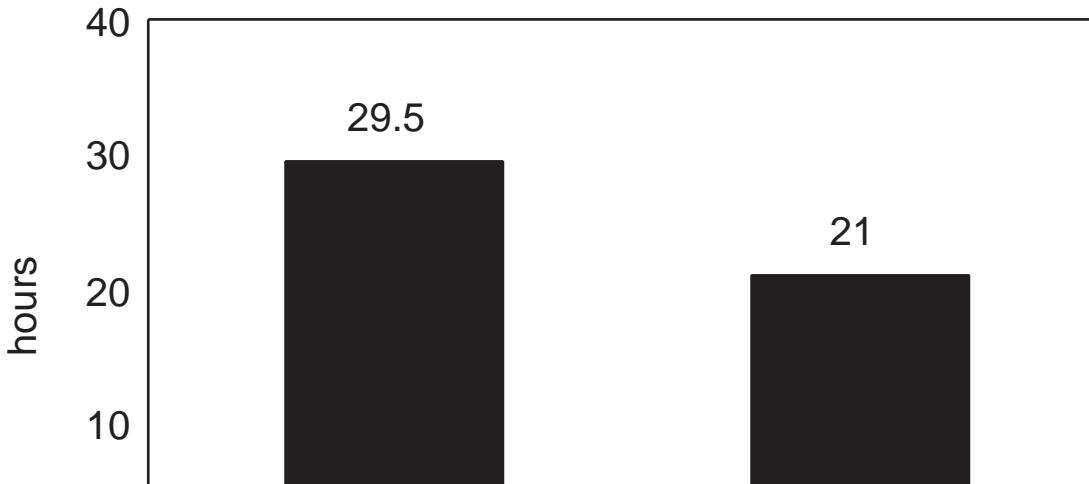


Figure 6. Median delay to recompression.

When the above influences are combined, the apparent effect of delay to treatment is biased towards the null, especially in the more severe cases. In other words, severe cases are delayed less, but because they are more severe, they have a worse outcome. Therefore, because the outcomes are worse, any possible beneficial effect of prompt, non-delayed treatment is overshadowed.

Diagnostic Ambiguity Contaminates Many DCI Databases and Cases that are Inaccurately Diagnosed as DCI Do Not Respond to Recompression

There are no confirming tests for the diagnosis of DCI. DCI diagnosis depends on expert opinion and judgment that proceeds primarily by exclusion through ruling out other causes that might explain the presenting symptoms after a dive. A DAN study in 2003 used a series of 200 computer-generated vignettes to analyze the decision-making process of an international group of physicians recognized as experts in the diagnosis of DCI (19). Rational and classical signs and symptoms, particularly the time course for symptom onset, were determined to be of greatest importance to experts. The study showed that after ruling out other potential causes for the symptoms, they used symptom onset time, typical symptom makeup and response to treatment to determine their diagnostic certainty.

Because response to treatment is a post hoc finding, diagnostic ambiguity confounds the analysis if delay is hypothesized to worsen outcome. Cases in the database that were ambiguous may not have truly been cases of DCI. Unfortunately, diagnostic ambiguity arises more frequently in presentations where the symptoms are mild and the onset is delayed. Also, as mentioned above, mild cases tend to engender less urgency for treatment; therefore, mild cases frequently experience longer delays. Because a cer-

tain unavoidable percentage of the mild and ambiguous cases are not DCI, they will not respond to recompression treatment. The analytical problem comes when these treatment failures are ascribed not to an incorrect diagnosis but to the associated delay (see Figure 7).

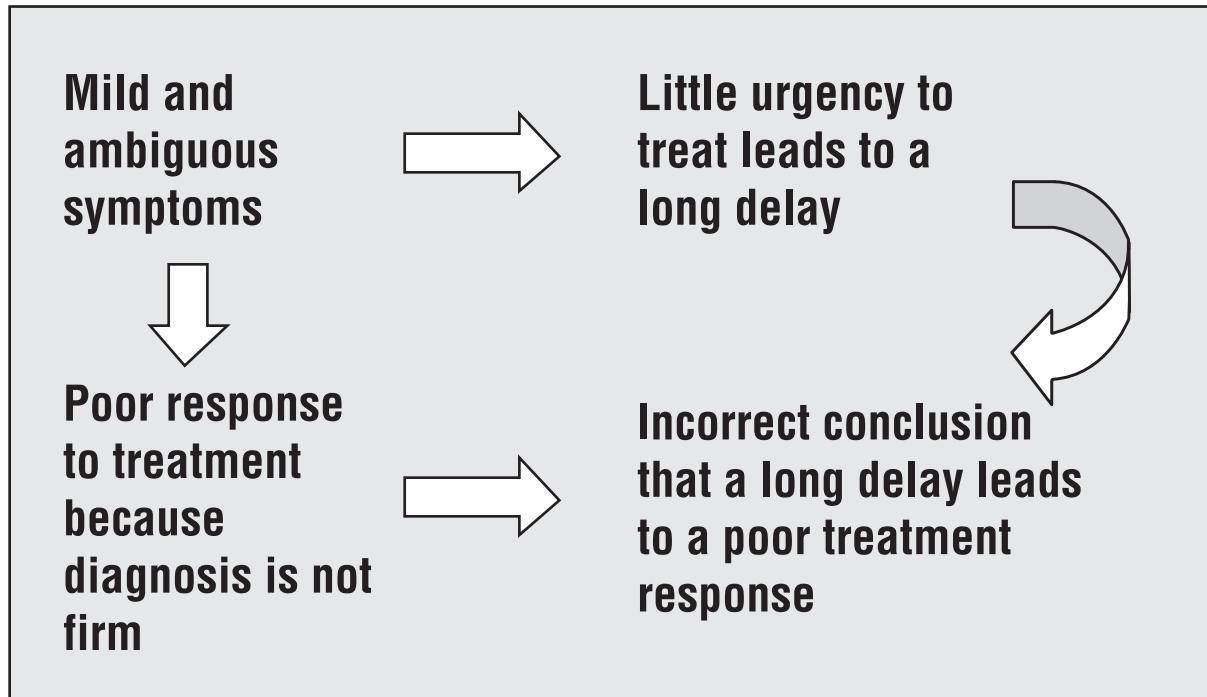


Figure 7. Diagnostic ambiguity.

The Presence or Absence of Residual Symptoms after Treatment is an Inadequate Primary Outcome Measure

Although it should be intuitively obvious that it is important to record the type, evolution and severity of any residual symptom remaining after treatment, practical matters make this process difficult, and generally it has not been done. As stated before, investigators who compare outcomes in patients using residuals without defining the residual's severity or evolution are not making equivalent comparisons. An example of this practice would be to declare as equivalent two patients with small regions of patchy numbness after treatment when one patient was paraplegic on admission and the other was not. If the effect of delay is to be determined, then it is essential to accurately assess and record the diver's condition over the course of his illness beginning with the termination of the pressure time exposure and continuing through the response to treatment. From the analytical point of view, the missing values cause the problem. If the answer to a question is blank, is it yes, or is it no? More on how DAN plans to prospectively address this problem later.

Summary of Why the Literature is Conflicted

In summary, the assessment of the effect of delay to treatment on outcome can be influ-

enced by: 1) the severity and urgency interaction; 2) diagnostic ambiguity; and 3) inappropriate outcome measurements. The 1987 to 1997 data described below is a case in point. The cases were mild, the diagnosis uncertain and the presence of residual symptoms were used as an endpoint, while the severity of the residual was not available for comparison between cases. It would not take many misdiagnosed, non-responding cases in the mild treatment group to incorrectly cause the effect that was seen. The following describes how an analysis can go wrong.

DARF 1987-1997 Example of the Analytical Problem

This effect of diagnostic ambiguity and inadequate outcome measures can be shown in an analysis of the DAN DARF data from 1987 to 1997, where 4,786 reports were analyzed to see if delay to treatment >12 hours had a worse outcome than those treated within the initial 12-hour period after the dive. The only outcome measurement available was the presence or absence of residual symptoms after all treatments.

The initial results showed there was no difference in residuals between the early and late treatment group (7.7 percent incidence of residuals in the early group compared with 7.2 percent incidence in the late group), but a different picture emerged when the cases were stratified by severity of presentation. An algorithm was devised based on the severity of symptoms at the time of presentation to allow the investigators to group the cases into mild versus severe categories. The mild group showed a statistically significant adverse effect from delays of >12 hours (<12h = 3.9 percent incidence of residuals, >12h = 5.9 incidence, p<.022 by chi square). However, the severe group showed just the opposite! (<12h = 13.3 percent incidence of residuals, >12h = 10.3 incidence, p=0.08).

These data appear to describe an inverse time to treatment dose response, but clinical experience and common sense tells us that this is unlikely. Biologically speaking, it is apparent that something is not methodologically correct if we can show an adverse effect of delay to treatment in mild cases but a favorable effect of delay in severe cases. Is this effect of delay on only mild cases an artifact? If the difference were to persist into the follow-up period, it would be believable. However, this is not the case.

Is the Long-Term Outcome of DCI Treatment Truly Compromised by Delay to Treatment in Mild Cases?

Similar to the flawed DARF 1989-1997 analysis, the DIRF 2001 "Doubt, no doubt" and the DIRF 1998-2002 datasets showed that mild cases had slightly less complete relief if treatment were delayed more than 24 hours. We covered the possible causes and significance of this finding earlier in our discussion of the DARF 1989-1997 data. However, new information on the topic was provided by the DIRF 1998-2002 dataset because follow-up was obtained at three, six, nine and 12 months. Although there was a slight difference in the percentage of complete relief at discharge between the early (<24 h) and late (>24 h) treatment groups, that difference disappeared in the follow-up period. The lack of a delay effect in the follow-up data favors the interpretation that the difference in percent complete relief at time of discharge based on delay to recompression treatment for mild cases is an artifact.

Data Cleaning in DDIRF 2001 "Doubt, No Doubt" and DDIRF 1998-2002

The problems outlined above are familiar to any analyst of retrospective data, and the best solution is to study the issue prospectively with a predetermined series of questions using a well thought out experimental design. Even when the questions were not thought out in advance, contacting the subject and interviewing him a second time can often obtain critical data. This technique was used to in two instances described previously to re-study latency in cases of paralysis (DDIRF 1990-1997) and motor weakness (DDIRF 1998-2002). The DDIRF 1998-2002 was also examined for the effect of treatment delay on mild cases.

When repeating an interview is not possible, analytical problems can be confronted retrospectively by applying filters to the dataset that categorize the cases by severity and earmark the diagnostically ambiguous ones. This technique was used in the DDIRF 2001 "Doubt, no doubt" dataset. Although this process can introduce bias through the filter design, if the criteria are clearly defined, consistently adhered to and appropriately applied, then the analysis will be meaningful. A more detailed discussion of the analysis of effect of delay to treatment in mild cases in these data sets follows.

Effect of Delay to Recompression Treatment on the DDIRF 2001 "Doubt, No Doubt" Data

The "Doubt, no doubt" data set was an attempt to retrospectively deal with the question of diagnostic ambiguity. For the DCI diagnosis symposium held at Duke University in April 2003, DAN developed a series of criteria to sort DCI cases in the injury databases by severity and diagnostic confidence.

The best data available were the 522 cases collected using the DDIRF during the calendar year 2001 (20). All cases had received recompression; therefore, the response to treatment was known. Because the DDIRF has a field that allows the reporting physician to list his final diagnosis, the opinion of the reporting physician was used as the primary screen for diagnostic confidence. All cases still listed as DCS, AGE or DCI by the reporting physician were classified as no doubt. Cases listed as "ambiguous," "lung barotrauma without AGE," "other," or "unrelated to pressure" were classified as doubtful (doubt).

Dr. Petar Denoble of DAN Research applied additional filtering to the dataset. He reclassified the remaining no doubt cases during a detailed chart review by reclassifying as doubtful cases that did not have the following criteria:

- For AGE, symptom onset greater than 15 minutes post dive, cases without at least one cerebral symptom, and cases with symptom duration of less than 15 minutes.
- For DCS, single dives to less than 30 fsw, symptom onset more than 48 hours after the dive unless there was an intervening altitude exposure, and symptoms that persisted less than 20 minutes with O₂ or less than 60 minutes without O₂.

To better understand severity at the time of presentation, the cases were hierarchically categorized into the following bins according to the most severe symptoms: (1) motor weakness or paralysis; (2) mental status changes or involvement of coordination or the

special senses; (3) pulmonary or cardiovascular symptoms; (4) paresthesia or altered skin sensitivity; (5) isolated pain; or (6) constitutional symptoms such as fatigue, headache, simple dizziness or nausea.

After the filters were applied, 399 of the original 522 cases remained as no-doubt cases. There was a wide range of delays to recompression in the dataset. Some cases were treated in less than an hour's time, and others waited many days before being recompressed (range 0.14 to 871 hours). In support of the argument that urgency influences delay, the median value for delay to recompression was 21 hours for the non-doubtful cases as opposed to 29 hours for the doubtful ones (previous Figure 6). Although the outcome measurement in the DAN 2001 analysis remained the presence or absence of residuals (previously discussed as inappropriate), because the dataset was complete enough to allow rudimentary filtering to decrease the diagnostic ambiguity and because it allowed assignment of severity categories, stratification was possible to control for the other confounding issues previously discussed.

Results of Delay to Treatment Analysis in "Doubt, No Doubt"

In the unstratified data, delay to recompression was not shown to be a predictor of complete relief. However, when the data set was stratified by doubt versus no doubt and severity, delay was shown to a clinically weak but statistically significant ($p=0.04$) predictor of outcome. When analyzed by logistic regression, each hour of delay (compared to immediate recompression) decreased the odds of complete relief by about 1/2 percent (0.42 percent). That means that if a certain percentage of the divers were expected to have complete relief with immediate recompression, that percentage would wane as time progressed. Because we used logistic regression, the results could also be controlled for the age of the diver, the diver's BMI and the diver's gender. The regression revealed that in addition to delay, age was also a significant negative predictor ($p=0.01$), but other controlling variables were not. For each year of age, the odds of complete relief fell by about 2.5 percent.

DIRF 1998-2002 Analysis

Two hundred four sequential cases form the 2002 DIRF injury reports designated as having mild neurological symptoms were selected for an analysis of symptom relief by recompression treatment delay. The same filter was used to identify and eliminate cases with diagnostic ambiguity as in the "Doubt, no doubt" dataset. The narratives of all cases were reviewed and telephone follow-up calls made where possible.

Results of Delay to Treatment Analysis in DIRF 1998-2002 Analysis

When the outcome at discharge was analyzed, 75 percent of the cases treated within 24 hours achieved complete relief compared to 68 percent of cases treated after 24 hours ($p=0.04$). However, complete relief at the 3-, 6- and 9-month follow-up periods was not different. By three months, 84 percent of the divers in both the early and late groups no longer had symptoms putting the validity of the original findings in some doubt. Figure 8 summarizes the results of the two preceding DIRF 1998-2002 studies.

DIRF 2001 Doubt, no doubt" (n= 522)	DIRF 1998-2002 (n=202)
Stratified by severity	Treated in <24h complete relief in 75%
Filtered for ambiguity	Treated in >24 h complete relief in 68%
Logistic regression	(p=.04)
Outcome accepted	No difference in complete relief at 3,6,9 or 12 mo
Odds of complete relief decreased 0.42% per hour delay (p=.04)	

Figure 8. DAN data on delay in mild cases.

Discussion of Biology of Delay

In spite of the lack of differences in the follow-up groups presented above, it is impossible to know with the data at hand if delay to recompression treatment is more important in the earliest minutes and hours following an injury than in a later phase of the disease. However, it is not unreasonable to believe that early recompression treatment might be more important in preventing damage caused by autochthonous and embolic inert gas collections than in the treatment of the biochemical- and edema-related changes that are hypothesized to persist for longer periods of time. It may make biological and mechanistic sense to strive to treat early for the severe cases, but less so for the mild ones. The only way to answer this question is through prospective study that is focused on time-related responses to treatment.

DAN's Plans to Prospectively Assess the Effect of Delay

The previous sections discussed the pitfalls of analyzing data variables in isolation and without clear and appropriate outcome measures. These pitfalls result from extrapolation beyond the original objectives for which the data collection instruments were designed. An effective survey instrument should collect data to answer specific questions. Comprehensive data collection has epidemiological value and forms the basis of more detailed research, but it suffers limitations when applied outside its original objective. The response rate of a survey is also important, and this is often the cause of research failure. A return of less than 70 percent cannot exclude bias and is not a representative sample (21).

For these reasons, DAN has designed a new injury collection instrument that employs the dual philosophy of asking specific and focused questions in a way that will result in a high response rate. The Scuba Epidemiological Reporting Form (SERF) is a one-page data collection instrument specifically designed to assess the effects of pressure-time exposure, the evolution of clinical presentation, clinical severity and delay to recompression. It is a simple and accessible format that will insure a high response rate.

The SERF is a one-page digital form designed for completion in less than five minutes by health care providers involved in treating injured divers. It is designed to be completed post hoc, after all chamber treatments. It is based on information technology developed by DAN for Project Dive Exploration (PDE). The SERF and PDE data fields are compatible.

The SERF addresses the following goals: (a) simplification to increase the reporting rate; (b) standardization for use by International DAN (IDAN) chambers; (c) unambiguous categorization of presenting injury and severity; (d) capture of key time points for exposure, treatment, and recovery; (e) capture of specific symptom evolutions; (f) assessment of diagnostic certainty; (g) capture of depth-time profiles when available on dive computers; and (h) compliance with US HIPPA (Health Insurance Portability and Privacy Act) guidelines.

The SERF is designed to stratify DCI cases by severity at the time of presentation, efficiently capture key time points (symptom onset times, treatment times, symptom resolution progress), improve response rate (one-page design) and catalogue the electronic dive profile. The SERF also has a field for physician confidence in the diagnosis. These features should allow DAN to effectively control for variables such as severity at presentation, individual depth-time exposure, individual diver health and regional treatment differences when we next examine the effect of delay to recompression on outcome.

The SERF (Figure 9) will be distributed on CD-ROM. DAN will provide the software and hardware for downloading an injured diver's depth-time profile when it is available on a dive computer. The profile will become part of the diver's records and electronic dive profiles will be used to investigate the relationship of exposure to injury severity. Although reports submitted by e-mail to DAN will be anonymous, participating centers will have immediate access to individual case reports and summary reports of incidence, treatment activity and effectiveness. As incentives for chamber participation, cases submitted to DAN will be redeemable for DAN medical education seminars and other products. It is hoped that data from this and other similar efforts will help researchers at DAN and elsewhere to better define the true risk of delay to recompression treatment as well as to answer other important questions regarding recreational diving safety.

DAN SCUBA EPIDEMIOLOGICAL REPORTING FORM						Hospital ID:	Chamber ID:	Add New	All Records	Close	
DIVER DATA						DIVE DATA					
Diver ID: _____			Total # of consecutive days diving: _____			Breathing gas at depth %02 _____			CRITICAL CLOCK TIMES AND DATES		
Date of diving injury: _____			Total # of dives in that period: _____			<input type="checkbox"/> air <input type="checkbox"/> nitrox <input type="checkbox"/> trimix <input type="checkbox"/> heliox <input type="checkbox"/> Flying after diving or altitude exposure within < 24hr?			HH:MM	DD-MMM-YY	
Age: _____ Gender <input type="checkbox"/> m <input type="checkbox"/> f			Symptoms before last dive? <input type="checkbox"/> yes <input type="checkbox"/> no						Format example: 17:30 12-Dec-04		
Medical conditions* <input type="checkbox"/> none <input type="checkbox"/> Other			Max depth of last dive <input type="checkbox"/> ms <input type="checkbox"/> fsw						End of last dive: _____		
<input type="checkbox"/> asthma <input type="checkbox"/> hypertension <input type="checkbox"/> diabetes <input type="checkbox"/> cardiac <input type="checkbox"/> psychiatric <input type="checkbox"/> neurological			Estimated bottom time: _____ m						Check if O2 Given <input type="checkbox"/>		
Rapid ascent? <input type="checkbox"/> yes <input type="checkbox"/> no			Omitted decompression? <input type="checkbox"/> yes <input type="checkbox"/> no						First surface O2: _____		
						Preflight surface interval (hr): _____			First recompression: _____		
						Profile type <input type="checkbox"/> multilevel <input type="checkbox"/> square					
						Dive planned by <input type="checkbox"/> computer <input type="checkbox"/> table					
Symptoms any time before treatment						Symptom onset time after dive		After Suface O2	After 1st Tx	After All Tx	At 24 after Tx
Pain		Arm <input type="checkbox"/>	Pain Scale: 0=none, 10=worst pain imaginable	Leg <input type="checkbox"/>	Check if bilateral <input type="checkbox"/>	Elapsed time (hours:minutes) <input type="checkbox"/> hrs <input type="checkbox"/> min					
Motor Weakness		MOTOR STRENGTH CODES: 5=Normal Strength, 4=Active power against both resistance and gravity, 3=Active power against gravity but not resistance, 2=Active movement only with gravity eliminated, 1=Flicker or trace of contraction, 0=No movement or contraction (flaccid)									
		Arm <input type="checkbox"/>	Check if bilateral <input type="checkbox"/>	Leg <input type="checkbox"/>	hrs <input type="checkbox"/> min						
Sensory		Arm <input type="checkbox"/>	Subjective <input type="checkbox"/>	Leg <input type="checkbox"/>	Objective <input type="checkbox"/>	Check if bilateral <input type="checkbox"/>					
Bowel / Bladder		inability to defecate or void									
Vertigo		true vertigo; uncontrollable spinning sensation									
Cortical		confusion, apathy, blindness, deafness									
Respiratory		shortness of breath, tachypnea									
Constitutional		headache, fatigue, mild dizziness, nausea									
Skin Rash		not due to envenomation or allergy									
Abnormal Gait		normal or abnormal									
Treatment Summary											
1st Recompression Total number of recompressions <input type="checkbox"/>											
<input type="checkbox"/> T6* <input type="checkbox"/> T6A* <input type="checkbox"/> TT9 <input type="checkbox"/> T5 <input type="checkbox"/> Comex 30 <input type="checkbox"/> Other HB <input type="checkbox"/> None											
Total number of recompressions until Sx plateau (< 10% change) <input type="checkbox"/>											
Adjunctive therapies <input type="checkbox"/> Yes <input type="checkbox"/> No											
Assigned Diagnosis											
DCI: <input type="checkbox"/> DCS <input type="checkbox"/> AGE <input type="checkbox"/> Not specified <input type="checkbox"/> Not DCI*											
Confidence in assigned diagnosis											
<input type="checkbox"/> Confident <input type="checkbox"/> Likely <input type="checkbox"/> Possible <input type="checkbox"/> Doubtful											
Ear Exam											
Hearing <input type="checkbox"/> normal <input type="checkbox"/> abnormal TM <input type="checkbox"/> normal <input type="checkbox"/> barotrauma Electronic dive profile available? <input type="checkbox"/> yes <input type="checkbox"/> no											
Import Electronic											
<small>* Please describe in comments Review by physician: _____</small>											

Figure 9. Scuba Epidemiological Reporting Form (SERF).

Conclusion

It is difficult to appropriately analyze all of the available data on delay because of problems with confounding from severity, diagnostic ambiguity and inappropriate outcome measures. Some good latency data is available, and no incontrovertible cases of paralysis or motor weakness with a symptom onset time greater than 12 hours were found in the DAN datasets. The majority of severe cases had had latencies less than one hour after surfacing. A small effect of delay to treatment in mild, but not severe, cases is seen in the retrospective analyses of three DAN datasets. This effect disappears on follow-up and may be due to the methodological explanations stated above.

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DISCUSSION

JORDI DESOLA: *Editorial note: a long commentary from Dr. Desola was difficult to hear on the recording and did not transcribe well. The main thrust of the argument was that delay to recompression is less important than ensuring that other aspects of the management such as surface oxygen, administration of fluids and adjuvant drugs, and the recompression itself are conducted in an expert manner. Dr. Desola finished by stating that whilst patients should go to a chamber as soon as possible, "the quality (of treatment) is the most important thing."*

JAKE FREIBERGER: The copy of my article in the handout is from February and has been significantly modified. Dr. Desola's paper is referenced in revised paper.

KLAUS TORP: Jake, you mentioned there was no difference between less than 24 hours and greater than 24 hours. How much greater was greater than 24 hours? Were they all treated with recompression?

JAKE FREIBERGER: Yes, they were all treated with recompression and the greater than 24 hours category was open-ended. The two groups in the 2002 data set of mild neurological cases were divided into treated before 24 hours and after 24 hours. Those treated after 24 hours could have been treated at 25, 48, 72 hours or even longer.

KLAUS TORP: Do you remember the range?

JAKE FREIBERGER: I think the longest wait for a diver to be treated was two or three days. I don't think it was anything silly like two weeks.

JOHN ROSS: It's excellent to see the DAN data being analyzed in this way. There was a similar exercise presented in 2000 in Sweden that came to much the same conclusions.

One thing you didn't pick up on, however, was the fourth reason why you don't get a relationship between time to treatment and outcome. People with severe disease tend to present very quickly, and the treatment's often not very effective. We're now coming towards our second audit cycle in Scotland, and we've now got about 650 cases. We're not getting as many severe cases now, and as those cases drop out, we do find a time to treatment relationship with outcome, but it's in mild to moderate cases, not in severe cases where treatment may not be terribly successful.

JAKE FREIBERGER: The problem with the severe cases is exactly as you say. Severe cases have a less effective response to treatment. That may overshadow the fact that they're often evacuated sooner and treated sooner. In addition, they present sooner.

ALF BRUBAKK: This was quite interesting. Your data clearly show that in mild cases delay probably doesn't mean so much. However, I think one of the reasons you don't see any difference in the severe cases is because initially you're treating the bubble and its mechanical effect while after some hours, you're treating a biochemical effect. What you're doing is giving hyperbaric oxygen for the secondary effect. If you can stop the first effect, you have probably solved the problem. I have enormously impressive experimental evidence that shows a recompression of 10 meters on breathing air make the bubbles disappear very quickly and on return to the surface, very few reappear. We also published that we see no neurological deficits from that kind of treatment, and we've found that 10 meters on air is just as effective as 10 meters on oxygen for removing bubbles if you do it quickly – within the first hour. It seems that pressure removes the bubbles, and oxygen takes care of the excess gas. I would challenge what's been said here, that time doesn't matter. I think it matters if you can't do it very quickly. I would think that we should treat the serious cases rapidly. They need immediate recompression. After some hours, my guess is you will not see large differences in treatment outcome.

JAKE FREIBERGER: The problem is one of resolution. DAN's studies – and most of the literature – have resolution on the order of hours or days, not minutes. It's difficult to make any statement based on delay to recompression if you're only able to resolve the difference between less than 12, greater than 12, less than 24, greater than 24 hours.

CUAUHTEMOC SANCHEZ: Following up on Alf's comment, we presented 31 cases of arterial air embolism in '92 in which there was a 2.5 times worse outcome in treatment delay before or after six hours. After six hours, there was no difference. When we say that time makes no difference, it depends on the time frame. If you treat within one hour, everyone had a good outcome, including with psychometric testing. The results deteriorate up to six hours, and after six hours, there was no difference because the pathophysiology has already started finalizing the ischemic event. Once the tissue is dead, there is no difference in the treatment outcome after six hours. For me, time does matter if you treat urgently. After six hours there is no difference, because the damage is already done.

JAKE FREIBERGER: Very good point.

ALF BRUBAKK: We have a large dataset that shows immediate treatment will probably give very few residual symptoms. That's from all the tests that the U.S. Navy has done. Their dives produce a higher percentage of very serious decompression sickness, and one of the U.S. Navy people said that they do not consider it a problem if they recompress the affected diver immediately. You might disagree from an ethical point view, but that's their position.

JAKE FREIBERGER: Well, I think that's probably true. The issue, though, is that in the setting of recreational diving, it's going to be very unusual to be able to transport and treat a patient within those more effective time limits. Thank you.

SIMON MITCHELL: Alf, we'll be interested to revisit your comments on the effect of quick recompression when we talk about in-water recompression. I know there're a few technical divers in this room who are interested in that issue. Technical divers have some spectacular stories of people developing what sounds like serious DCI who control it immediately by recompressing in-water and don't appear to have any problems afterwards. So we will come to that.

DAVID DOOLETTE: We have come to another decision point in the tree of Figure 1 of the Introduction paper. If we decide that recompression is required, we must ask if recompression needs to be provided on an emergency basis. The previous paper indicated that for mild cases, a delay to treatment might not result in worsening in the medium term. We might decide that emergency recompression is not required, and evacuation does not have to be by the fastest means possible. In this context, we must ask if we can transport a diver from a remote site to a treatment center by commercial airliner? Chris Wachholz will speak on the topic, "Can Divers with Symptoms of Mild DCI Fly on Commercial Airliners?" Chris is the Vice President of the International Department at DAN and one of the co-organizers of this meeting with Simon, myself, and Dick.

CAN DIVERS WITH MILD SYMPTOMS OF DCI FLY ON COMMERCIAL AIRLINERS?

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Introduction

Recreational divers travel to remote locations throughout the world, and a few develop decompression illness (DCI). Rapid recompression is the optimal therapy for these individuals, and transport by aircraft is usually the fastest means of reaching a chamber when one is not available locally. Air transport can occur by air ambulance or by commercial air carrier. Air ambulance evacuation offers a one-atmosphere cabin pressure, 100 percent oxygen for the duration of the flight, and medical support. All these are mandatory for critically injured divers. The question at issue is, what might be the consequences for divers with mild DCI who were transported by commercial air carrier instead of by air ambulance? Would their signs and symptoms be exacerbated, and would their ultimate therapeutic outcome be less satisfactory than for divers who did not fly?

In this paper, we review the experience of DAN America with divers who were diagnosed as having DCI and who travelled by commercial air carrier. The objective was to present information that workshop participants might use in developing guidelines for transporting a diver with mild DCI at a remote dive location to an adequate recompression facility. An appendix summarizes information on commercial air transport regulations, policy and practice.

Flying After Diving

DAN America receives information on recreational scuba diving injuries from about 100 hyperbaric chambers each year, primarily from the North American and Caribbean regions. Of approximately 1,000 reported DCI cases, written summaries are submitted for about 500. After follow-up and review, these cases are available for analysis.

Of DCI cases collected by DAN during 1998-2002, 10-20 percent flew aboard commercial aircraft after diving (1-5). It might seem reasonable to assume that flying caused these injuries, but in fact, more divers had symptoms before flying than developed symptoms during or after flight. A total 642 divers flew by commercial air during 1987-1990 (6) and 1998-2002 (1-5) and were later recompressed for DCI. Of these, 63 percent had symptoms before flying.

Divers who had DCI symptoms before flying might provide insight concerning the purposeful transportation of injured divers by commercial air. We identified 1,635 diving injury cases collected by DAN from 1998-2002 to investigate the effect of flying on DCI: 126 cases flew with symptoms, and 1,509 cases did not fly (1-5). We did not know the flight durations.

Cases were stratified by severity where severity was measured by a hierarchical system in which each case was retrospectively classified according its most severe sign or symptom (3-5). Six severity categories, defined from greatest to least, were:

1. Serious Neurological. Objective signs including bladder or bowel dysfunction; muscular weakness; incoordination; vertigo; disorders of vision, hearing, consciousness, or higher function.
2. Cardiopulmonary. Objective signs including cough, hemoptysis, dyspnea, and respiratory distress.
3. Mild Neurological. Subjective symptoms including paresthesias, numbness, tingling, sensory changes.
4. Pain. Subjective symptoms including ache, cramps, discomfort, stiffness.
5. Skin. Swelling, burning, itching, rash, marbling.
6. Constitutional. Dizziness, fatigue, headache, nausea, vomiting.

When grouped together, Categories 1-3 are equivalent to Type II DCS, and Categories 4-6 are equivalent to Type I DCS. Figure 1 illustrates the distribution of the 1,635 cases within the symptom categories. At 45 percent, Mild Neurological cases were most common. None of these cases were categorized as Skin or Constitutional.

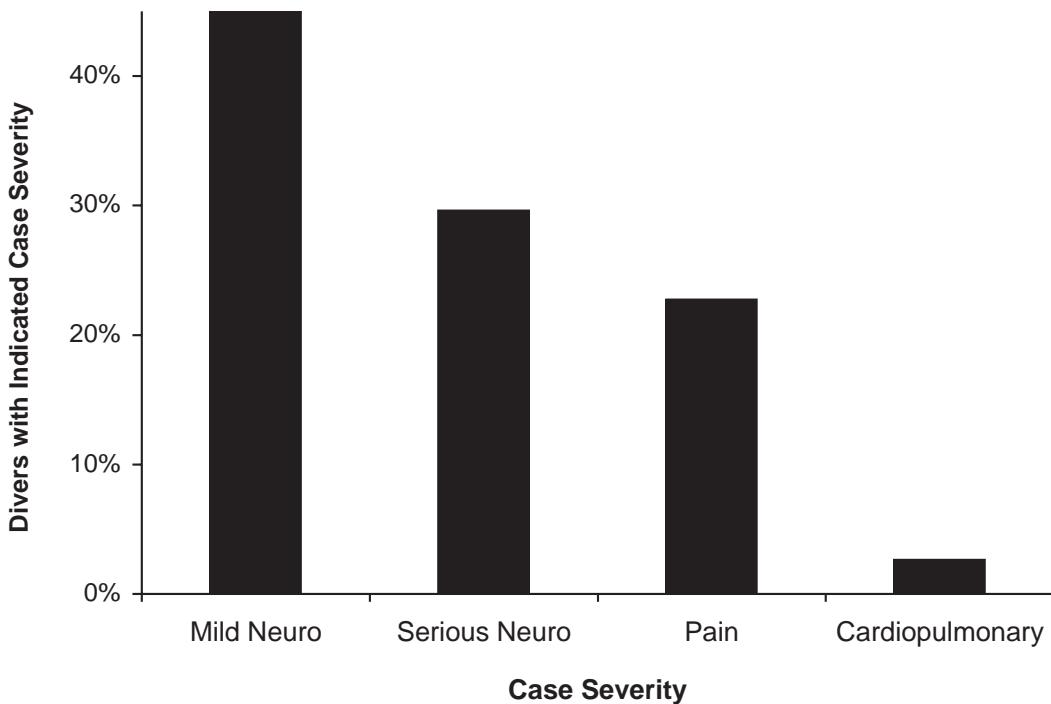


Figure 1. Distribution of case severity in 1,635 DAN DCI cases.

To assess the effect of flying on DCI, we measured therapeutic outcome as the percentage of cases with complete relief of symptoms at the end of all recompressions. We did not know the nature of the residual symptoms. Since flying after diving is a secondary decompression that can initiate decompression sickness (DCS) itself (7), we stratified cases according to the delay before flight into three groups: did not fly, flew after 24 hours, and flew within 24 hours. It should be remembered that the divers who flew all had symptoms before flight.

Figure 2 compares the percentage of cases with complete relief for the three stratified groups. For Serious Neurological cases, 33 percent who flew within 24 hours had complete relief after treatment, while over 70 percent who flew after 24 hours or who did not fly had complete relief ($p=0.015$). For Mild Neurological cases, 50 percent who flew within 24 hours had complete relief after treatment, while about 70 percent who flew after 24 hours or who did not fly had complete relief ($p=0.005$). This agreed with an earlier analysis (8). For divers who waited longer than 24 hours before flying, there was no difference in the percentage who achieved complete relief from divers who did not fly.

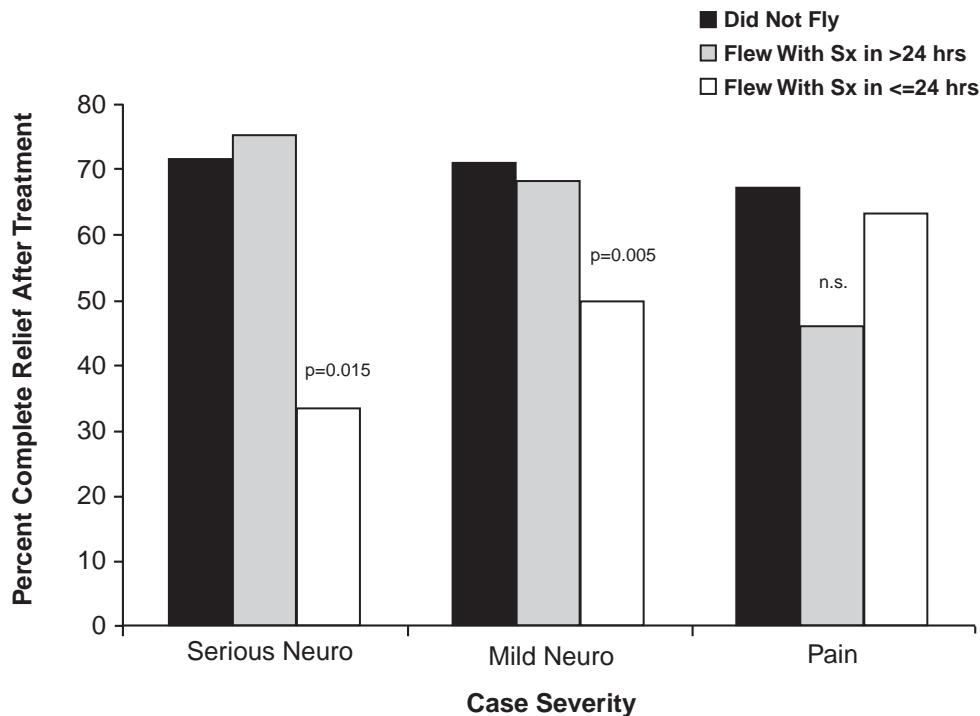


Figure 2. Percent complete relief after all recompressions for divers with DCI who did not fly and for divers who flew with symptoms (1-5).

By traditional thinking, long delays to recompression should have worse therapeutic outcomes than short delays. Why, then, would divers who waited for more than 24 hours before flying have better outcomes than divers who waited for less than 24 hours? This seems counterintuitive. In the previous paper, however, Freiberger and Denoble cited evidence that delay to recompression longer than about 12 hours had little effect on treatment outcome (8). If this is correct, then the effect of time to flight may reflect the secondary decompression of flying and delay to recompression, per se, may be unimportant.

The Truk Experience

Truk lagoon (Chuuk) is a remote but popular dive site because of its many World War II warship wrecks. Before a recompression chamber was installed in the spring of 2003, Truk was a model for the problem of how to transport a diver with suspected DCI from a remote site to hyperbaric care.

Medics on the Diving Emergency Hotline at DAN America typically receive six to eight calls from Truk each year. Callers who describe possible DCI symptoms are screened for symptom severity, medical background and dive history. After providing recommendations for immediate care, DAN Medics consult attending hyperbaric physicians at Duke University Medical Center. Three options are considered when air transport is indicated: air ambulance, U.S. Coast Guard (from Guam) and commercial air. The choice is driven by symptom severity, delay to transport and the need for oxygen and ancillary medical care. Patient safety is the top priority.

Continental Micronesia Airlines provides scheduled air transport throughout the South Pacific islands. In the absence of local air ambulance services and national health care, Continental has recognized the need for accommodating sick or injured passengers and has developed medical guidelines for off-island fitness to travel. These guidelines recognize the unique nature of diving injuries. The DAN Medical Staff has consulted with Continental at short notice on a number of occasions to arrange for the transport of injured divers. Medical escort, reduced flight elevation, and emergency high-flow oxygen during flight were key considerations.

From 1999-2002, DAN assisted in the transport of 12 divers with DCI from Truk, primarily to Guam where the nearest recompression chamber is located at a flying time of 1.5 hours. Five cases were evacuated from Truk by air ambulance and seven cases by Continental Micronesia Airlines. The choice of transport mode was governed by case severity and availability of an air ambulance as compared with regularly scheduled air service. Some patients who flew commercially were accompanied by one of the authors (GM), a trained diving physician.

Four of the five cases transported by air ambulance were classified as Serious Neurological. Four of the seven cases transported by commercial air were classified as Serious Neurological, and all were stable. The mean estimated preflight surface interval for commercially transported cases was 40 hours (range 21-57 hours). All 12 cases received surface oxygen, and in-flight oxygen (2-4 L/min) was available for many commercial cases. Cabin altitudes for the commercial cases were about 7,300 feet.

Five of the seven cases transported by commercial air reported complete relief of all signs and symptoms. Of two commercially transported cases that were classified as Serious Neurological, one had Mild Neurological symptoms after recompression and the other had Pain (occasional shoulder tightness). In another Serious Neurological case, the diver flew from Truk to Florida, against medical advice, instead of to Guam but had complete relief after recompression, nonetheless. One Serious Neurological case transported commercially became worse in-flight but had complete relief upon recompression.

Discussion

Mild Neurological cases were most common in the DAN diving injury data followed by Serious Neurological, Pain, and Cardiopulmonary cases (Fig. 1). For divers who flew with symptoms, recompression therapy was less effective in both Serious Neurological and Mild Neurological cases if the divers waited for 24 hours or less (Fig. 2). For divers with symptoms who waited longer than 24 hours before flying, recompression therapy was as effective as for divers with symptoms who did not fly. These results apply to the limited number of cases in the DAN data and are not necessarily representative of all divers who fly with DCI symptoms.

Cases evacuated from Truk were generally consistent with these observations, although there were too few to support statistical comparison. Surface oxygen, in-flight oxygen, reduced cabin altitude and medical support were usually available, and most of the

flights were only 1.5 hours in duration. These factors may be important to the chances of successful resolution, and their availability should be considered when deciding whether to evacuate an injured diver by commercial air.

Appendix: Commercial air transport regulations, policy, and practice

U.S. regulations do not require airlines to provide oxygen for passengers (9). If an airline does provide oxygen, the tanks must be FAA certified and remain airline property to ensure proper servicing and maintenance. Exceptions are not allowed. Most carriers required notification of oxygen needs by the patient's physician, and airlines in the United States require a physician's written prescription stating the duration and oxygen flow rate for each leg of the flight (9,10). Continuous oxygen may not be available from U.S. air carriers in airports before boarding, after landing and during layovers.

Stoller surveyed 33 airlines (11 US-based, 22 international-based) and found that 25 (76 percent) offered in-flight oxygen for general respiratory patients (11). The mean time required to make arrangements for in-flight O₂ by telephone was 10.2 minutes (range 4-20 minutes), and no more than two calls were required. Liter flow options ranged from two flow rates (36 percent of carriers) to up to 15 liters per minute by one carrier (12).

International air travel regulations do not generally permit patients to bring their own oxygen, but in emergencies, oxygen equipment from the patient's health facility may be used (12,13). The oxygen equipment used by most airlines must be attached to the floor for safety. An airline is typically able to provide two E-cylinders (11).

A joint report of the U.S. House of Representatives and the American Medical Association recommended that "organized medicine should work with the FAA, air carriers, and respiratory care organizations to revisit current regulations and consider the feasibility of allowing passengers to procure medical oxygen from designated FAA-certified vendors for use during flight" (10).

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DISCUSSION

SIMON MITCHELL: When your physicians made the decision to fly someone doing the leg from Truk to Guam on a commercial airliner, was that ever in the context of an air ambulance being available?

CHRIS WACHHOLZ: Yes, in some cases – and some of the physicians that were involved in these cases are in the room here – but my understanding is that in some of the cases, there was no air ambulance available, or it would have taken longer to get the air ambulance to transport the patient than would the next available commercial flight.

SIMON MITCHELL: But was that decision ever made when there was an air ambulance available, that is, they could have done it by air ambulance in a similar time frame but chose to use a commercial airliner instead?

CHRIS WACHHOLZ: I believe so, yes. George Macris, one of the paper's authors, has more experience than DAN with use of airliners for transport of divers with DCI.

GEORGE MACRIS: We've been medevacing patients from Truk for 20 years, and there are a few more cases in the series than in Chris' paper. The patients' decisions to go by commercial airline were to avoid further delay with air ambulance. There was also situational anxiety due to the rustic nature of Truk; the hospital is a bit rustic, to say the least. Sometimes weather was coming in, and the air ambulances out of New Guinea are weather-restricted and can only land during the day. In the context of mild DCI, our rule of thumb has always been that patients who are stable or improving within 24 hours can safely get on an aircraft for a 100-minute flight.

Altitude control on the 737/800 and newer aircraft are different than on older aircraft. They bring the cabin altitude up and down gently and are programmed according to the flight plan. Sometimes they don't even reach 7,300 feet, which is the maximum cabin altitude. One of the other authors in our little group is a Continental pilot / ER physician / aerospace doctor who monitors the altimeters constantly.

Our experience in Guam, with small numbers, is no problems at 24 hours or longer where symptoms are stable or improving during 100-minute flights with or without O2 on newer aircraft such as the 737/800 series. The patients land, do well, and rarely have anything significant in-flight problems other than a little abdominal pain maybe from gas expansion. They have responded nicely to therapy. I think it's time to treatment, but only after the 24-hour wait. That's a counterintuitive thought but applies when you're using a non-standard transfer.

CHRIS WACHHOLZ: Yes. One of the important points you make, George, is that the safety of using airliners in a 1.5-hour flight may be very different than using airliners for a much longer flight.

KLAUS TORP: Chris, you compared flying at less than 24 hours and greater than 24 hours with the no flight but treated patients. Do we have any idea when those patients were treated? You compared the success rate of the early flight and late flight to the no flight patients, but do we know anything about the delay to treatment for those no flight patients?

CHRIS WACHHOLZ: I believe they run the gamut and are not limited to being treated within 48 hours. They were simply flown within 48 hours, and the treatment time might be a lot longer. Petar, could you answer that question?

PETAR DENOBLE: We didn't compare time to treatment, just the two groups, flying or not flying. The counterintuitive outcome may be because this was not a clinical trial where we prospectively assigned to two different groups. Probably the people who

flew more than 24 hours after symptom onset or after a dive get their symptoms later, and that's why they ended up in the later group.

IAN MORRISON: (Qantas Airlines, Sydney). Thank you, Chris, for inviting me here today. I must say, I've learned a great deal. This is an area of medicine that I'm totally unfamiliar with. We tend to stick in our own little worlds, and mine is aviation medicine. Having said that, we are certainly aware that we do carry people with mild DCI throughout the year. Unfortunately, we never know the outcome, and that's something we would clearly like to know.

I can see that there is an opportunity for collaboration with DAN and IATA, the International Air Transport Association. I am on the medical advisory group for IATA, and we meet twice a year. I think there would be great benefit in forming collaboration between the two organizations as well as MedAire (DAN's assistance company). I didn't know about DAN, but most of the airlines in the world (more than 55) use MedAire (based in Phoenix, Arizona) for in-flight medical care. MedAire also screens people who turn up unwell before they board the aircraft. It certainly does seem to be a good idea that we get together and form a relationship that would be ongoing to help yourself and the airlines in general. Thank you.

SIMON MITCHELL: Thank you very much, Ian, for taking the time to come along today. I have one question for you. Is it then true that Qantas does not actually have a policy on transport of divers with decompression illness? Is it just something that's done on a case-by-case basis, or is there a protocol? An example would be a physician trying to get a patient on a flight from Papua New Guinea back to Brisbane on one of your planes.

IAN MORRISON: I think I can safely say that Qantas is one of the airlines that is less conservative than most of the others. We deal with DCI on a case-by-case basis and are largely guided by what you tell us. If there is an obvious problem in carrying somebody, of course, we get a little nervous, but we do our best to get people out. Certainly, if it's a life-threatening situation, and there is no air ambulance there, we will do whatever is required. On our website, we have the standard sort of conditions of travel in terms of health and fitness. We have general guidelines, but not specific for DCI. Having said that, I should mention that we do have the ability to set up stretchers, curtain them off, and carry a 3,500-liter oxygen cylinder. On Qantas, you can bring your own oxygen if required domestically without question and, internationally, on a case-by-case basis.

ALISON DREWRY: You referred to the perhaps slightly worse outcome for people who flew earlier in their course of mild DCI. They had a slightly worse outcome initially than those who flew a bit later in their mild DCI. Both sets were treated and ended up the same. Could that possibly be explained if the disease only lasts five days?

CHRIS WACHHOLZ: Yes.

SIMON MITCHELL: We're carrying on down the decision tree in Figure 1 of the Introduction paper. We've asked, "Does emergency recompression need to be provided?" At the moment, we're exploring the decision path option where urgent recompression is not necessary, and we're looking at options for non-urgent evacuation. We have just considered the issue of transporting people on commercial airlines, which interestingly enough, may actually be quicker than waiting for an air ambulance. That's an important point.

An often-overlooked issue in discussing evacuation of decompression illness is transporting divers overland for substantial distances. That happens regularly in Queensland, Australia where there's a huge barrier reef on the coast and one hyperbaric chamber in the middle and another one at the very Southern end. The chamber in the middle receives most of the patients and is often faced with evacuating patients having equivocal or mild histories over considerable distance.

Air evacuation would be very costly to move this number of DCI patients. The Townsville chamber, where Dr. David Griffiths is the director, has developed a pattern of evacuating some of these divers by Greyhound bus, which has been very successful for them. We thought it was relevant to ask David to discuss his experience.

GROUND TRANSPORTATION OF DIVING INJURIES TO TOWNSVILLE

Dr. David Griffiths, MBBS, FANZCA
Director of Hyperbaric Medicine
The Townsville Hospital

Dr. Robert Webb, MBBS, FANZCA
Staff Specialist
The Townsville Hospital

Townsville is an Australian coastal city situated in the state of Queensland at the mid-point of the Great Barrier Reef, which is about 2,000 km in length.

Approximately 1.5 million recreational scuba dives per year are undertaken by paying customers, from recreational dive boats operating along the Barrier Reef or from Barrier Reef Island Resorts (1). Several mainland centres act as homeports to this industry, in particular, Port Douglas and Cairns to the North, Townsville itself, and Airlie Beach and Mackay to the South. Each of these towns has a hospital with an emergency service that has facilities for physical and neurological assessment by a Medical Officer, chest X-rays, and the provision of 100 percent oxygen at 1 Atmosphere Absolute (ATA) together with intravenous fluids. Of these centers, only Townsville has a Hyperbaric Medicine Unit (HMU). This unit treats more than 60 cases of decompression illness (DCI) per year. The nearest alternative Hyperbaric Service is in Brisbane, which treats more than 30 divers per year. This situation should be contrasted with the southeastern USA, where 17 chambers treated 101 divers in 2001 following shorter retrieval distances, but with similar mean delays of ± 63 hours from symptom onset to first HBO₂ (2).

The arterial roads connecting the Northern and Southern Queensland coastal towns span approximately 400 km each way from Townsville and do not cross any mountains. The highest hill crossing is 200 metres above sea level. Travel times by bus from Cairns and Airlie Beach to Townsville are five and four hours respectively. Each of these nominated towns has an airport with 24-hour landing facilities for Kingair, Royal Flying Doctor Service (RFDS) fixed wing aircraft. These planes, which carry a well-equipped Medical Officer, are capable of maintaining a sea level cabin altitude in flight, but unfortunately, they are almost continuously in service. The Townsville Hospital Emergency Department Retrieval Service Coordinator must prioritise the retrieval of any patient with a diving injury against the usual RFDS patients for transfer with a head injury, premature labour, acute abdomen, etc. This commonly results in a delay of several hours prior to the fixed wing retrieval of a diver from a regional centre with anything less than devastating medical signs or symptoms.

Our helicopter retrieval service is similarly medically equipped to the fixed wing aircraft but is limited in its availability and although instrumented for low visibility and night retrievals, is not allowed to fly at less than 500 metres over water at night. No sand cay landings or winching retrievals are permitted at night.

A consequence of this, there is an emphasis on surface transport retrieval for many diving injuries from Regional Queensland centres that are not life, limb function, or sphincter threatening. Our road ambulance service is not equipped or funded for inter-city transfers, so the majority of our divers arrive in Townsville by bus, dive boat or in a car driven by a friend or partner, without the benefit of O₂ or IV fluids during their transfer. This often follows initial Base Hospital assessment and or treatment if indicated.

HMU Policies and Definitions Extant Throughout the "Ground Transportation Review"

A. Diver Retrieval Methods

1. Air. Fixed or rotary wing ambulance retrieval with continued O₂ and IV fluid first aid in transit.
2. Surface. Ground transportation without first aid in transit with no altitude exposure to greater than 200 m above sea level.

B. Townsville Hospital HMU DCI Severity Scoring Method as applied to Pre-HBO₂ Medical Assessment

1. Severe DCI. Threatening life or mobility
 - a. Loss of consciousness from DCI
 - b. Cardiopulmonary DCI
 - c. Objective weakness / objective sensory loss
 - d. Loss of bladder / bowel control
2. Moderate DCI. Symptomatic with subtle signs of DCI
 - a. Impaired higher function on mini-mental testing
 - b. Impaired Romberg's Test
 - c. Subjective sensory changes
 - d. Minor weakness judged due to limb pain
 - e. Cutis marmorata
3. Mild DCI. Symptomatic DCI with no objective signs except
 - a. Minor skin rash
 - b. Lymphatic DCI
 - c. Sharpened Romberg's Test less than 30 seconds

C. The Townsville Hospital Policy for Retrieval of Injured Divers

1. Severe and Moderate DCI. Objective physical signs
 - a. Must be managed with intensive first aid (i.e. lie down, true 100 percent O₂ and IV fluids) on site, in transit, and if appropriate, in a regional hospital or medical center

- b. Rotary or fixed wing air ambulance retrieval to the HMU must be arranged as soon as possible. Surface retrieval may be accepted from regional centres only for moderate DCI, if the delay to air ambulance uplift exceeds the surface retrieval time.
- 2. *Mild DCI*. Subjective symptoms only
 - a. Should receive first aid with 100 percent O₂ and oral fluids
 - b. The retrieval method will be determined by
 - i. The dive site location
 - ii. Local hospital or clinic availability
 - iii. Retrieval assets available
 - iv. Daylight availability and weather conditions.

D. The Townsville Hospital HMU Policy for HBO₂ Rx of DCI

- 1. Severe and moderate (objective signs) DCI patients will be treated with HBO₂ Rx as soon as medical assessment is completed within TTH Emergency Department (ED) and HMU.
- 2. Mild (subjective) DCI patients will be treated with ongoing first aid in ED with high flow O₂ via a Hudson's Mask together with IV fluids, followed by HBO₂ Rx at the next opportunity during working hours, ONLY when the diver is confirmed as having no objective signs of DCI, by an experienced Hyperbaric Medical Officer
- 3. Initial HBO₂ Rx is followed up with short HBO₂ Rx daily or occasionally twice daily
- 4. Treatments are continued until the diver is symptom free, or no improvement is evident over two days
- 5. On completion of HBO₂ Rx, commercial flights are discouraged for two weeks within Australia and three weeks on long-haul overseas flights

E. Method of Scoring Outcomes Following HBO₂ Rx for DCI.

- 1. Complete relief of all signs and symptoms of DCI
- 2. Residual symptoms only of DCI
- 3. Residual signs and symptoms of DCI
- 4. Not DCI, alternative diagnosis made

Methods

We have undertaken a review of all 123 divers presenting to the Townsville Hospital HMU over the past two years, from Nov. 4, 2001 to Nov. 3, 2003, who were treated with Hyperbaric Oxygen.

Six of the 123 patients were subsequently diagnosed as having non-DCI conditions, so have been excluded from further analysis. Data from the remaining 117 patients diagnosed with a decompression illness are presented and compared with DAN data, derived from the 2003 DAN publication "414 Complete reports of DCI to DAN in 2001" (2). The following case characteristics are described below:

- Diver Retrieval Method, with and without altitude exposure (Table 1)
- DCI Severity Score (Table 2)
- Effect of First Aid O₂ on discharge status (Table 3)
- Delay from symptom onset to first HBO₂ effect on discharge status (Table 4)
- Number of HBO₂ treatments given per diver (Table 5)
- Proportion of all divers with complete relief at discharge (Tables 6 and 8)
- Outcomes at discharge following HBO₂ Rx for moderate or mild DCI (Table 7)

Results and Discussion

HMU Diver Retrieval Method

Thirty-six divers (30.8 percent) were retrieved by air. Eighty-one (69.2 percent) were retrieved by surface transport. None were retrieved by road ambulance with oxygen and IV fluids.

The surface retrievals included four divers (3.4 percent), who experienced significant altitude exposure prior to low-level (under 200 m altitude) road retrieval to the HMU. (Three divers were retrieved by commercial aircraft flights with cabin altitudes of ±2,700m above sea level and one diver by road travel from mountains over 800m in altitude.) None of these four surface retrieval divers with altitude exposure had severe, objective signs of DCI, and all four were discharged from the HMU with no residual symptoms. (One had symptom recurrence in flight to New Zealand 16 days after completing HBO₂ Rx.)

Table 1. Comparison of Townsville HMU and DAN data describing retrieval modality and circumstances

	HMU Data 2001/2003	DAN 2003 Report (2001 data)	
Number of divers with final diagnosis of DCI	117 (100%)	414 (100%)	p-value by Chi Square test
Number (%) retrieved by Air Ambulance	36 (30.8%)	18 (4.3%)	
Number (%) retrieved by Surface	81 (69.2%)	396 (95.7%)	p<0.01
Total Number (%) retrieved by surface	81 (100%)	396 (100%)	
Number (%) retrieved by surface transport without exposure to altitude	77 (95.1%)	317 (80.1%)	p<0.01
Number (%) with altitude exposure after diving prior to surface retrieval	4 (4.9%)	79 (19.9%)	

DAN Diver Retrieval Data

Only 18 (4.3 percent) of the DAN USA injured divers were retrieved by Air Ambulance. Of the 52 divers (12.5 percent) who flew by commercial aircraft (cabin altitude of \pm 2,700 m above sea level), 35 (8.5 percent) of the DAN divers reported symptoms prior to their flight.

The much higher proportion of DAN divers with altitude exposure prior to HBO2 Rx and a significantly lower proportion retrieved by air ambulance almost certainly represents an element of "self retrieval" using commercial aircraft from remote dive locations.

No DAN data is published on the proportion of divers retrieved by road ambulance.

No published DAN data compares HBO2 treatment outcome with retrieval method.

Table 2. The Townsville Hospital DCI severity scores (when assessed in TTH HMU) and retrieval method

1. Severe DCI	Air Ambulance Retrieval	14
	Surface Retrieval	1*
	TOTAL	15 Divers (12.8%)
2. Moderate DCI	Air Ambulance Retrieval	17
	Surface Retrieval	38
	TOTAL	55 Divers (47%)
3. Mild DCI	Air Ambulance Retrieval	5
	Surface Retrieval	42
	TOTAL	47 Divers (40.2%)
All confirmed DCI	TOTAL	117 Divers (100%)

*Rough seas prevented Heli Medevac

Of the five HMU divers with mild DCI who were retrieved by Air Ambulance, one came from Papua New Guinea and one from Thursday Island (at the Northern tip of Australia). The other three included two divers from regional centres with mild ataxia, not initially recognised as being due to middle ear barotrauma, and one diver who was retrieved by helicopter to Cairns following an initial report of increasing symptoms, which later reduced on 100 percent O₂ at 1ATA.

Table 3. Effect of O₂ first aid on discharge status

	HMU		DAN	
	Divers	Complete relief after HBO ₂ Rx	Divers	Complete Relief after HBO ₂ Rx
1 st Aid O ₂	102 (87.2%)	71 (69.6%)	178 (43%)	139 (78%)
No 1 st Aid O ₂	15 (12.8%)	10 (66.6%)	236 (57%)	160 (68%)
TOTAL	117 (100%)		414 (100%)	

Proportionally, twice as many HMU divers received first aid O₂ prior to HBO₂ Rx compared to DAN divers. However, there was no significant difference in outcomes with or without first aid O₂ in the HMU series ($p=0.77$, Fisher Exact), perhaps because first aid O₂ was more commonly given to early onset and severe DCI victims in both the HMU and DAN series. Twenty (19.6 percent) of the 102 HMU divers who received first aid O₂, reported initial recovery on first aid O₂, but relapse on its withdrawal prior to HBO₂.

Eleven of these 20 HMU divers were diagnosed with mild DCI (Cat 3). Each of these divers achieved complete and lasting relief prior to discharge from the HMU.

Eight of these 20 HMU divers were diagnosed with moderate DCI (Cat 2), and only two achieved complete relief at discharge. The remaining six were discharged with minor residual symptoms (typically intermittent fleeting limb tingles). None had residual signs at discharge.

The one severe DCI (Cat 1) diver in this group achieved complete relief prior to discharge from the HMU.

Therefore, 14 of these 20 HMU divers had complete relief at discharge (70 percent).

The overall rate of completed relief at discharge is not statistically different from the total moderate and mild DCI groups, irrespective of first aid O₂ administration.

Twenty-one (12 percent) of 178 DAN divers reported symptom improvement or resolution following first aid O₂. DAN divers with first aid oxygen were noted to have a statistically significantly ($p=0.02$ Chi square test) greater likelihood (10 percent) of complete relief at discharge following HBO₂ Rx.

Table 4. Delay from symptom onset to 1st HBO₂ Rx (hours).

	HMU Air	HMU Surface	All HMU	All DAN
No. of Divers	36	81	117	414
Median Delay	24	41.8	37.8	21
Average Delay	30	63.5	53.2	44
Range	4.9 - 151	2.6 - 529	2.6 - 529	1 - 648

Table 5. Number of HBO₂ Rx per diver.

	HMU	DAN	Statistical Significance
Median	3	2	
Average	3.7	2.4	p<0.01
Range	1 - 19	1 - 13	

Although TTH HMU and DAN have similar follow-up HBO₂ treatment criteria, HMU treated divers received an average of 1.3 more HBO₂ treatments than DAN divers with DCI.

- 77.8 percent of HMU divers received 1 to 4 x HBO₂ Rx.
- 79 percent of DAN divers received 1 to 3 HBO₂ Rx.

Table 6. Proportion of ALL divers with complete relief at discharge following HBO₂ Rx.

HMU	DAN
80 of 117 Divers (68.4%)	299 of 414 divers (72.2%)

Difference not significant (p=0.42 by Chi square test).

Table 7. Outcome at discharge following HBO₂ Rx for moderate or mild DCI, in 102 divers retrieved to Townsville by air or surface transport.

	Complete Relief	Residual Symptoms	Residual Signs & symptoms	TOTAL
Surface Retrieval	57 (71.2%)	22 (27.5%)	1 (1.3%)	80 Divers
Air Ambulance Retrieval	13 (59.1%)	6 (27.3%)	3 (13.6%)	22 Divers
TOTAL	70 (68.6%)	28 (27.5%)	4 (3.9%)	102 Divers

No significant difference in outcome for air versus surface retrieval (p = 0.4 Chi square test).

Table 8. Number (%) of divers with complete relief at discharge.

	HMU	DAN
Recompression within 12 hours of symptom onset	(83.3%) 10 of 12	(79.4%) 127 of 160
Recompressed greater than 12 hours after symptom onset	(65.7%) 69 of 105	(65.8%) 156 of 237
TOTAL	117 Divers	397 Divers

NB: Includes all HMU divers, but only DAN divers from units treating more than five divers per year (n = 397).

HMU divers were more likely than DAN divers to be treated with hyperbaric oxygen treatment after greater than 12 hours from symptom onset. Significantly more DAN divers treated within 12 hours of symptom onset achieved complete relief than those treated more than 12 hours following symptom onset. The HMU figures, whilst following this trend, did not reach statistical significance.

Conclusions

1. All HMU divers with severe DCI (Cat 1) were retrieved (when possible) by air ambulance (14 of 15). No comparable DAN data is published.
2. 38 of 55 (69 percent) of HMU divers with moderate DCI (Cat 2) were retrieved by surface transport, without O₂, or IV fluids whilst 42 of 47 divers (89 percent) with mild DCI (Cat 3) were retrieved by surface transport.
3. HMU divers were twice as likely as DAN divers to receive first aid O₂ and to report symptom resolution prior to HBO₂ Rx. The 20 HMU divers who relapsed on withdrawal of first aid O₂ had outcomes similar to those without this experience.
4. All 11 of the divers with mild DCI who experienced symptom resolution with first aid O₂, but who relapsed on its withdrawal, were discharged with complete relief following HBO₂ Rx.
5. Average retrieval times to the HMU were longer than in DAN divers in the USA. (Average symptom onset to first hyperbaric oxygen treatment time: HMU 53.2 hours; USA 44 hours.)
6. More HBO₂ treatments were required in the HMU to achieve similar outcomes to those of DAN USA. (HMU diver average of 3.7 x HBO₂ Rx; USA 2.4 x HBO₂.)
7. There was no significant difference in the proportion of ALL HMU and DAN divers with complete relief on discharge after HBO₂ Rx.

8. HMU divers with moderate or mild DCI (Cat 2 or 3) who were retrieved to the HMU by surface transport (without O₂ or IV fluids during transfer) did NOT have poorer outcomes following HBO₂ Rx than those Cat 2 or 3 divers retrieved by air ambulance.

References

1. Windsor D. A Study Into the Number of Dives Conducted on the Great Barrier Reef in 1994. SPUMS J 1996;26:72-4.
2. Divers Alert Network. Report on decompression illness, diving fatalities and project dive exploration: 2003 edition (based on 2001 data). Durham (NC): Divers Alert Network; 2003. 132 p.

DISCUSSION

RICHARD MOON: David, I'm very interested in your policy of being willing to wait until bankers' hours before treating your mild cases. Does that reflect a belief on your part that it doesn't make any difference whether you treat them urgently in the middle of the night or wait until the next morning? Have you actually looked at that statistically to see if your outcomes are the same, or is it a sense that you feel based on anecdotal clinical experience? Have you done the analysis to look at time to treatment for mild cases?

DAVID GRIFFITHS: The outcomes are apparently, from data that I presented, not different for those with a small delay on arrival to us by road as opposed to by air. On that basis, I have assumed there's no significant difference in the outcome if they wait three hours. If they arrive at 5 in the morning, the evidence that I have suggests that I wait another three hours before I treat them at 8, when we have our full team on standard time, and we don't need to put people into fatigue leave at the end of the day. The real difference is unlikely to be large, but we have not been able to measure it.

CHRIS WACHHOLZ: David, I take it that none of your cases were transported by airliner. Is that right?

DAVID GRIFFITHS: We have had a couple of people who have come to us from overseas who've developed symptoms either overseas before travel and have then come on by surface transport to us. One or two have had treatment previously and then flown and developed symptoms again and come on down to us. But in this particular series, there was only one patient who had in fact been treated elsewhere, flown to Cairns by airliner, and then come down by road from Cairns for further treatment.

CHRIS WACHHOLZ: Among the mild cases that were transported by air ambulance, have you looked at why they were transported by air versus ground? Was it misdiagnosis, or was it because they were away from any area where they could take the bus?

DAVID GRIFFITHS: The details are in the printed information. From memory, one came from Papua New Guinea, and one came from Thursday Island right up in the north. It's not practicable to bring them by other means. One was reported by a dive boat to have much worse symptoms than the diver actually turned out to have, perhaps because the dive boat wanted to deliver the diver to us fairly quickly. The other two case details are in the written report.

MIKE BENNETT: Can you expand on what you actually say to these people before you send them on the bus and, in particular, what if any advice you give them about oral fluids?

DAVID GRIFFITHS: The majority come to us either from a general practitioner in one of the centers or, more typically, from the base hospitals. In the base hospitals, we obviously have a detailed discussion about the diver with the medical practitioner who examines the diver. If the diver has objective neurological signs, then we insist that if it's at all possible, we get the diver to us as quickly as possible by air ambulance, on intravenous fluids, and on oxygen. If the diver has no objective signs, and particularly if the diver has been relatively late in presentation – and you've seen our presentation times are quite long – then we'll insist that the diver be adequately hydrated prior to referral to us. If there's a bus leaving fairly soon and they can get to us on that, in the opinion of the referring medical practitioner, we invite them to send them to us that way.

BOB LONG: Regarding your definition of mild, what about the cases that have been on surface oxygen for several hours prior to contacting you? Does that affect your definition or your recommendations?

DAVID GRIFFITHS: In the printed paper, there's more information regarding those that had oxygen. A significant number of them went on to complete resolution. I believe there were about 20 who had surface oxygen and a reduction in symptoms. Some relapsed when they came off oxygen prior to transfer to us, and we categorized them when they were referred to us by the referring hospital. If they were mild, they were categorized as mild. When they got to us with those mild symptoms, then we treated them. There were a few whose symptoms disappeared altogether. Not in this series, but a year before this series, there was one young woman from Papua New Guinea who had very severe spinal decompression illness who was given oxygen onsite and in an air ambulance in transit to us. She completely recovered by the time she reached us, but that was unusual.

DAVID SMART: Tasmania is a little island south of Australia, quite mountainous. When we have to take our divers over 600 or 800 meters (which is common in Tasmania), would you recommend using bus services?

DAVID GRIFFITHS: If they're going to have to go over that substantial an altitude, use of aircraft is probably preferable. I once had to retrieve a diver from Tasmania's west coast, but the chamber in Hobart is on the east coast. We transported this case by helicopter almost around the island to get to the hyperbaric chamber so that we could avoid substantial altitude. This was a fellow whose hose had been severed by the boat when he was diving far too deep on a hookah. He had taken out the non-return valve from his full-face mask so that all the air had been sucked up the hose and had the mask collapse on his face and had hemorrhages in both of his eyes. We were reluctant to move him immediately from the dive site for fear of him getting decompression illness at altitude. We kept him on surface oxygen for two hours – which is how long it took to get the helicopter to him – and then flew at low altitude back to Hobart and had a good outcome.

SIMON MITCHELL: Let's move on to explore the other limb in Figure 1 of the Introductory paper, the "emergency recompression required" question. We've considered options for evacuation for non-emergency recompression. Let's now consider options for providing recompression on an emergency basis. The first question we ask is: "Can we do this at the location where the diver is?" That is, is recompression available onsite or very close by without transporting the patient? All of us have been in the position of being referred a diver in a location where there is a chamber, but we're not sure of its quality or the capability of its staff. What are the minimum requirements for an acceptable chamber? Another situation that arises more often recently is the claim by accompanying divers that they are capable of conducting in-water recompression. It's a controversial issue, and it won't go away. As technical divers press more boundaries, we're going to see more of this. That's another on-site recompression issue that needs to be dealt with. We've asked Dr. James Francis from the United Kingdom speak about this. He's a vastly experienced ex-Royal Navy diving physician.

TREATMENT IN REMOTE LOCATION HYPERBARIC CHAMBERS AND IN-WATER RECOMPRESSION

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Introduction

Although recompression had been employed in the management of caisson disease since 1889 (1), it was not until 1924 that the U.S. Navy Diving Manual recommended that divers with decompression sickness should be treated with recompression. Since then numerous empirical tables have been published, based on a variety of philosophies as to the optimum depth of recompression, bottom time and subsequent rate of decompression. Initially, these various tables employed air as the breathing mixture, and they tended to be long and deep. It was only after Behnke and his colleagues' groundbreaking work in the mid-1930s that the concept of using oxygen as a therapeutic breathing gas was introduced (2,3). However, based largely on safety considerations, the U.S. Navy Dive Manual continued to prescribe the use of air tables for the next 20 years.

Behnke and Shaw's oxygen tables were published by the U.S. Navy Bureau of Medicine in 1944 (4), but by the following year it was apparent that the failure rate of these tables was as high as the 1924 USN air tables (5). As a result, Van Der Aue and his colleagues developed new air and oxygen tables (USN Tables 1-4) (6). The principles underlying these tables were that the seriousness of a case would be defined by the depth at which the symptoms were relieved – mild cases less than 30 msw, and serious ones greater. Mild cases would be treated at an initial depth of 30 msw, with oxygen being used from 18 msw if it was available and the decompression following Haldanian principles (tissue gas pressure not exceeding twice the ambient pressure). Serious cases were initially compressed to 50 msw breathing 50 percent nitrox if oxygen was available and 100 percent O₂ from 18 msw to the surface. If oxygen was not available, air was breathed throughout. Again, decompression accorded to Haldane's principle.

The initial success rate with these tables was impressive, with complete recovery achieved in 107 of 113 cases (7). However, this success rate was not sustained, particularly in recreational divers. This led Goodman and Workman to develop another set of new tables (8). They adopted an original approach, proposing the use of shallow 100 percent oxygen tables. They argued that, beyond 2.8 bar, the benefit of using pressure to reduce bubble size is increasingly small, and this is at the cost of increased uptake of inert gas. Additionally, breathing 100 percent oxygen was preferable to using mixtures on the basis that it maximizes inert gas washout. Based on an extensive series of human experiments, the tables that we now recognize as USN 5 and 6 were eventually published.

Original features of these tables were the introduction of air breaks to avoid oxygen toxicity and, with Table 6, the flexibility to extend the table to take account of the clinical progress of the patient. It would be possible to extend the discussion of the development of therapeutic tables to cover saturation decompression for poorly responsive patients who have been compressed for a considerable period; equally, the use of deeper, mixed gas tables for severe or poorly responding cases could be discussed.

However, the purpose of this introduction is to sketch out the development of the short oxygen tables that today are used to manage the great majority of cases of decompression illness, the important principles being that the limited use of pressure and 100 percent oxygen breathing with air breaks has evolved, empirically, as the optimum way to manage the condition.

The Options for Recompression in Remote Locations

Compression Chamber.

The most obvious option is to use a compression chamber. Within this category, there are two further options: use a portable chamber or a multiplace chamber located at the remote location.

Portable Chamber. This option can be dismissed as unrealistic in most recreational diving situations. First of all, the only practical chamber for use in this context is a light, collapsible one. These chambers are too expensive for all but the wealthiest of sports divers (retail price ~ US\$ 50k). Second, it requires a trained operator – not commonly found amongst recreational divers, although there is no reason in principle why an individual or club with the resources to buy a chamber couldn't be trained how to use it.

However, the main reason why these chambers are inappropriate for use in these circumstances is that they are not designed for the definitive management of DCI. Being small, monoplace chambers, they suffer from some serious deficiencies. Most importantly, the chamber has to be decompressed to allow access to the patient for physical examination and for maintenance of the airway, urinary catheter or intravenous access, should any of these become compromised during a treatment. Other disadvantages include the limited depth capability of these chambers (normally 2.8 ATA); poor internal temperature control – which can be a real issue in extreme climates; and people with a tendency to claustrophobia may not tolerate the very confined space with minimal view outside the chamber. Consequently, I will not discuss this further.

Local Chamber. If one exists, this is the obvious choice for managing DCI in remote locations. However, it is necessary to know the limitations of the chamber facility before referring a patient for treatment. The adequacy of chamber facilities was assessed was addressed by a Working Party of the Faculty of Occupational Medicine of the Royal College of Physicians of London in 1994 (9). In addition to stating that it is the responsibility of the referring physician to

ensure that the receiving facility is appropriate for a particular patient, and for the safe transport of the patient to the facility, the report identified four categories of hyperbaric facility:

Category 1. Comprehensive multiplace hyperbaric facility capable of supporting the treatment of patients who are critically ill, from any cause, and who may require intensive hyperbaric therapy.

Category 2. Multiplace facility capable of receiving elective or emergency referrals for any accepted application of hyperbaric oxygen therapy, but excluding those who are critically ill at the time of referral or who are considered likely to become so.

Category 3. Multiplace chambers without some of the capabilities of categories 1 or 2, which are sited specifically for the treatment of diving emergencies.

Category 4. Monoplace chambers at relatively low pressure and without an air-lock capability. The report envisaged that these facilities would normally be located within or close to a hospital and considered that, normally, monoplace chambers are not suitable for the immediate treatment of acute decompression illness.

Since we are interested in defining the minimum standards for a remote chamber, we will look at the criteria for Category 3 chambers in greater detail. Items that I have added are designated with an asterisk.

Buildings

There should be adequate access by road, sea and / or air, depending on the location of the facility. There should be a reception area of sufficient size and adequately equipped to assess the patient. Since it may be necessary to undertake clinical treatments other than recompression, it should be clean with surfaces that can be readily sterilized. Other factors to consider within the building:

- Heating or air conditioning as necessary
- Adequate lighting
- Toilet facilities
- Clearly designated chamber area, with controlled access
- Facilities for recording and storage of clinical notes and chamber records
- An area for the preparation and consumption of food
- If possible, space to accommodate friends or relatives of the patient.

Chamber Construction

The chamber should be fit for purpose. More specifically, it should be certified as such by a reputable agency, such as Lloyds of London, and should meet the requirements of the insurers. Other requirements include:

- Sufficient space in the main chamber to accommodate at least two people comfortably.

- A bunk for the patient and a seat for the attendant*
- A man-lock with access hatches of sufficient size to allow convenient access for the patient (who may be on a stretcher) and attendant(s). Additionally, a medical lock for the transfer of small items into and out of the chamber is useful.
- At least one viewing port
- Two-way verbal communications
- Adequate lighting and heating / cooling
- Built-in breathing system (BIBS), ideally with overboard dump, for patient and attendant (minimum).*
- Sufficient monitoring of the chamber environment and intervention measures to control: pressure, temperature, humidity, carbon dioxide and oxygen levels
- Internal surface that can be sterilized.
- Ideally, there should be an uninterruptible power supply.
- Adequate fire suppression equipment.

In addition, there should be a separate area that contains gas compression and storage equipment. There should be sufficient redundancy in the system to allow treatment to continue despite the failure of a compressor or other essential equipment.

Medical Equipment and Facilities

There should be adequate equipment for initial assessment, continued monitoring and treatment (including resuscitation). Equipment and drugs should be appropriate for use in a chamber. For example, thermometers and sphygmomanometers should not contain mercury, and if drugs in glass vials are to be used, they must be opened at one atmosphere. Only low voltage electrical equipment should be used in chambers, and it must be designed or adapted to operate normally at raised atmospheric pressure. Specific requirements include:

- Sphygmomanometer
- Stethoscope
- Auriscope / ophthalmoscope
- Thermometer
- Neurological examination equipment
- Equipment for: urinary catheterization; intravenous infusion; emergency drainage of a pneumothorax.

The report proposes that the monitoring equipment and drugs provided should be at the discretion of the Medical Director. There should be sufficient equipment for basic life support, including suction, airway establishment and maintenance of ventilation using a reservoir bag. A defibrillator should normally be available for use outside the chamber.

Staffing Requirements

The Cox report (9) identified the following key staff:

Medical Director – responsible for the direction of clinical activities; the production of assessment and treatment protocols; the appointment, delegation and supervision of clinical staff; medico-legal responsibility for the facility; safe custody and confidentiality of clinical records.

Hyperbaric Duty Doctor (who may be the Medical Director) – general medical support; examination of patients and recording of findings; prescription of hyperbaric and other treatments; patient discharge and onward referral.

Supervising Chamber Operator – overall supervision of the pressure system; safety of the chamber and its occupants; minor maintenance; supervision of other chamber operators; initiation of treatment in an emergency and maintenance of such treatment under the remote direction of a medical officer if necessary.

Medical Attendant – responsible for the direct medical care of the patient inside the chamber and implementing the decisions of staff outside the chamber.

Additional staff may include an assistant chamber operator and nursing staff. There should also be sufficient engineering and technical staff to maintain the pressure system and other equipment as necessary. Clearly, if a long or saturation decompression is contemplated, the referring physician should be satisfied that there are sufficient staff to complete the treatment.

The Cox report was updated in 2000 by the British Hyperbaric Association (10). In this report, the authors recognized that hyperbaric facilities vary in the way they are organized and therefore felt that rather than stipulating the function of various personnel, each facility should develop its own standard operating procedures to include the information and instructions that are necessary to guide and regulate the behavior of those taking part in the function of the facility in either a clinical or technical capacity. These SOPs should include emergency procedures and contingency plans. The report identified a position termed the Hyperbaric Therapy Provider as the person in overall administrative control of the facility. This individual need not have either a medical or technical role in the provision of hyperbaric treatment, rather this person either employs or contracts the medical and technical personnel or, as a self-employed person, provides medical or technical support for hyperbaric treatments.

The British Hyperbaric Association Code of Practice goes on to identify the required competencies of the personnel who provide hyperbaric care and identifies the health and safety issues that hyperbaric therapy providers need to address. Rather than reproduce all of this here, a more general statement may be useful, since it is unlikely that chambers in remote locations will operate according to this code.

In addition to being satisfied that the material provisions of a hyperbaric facility meet the minimum standards stated above, a referring physician needs to establish that the personnel who operate the facility have appropriate levels of knowledge, skill and experience to manage patients safely and efficaciously. This is no simple task. While it is possible to make some assessment of medically qualified staff, based on their qualifications and curriculum vitae, hyperbaric medicine attracts practitioners from disparate backgrounds and therefore such an assessment is by no means straightforward. In some jurisdictions, there is a formal qualification in diving and hyperbaric medicine. Examples include the Diploma of Diving and Hyperbaric Medicine awarded by the South Pacific Underwater Medicine Society, and the American Boards of Emergency Medicine and Preventive Medicine's offer of a certifying exam in Undersea and Hyperbaric Medicine. However, these are the exceptions rather than the rule. The situation is no better with hyperbaric technicians and nurses. Certification is available via the National Board of Diving and Hyperbaric Medical Technology in the USA, but in most of the world there is no equivalent qualification. With respect to the safe operation of the facility, the referring physician should be satisfied that the facility has adequate standard operating procedures and that the operational staff are familiar with them.

The Undersea and Hyperbaric Medical Society (UHMS) offers an accreditation service for hyperbaric facilities. The program is voluntary on the part of the facility owner and provides survey services to assess a variety of patient care and safety related issues. When invited to perform a survey, the UHMS sends a team of experts to the facility and surveys staffing and training, the installation in general, operation and maintenance equipment, facility and patient safety, and standards of care. At present, this is limited to the USA. In my opinion, it would be a good idea for DAN either to use the UHMS to conduct surveys of chambers in remote locations to which it may potentially refer cases, or conduct similar surveys itself.

In-Water Recompression

In-water recompression is not a novel concept. Reviewing the history of pearl diving in Australia, Edmonds relates its early use in the 1930s (11). Initially, in-water recompression was conducted using air, with the stricken diver returning to the maximum depth of the provocative dive with subsequent slow ascent to a 30-minute stop at 9 metres and 60 minutes at 3 metres before returning to the surface (12). Following Goodman and Workman's development of oxygen tables for use in compression chambers, oxygen became used during in-water recompression.

The history of the evolution of such treatments is well reviewed by Edmonds (13). However, it remains a controversial technique. For example, the U.S. Navy Dive Manual states: "Recompression in the water should be considered an option of last resort, to be used only when no recompression facility is on site and there is no prospect of reaching a recompression facility within 12 hours.... in divers with severe

type II symptoms or symptoms of arterial gas embolism (e.g., unconsciousness, paralysis, vertigo, respiratory distress, shock, etc.), the risk of increased harm to the diver from in-water recompression probably outweighs any anticipated benefit. (14)." Alternatively, Robyn Walker asserts: "Although this treatment is frequently disparaged, it has often been the only treatment available to severely injured divers, and has had many successes. (15)." Clearly, it will not be possible to reconcile such polarized positions in a brief paper. As a first step, it may be helpful to look at the risks and benefits of in-water recompression.

Benefits

- Minimal delay to recompression, with a potentially better outcome than a delayed or no treatment.
- It may be possible to provide an oxygen table.

Risks

- Environmental factors such as poor visibility, low water temperature at depth and rising sea state may make commencing a treatment unacceptably hazardous or cause a treatment to be aborted.
- Inadequate supply of gas or surface-supplied breathing equipment may limit or prevent a treatment.
- Nitrogen narcosis in the patient or attendant may compromise deeper air treatments.
- Fatigue in either patient or attendant may compromise a treatment.
- Seasickness underwater is potentially hazardous.
- Drowning is a potential hazard if the patient has only a mouthpiece to breathe from in the event of vomiting, loss of consciousness or hypothermia (violent shivering).
- Airway maintenance in an unconscious patient underwater is severely constrained.
- While the provision of hyperbaric oxygen is possible, rehydration underwater is difficult.
- Clinical assessment of the patient underwater is very limited. Tension pneumothorax could be lethal.
- The management of complications of DCI underwater may be difficult or impossible – e.g., urinary retention.
- Poor communications between patient and attendant or between attendant and the surface may cause potentially hazardous confusion.

From the above, it is obvious that an in-water treatment should not be contemplated lightly. If an in-water treatment is being contemplated, there are two basic methods – using oxygen or air.

Oxygen Recompression

From the introduction, it is clear that the use of oxygen is likely to result in a better outcome than using air. It is also likely to be safer. The treatment will be conducted at a shallower depth and consequently the patient and attendant may

return to the surface at any time. Since oxygen treatments are usually conducted at shallower depth than air treatments, there is also a lower risk of hypothermia, since wetsuits are more efficient thermal insulators with decreasing depth. Shallow treatments also allow the possibility of choosing a sheltered site that will offer some protection from adverse weather. Use of a full-face mask will permit verbal communication with the attendant and reduce any hazard from vomiting or the aspiration of seawater. Essential equipment includes: oxygen clean diving set; substantial supply of oxygen (7,000 L oxygen cylinder); 12 m supply line; full-face mask with non-return valve; adequate thermal insulation; shot line. The patient should be weighted to prevent upward drifting. The attendant should breathe air. Walker (15) recommends using a maximum depth of 9 msw with ascent at 12 min.m^{-1} after 30 minutes for mild cases, or 60 minutes for serious cases with an extension of 30 minutes at 9 msw if necessary. This should be followed by surface oxygen, one hour on, one hour off, for up to 12 hours. The U.S. Navy suggests using a 100 percent oxygen rebreather, descending to 30 fsw for 60 minutes for mild cases, or 90 minutes for serious cases (10). Ascent to the surface is to be interrupted by 60-minute stops at 20 and 10 fsw. The dive should be followed by three hours of surface oxygen breathing.

Air Recompression

The U.S. Navy recognizes that wherever possible oxygen should be used, but where only air is available it prescribes a profile as close as possible to Treatment Table 1A (Fig. 1). Again, a full-face mask is recommended or, preferably, use of a surface supplied breathing apparatus. If the water depth is insufficient (< 100 fsw), the patient and attendant should descend to the bottom and remain there for 30 minutes before decompressing according to Table 1A. Clearly, this is a long, deep table, and particular attention should be given to adequate thermal protection.

Air Treatment Table 1A

1. Descent rate - 20 ft/min.
 2. Ascent rate - 1 ft/min.
 3. Time at 100 feet includes time from the surface.

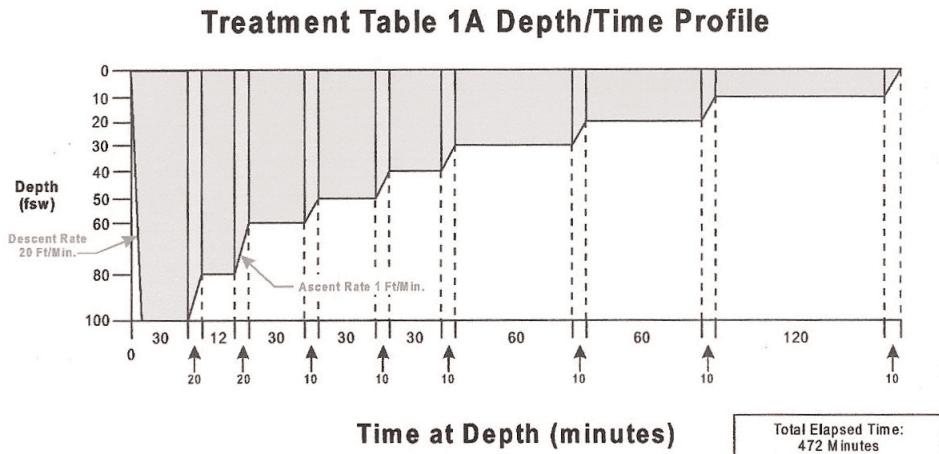


Fig 1. US Navy Treatment Table 1A

The outstanding question is, which patients are suitable for in-water recompression? This can be answered by identifying those patients for whom this is inappropriate. In so doing I would point out that this is very much a personal opinion.

- Unconscious patients and others who may have difficulty maintaining adequate ventilation, such as those with high cervical spinal cord involvement in DCI or pulmonary barotrauma with a possible pneumothorax.
- Patients who are unable to hold onto a shot line because of confusion, severe fatigue, vertigo or weakness.

Other limitations to the use of in-water recompression may include:

- Adverse weather conditions
- Inadequate equipment or gas supply
- Inadequate thermal insulation for the patient or attendant
- Refusal of the patient to return to the water

I would consider using oxygen recompression in severe, progressive or relapsing cases who are fully conscious and capable of holding onto a shot line, the reasoning being that early treatment is likely to arrest the progression of disease, perhaps prevent or ameliorate serious residual neurological deficits, and in rare instances, prevent death. In mild, static or spontaneously improving cases, for which the requirement for urgent treatment is debatable, in-water recompression using oxygen may be appropriate provided adequate equipment is available and a considerable delay to evacuation is expected. In other circumstances, I consider that the risks associated with in-water recompression probably outweigh the expected benefit, particularly if air is the only breathing gas available.

Conclusion

The ideal way to manage a case of DCI in a remote location is to use a compression chamber to treat the patient with a U.S. Navy Treatment Table 6 or equivalent. The referring physician needs to be satisfied that the receiving facility has adequate access, buildings, a chamber that is fit for purpose, adequate medical equipment and plant, and that the personnel who will provide the treatment have sufficient knowledge, experience and organization to deliver the treatment safely and efficaciously. If a long table or saturation decompression is anticipated, there should be an adequate number of staff to operate in shifts.

However, it is the nature of remote locations that such a facility is unlikely to be available within a reasonable time. In such circumstances, in-water recompression may be an option. This should only be considered for patients who are prepared to re-enter the water and only if adequate equipment, gas supply, and thermal insulation for the diver and attendant are available and that the weather conditions are set fair. My view is that only a shallow oxygen profile should be used and that this should be reserved for those

with severe, progressive, or relapsing DCI who are able to maintain their own airway and likely to continue to do so. There should be no symptoms or signs suggestive of a pneumothorax and the patient should be capable of holding onto a shot line for a protracted period.

Although in-water recompression may be used for mild, static or spontaneously improving DCI, particularly if there is going to be a long delay before the casualty can be evacuated, this should only be considered if there is an adequate supply of oxygen and the requisite surface-supply equipment is to hand. In other circumstances, I consider the risks associated with in-water recompression probably outweigh any expected benefit.

Acknowledgement

I am most grateful to Carl Edmonds for his critique of my original draft of this manuscript and his helpful suggestions for its improvement. His experience of in-water recompression of decompression illness is considerably greater than mine, and I value his expert opinion.

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DISCUSSION

PASQUALE LONGOBARDI: In Europe, a working group has, over five years, developed a new set of regulations pertaining to hyperbaric unit facilities and staffing. A Diving Technology Committee, representing European countries, has defined the training standard for doctors involved in diving. In the consensus conference held in Marseilles in '96, it was decided to let the doctor move the patients to the appropriate hyperbaric center in four hours. It's important that we define what to do after this first four hours.

JAMES FRANCIS: There are some standards being developed in Europe for the training of hyperbaric physicians, but Europe is one small part of the world.

JORDI DESOLA: This work that Pasquale described arose from a working group on safety in hyperbaric facilities. The first code of good practice for hyperbaric medicine was finished a few weeks ago and will be published in a few months after some protocol and regulation are reviewed. This is a little more oriented to Continental Europe and not exactly the same as in the United Kingdom.

There's one important difference between the European and UK Standards in relation to chamber personnel and the staff. The European Standard does not allow either the chamber supervisor or the chamber operator to start a treatment in absence of the physician. That's the only difference. The European Standard will be available in the OxyNet website.

ED KAY: I chaired a workshop in 2000 on in-water recompression and commend you on your presentation. There is one extra category that I think might be appropriate to your cost-benefit analysis, and that is the issue of missed decompression or blowup. I'm aware of one case in Seattle where a diver was lost because of a malfunction in an auto-inflator. If that diver had been taken down immediately and treated on a surface decompression table before the symptoms of decompression started, I think he'd be alive today. There is a fine line between treating somebody with omitted decompression and no symptoms yet, but I do believe it falls into this category.

JAMES FRANCIS: I was specifically talking about the management of decompression illness as opposed to omitted decompression, but assuming your IWR equipment kit is OK, I don't see any objection to returning to the depth of your dive and coming up properly.

FRANS CRONJE: DAN has struggled for many years with how to review recompression chambers. The quandary is that DAN needs to use the chambers but can't impose standards or will be held liable if those standards aren't met. In 1999, François Berman, an engineer and builder of hyperbaric chambers, was assigned the task with Bob Ramsey of developing the wish list to which you referred. It was a novel approach in that it was done from the premise of risk management, e.g., the actual risks related to hyperbaric facilities and recompression in remote locations were identified. They came up with a way to review the risks and have sensible responses rather than a prefab approach as you might find with the NFPA. The result is a book titled *Risk Assessment Guide for Recompression Chambers* that has been published by International DAN. Those of you who deal with remote chambers will be pleased to learn about the guide that has been implemented and used in some 25 chambers around the world as part of DAN's nonprofit mission. We hope the guide can be used further to ensure safety and reassure divers who use these international facilities.

MIKE DAVIS: In the issue of the *SPUMS Journal* that's in your package, there is an interesting article from Robert Grace who ran the chamber in Vanuatu for several years. It gives an insight into what it's like to provide hyperbaric facilities in an underdeveloped country. An issue he raised in correspondence, but did not mention in the article, is work by Kathy Bowen a year or two ago in the *SPUMS Journal*. This work described the cost-benefit of dealing with remote DCI where the cost to the local community in which the accidents occurred was not considered. If you talk to anybody who tries to provide recompression therapy in islands in a remote area of the world, they all say that a lot of divers do not carry insurance at this stage. If they are treated within the local community, there is a cost to that community. The health budget for the whole community might be only \$50,000 U.S., for example. You can use up all the island's oxygen supplies, and the next supply might be a considerable time in the future. This is an important aspect to be considered in this equation.

ALF BRUBAKK: I think probably the most used recompression procedure in the world is recompression on air in-water. This is used by a lot of people who dive all around the world with procedures that give them an enormously high risk of decompression

sickness. In the little studies I've been participating in, the divers don't know much about how to do IWR and do it in many different ways. I would suggest that it is high time we start to study this seriously to see if it is an option, because it appears to me the U.S. Navy procedure presented is impractical for many of these divers. The data seems to indicate that if the point is to get rid of the bubbles, you get rid of them much, much quicker with IWR and can even go back to the surface with a very few bubbles and repeat the IWR. There are many tricks that can be used probably. I think one of the problems that we have is that we call it treatment. I would suggest we call IWR advanced first aid and get around the treatment thing. Then we can go on and do all the normally accepted treatments afterwards. We should be calling IWR "advanced first aid." I can remember the discussions of about 20 years ago whether lay people should be allowed to do CPR: "Only doctors could do it, because CPR could injure." Now we're doing CPR all over the place. I suggest that we really seriously look at IWR and start programs to actually study how to do it effectively.

JAMES FRANCIS: Yes. The indigenous fisherman around the world have often just gone straight back in the water breathing air. I've talked to Frank Farm from Hawaii many times about that. He provides good anecdotes of occasions when two divers in the boat have gone bent, one was taken away by helicopter to the local chamber and the other has gone back down with a fresh bottle of the air. The outcome of one particular incident when this occurred was that the guy who had gone to the chamber ended up being paralyzed for life, whereas the one who'd recompressed in the water was apparently unharmed by the end of his IWR recompression. An anecdote, of course, but, yes, I'm aware that that occurs.

CUAUHTEMOC SANCHEZ: A lot of diving is done at night. Would you recommend doing IWR recompression at night?

JAMES FRANCIS: Well, I think it depends on how good the divers are at doing IWR. If you're doing something for the first time, it wouldn't be prudent in the dark of night. If it's something they did regularly, then maybe not as risky. I think it's based on experience.

FRANS CRONJE: There's a metaphor that's been useful in talking to divers, especially technical divers, who are interested in in-water recompression. This is to compare cardiac arrest to decompression illness in the sense that in-water recompression is like the precordial thump. It's expedient and great if you do it quickly, but it's not taught to lay people and people who don't know what they're doing. The next part of the metaphor would be CPR. The analog is surface oxygen that buys you a bit of time and gets you to the point where, hopefully, you can treat effectively and definitively. Finally, recompression is the analog of defibrillation, which would be the definitive treatment. This metaphor helps people appreciate the relative values of each intervention and understand their strengths and limitations.

JAMES FRANCIS: Yes, but I think at each stage, one needs to take into account risks and benefits.

DAVID ELLIOTT: You suggested that "mild and serious" would perhaps change your threshold for conducting in-water recompression. Can you make the same comment as far as using a local chamber or perhaps even monoplace chamber? Would someone having mild DCI lower your threshold for getting into a perhaps substandard chamber, perhaps a monoplace chamber? Or would conversely serious disease lower your threshold for recommending one chamber over another?

JAMES FRANCIS: I would not wish to treat somebody who is seriously ill in a substandard chamber as there are some terrible potential difficulties. If it's all you've got, one has to assess if it would make the situation worse. I really don't know the answer to this question. For a mild case, we've been talking today about whether or not we're going to recompress them at all, e.g., if it's absolutely essential to recompress them. If they are waiting for evacuation and if you've got a chamber handy, you're not going to do any harm by putting a mild case in a chamber. So the answer is, yes, I would use a chamber in that situation, because I predict very little harm. Equally, with a remote chamber, it is perfectly appropriate to do that, provided, of course, the chamber is safe to use. I think the severity would alter what chamber I would use under certain circumstances.

RICHARD DUNFORD: If I may, I'd like to disagree. To put somebody in a chamber and ensure no harm, you have to be very careful of what chamber and who's running it.

JAMES FRANCIS: I do agree the chamber has to be fit for its intended use.

SIMON MITCHELL: We now move further down the decision tree of Figure 1 in the Introduction paper. We have decided that emergency recompression is required, but that on-site recompression, either in a chamber or in-water, is not an option. Our only remaining option is urgent evacuation, and this will most often mean evacuation by fixed or rotary wing air ambulance. This is fairly standard practice for remote DCI.

The next presentation makes the point that evacuation by air ambulance is not necessarily completely benign. Air ambulance evacuations have their own hazards and logistical difficulties as well as costs, which have already been discussed. I've asked Michael Bennett to speak about this, because he has been intimately involved with air retrieval services and has considerable insight into their operation. Michael is the director of the Hyperbaric Medicine Unit at Price of Wales Hospital here in Sydney. He's an extraordinarily active diving and hyperbaric physician who's done an awful lot for the Undersea and Hyperbaric Medical Society over the last few years, mainly in terms of his research. More than anyone else, he's been responsible for putting the UHMS meeting together. In fact, without him, this workshop certainly wouldn't have happened.

THE RISK OF AEROMEDICAL EVACUATION

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Introduction

The transfer by air of injured divers is not uncommon. In the 2003 Divers Alert Network report, 23 percent of all reported cases of DCI involved exposure to air travel, of which 18.6 percent were by air ambulance (1). This suggests about 4.3 percent of divers with DCI undergo evacuation by air to a treatment facility. While it is often assumed that air transport of a diver with decompression illness (DCI) is always in the best interest of the individual concerned, this workshop is an indication that such may not always be the case. Among many considerations, one needs to be aware that aeromedical retrieval involves specific risks.

This presentation aims to identify those risks and quantify them where data exists. As an initial consideration, we may identify several categories of risk: general risks of aviation transport, risks specifically related to the pathology of DCI and financial risks.

Any person charged with the responsibility of managing a diver in a remote location will need to weigh all these risks against the likely benefit of transport before recommending a particular course of action to the diver.

General Air Transport Risks

These include:

Mechanical Failure

May result in a catastrophic outcome involving a crash and loss of life for patient, relatives and crew, or less catastrophic outcome resulting only in delay, detour from intended route or even stranding.

Emergency medical service (EMS) helicopters certainly do crash. Accident statistics from the USA suggest that EMS helicopters are twice as likely to crash as non-medical equivalent craft (2). In Australia during the last 20 years, there have been at least five major medical / rescue helicopter crashes in which several patients have died, along with crew members. At least three in-flight physicians have suffered significant injuries.

An epidemiological survey of 173 EMS air ambulance providers identified larger programs as those associated with lower risk of crash. Larger programs were eight times less likely to crash (2.6 versus 21.2 crashes/million flights, $p=0.001$). The overall incidence of mishaps was 11.4/million patient transports (3). This level of risk is probably significantly lower for fixed-wing retrievals and even for helicopter retrievals of divers,

given the rugged topography within which EMS helicopters sometimes operate in the continental United States. On the other hand, emergency rescue from rocks or small craft is intuitively a relatively high-risk operation.

While delay or stranding may be simply inconvenient, with DCI there is a possibility of deterioration over time, and the conversion of reversible signs into permanent disability. Further, the medical crew may run short of resources, particularly oxygen, in this situation. Therefore, while many delays may not mean the diver is in a worse situation than prior to attempted transfer, this may not necessarily be so – particularly if the diver has been evacuated with the intention of reaching a major center and has been taken further from a less well-equipped facility.

Human Error Leading to Crash

Similar considerations apply as for mechanical failure.

Restricted Equipment to Deal with Evolving Clinical Events

The equipment available during aeromedical evacuation will vary greatly. At one end of the scale, dedicated aeromedical rescue services will in effect provide a mobile intensive care with sophisticated treatment options available such as mechanical ventilation and cardiovascular support. For these services, a strong guiding principle is that of "escalating support." Under this principle, no critically ill patient should be moved deliberately into a situation where less sophisticated care is available. The move into the transfer vehicle should offer medical advantages over the alternative.

While few injured divers are critically ill, for most cases of DCI, the availability of compression facilities is likely to be highly desirable. Careful consideration should be given to a retrieval plan that involves removal of a diver from a hospital where simple (perhaps monoplace) recompression facilities are available, into an unpressurised aircraft for an extended flight – simply to access a larger facility.

Restricted Space to Make Physical Interventions

There is very little room to perform routine observations or special interventions in-flight in most aircraft – even those dedicated for this purpose. It is imperative for flight crews to anticipate possible instability and perform interventions prior to loading in the aircraft – if in their assessment such interventions are likely to be required at some time.

For this reason, it is not uncommon for in-flight physicians to intubate and institute mechanical ventilation for a patient with borderline respiratory failure while they are in the referral hospital. At least some of these interventions may have been avoided in the absence of a decision to transfer. One further risk of aeromedical evacuation, therefore, is the sum of risks associated with medical interventions that would not have been required in the absence of a decision to transfer.

Specific Air Transport Risks With DCI

In addition to the above, diving physicians are well aware of a number of specific risks of flying while suffering from DCI. At base, these involve the possibility of deterioration due to the physical environment of the transfer aircraft. Risks include:

Hypobaric Environment Leading to Expansion of Existing Bubbles or Evolution of New Bubbles

Boyle's Law dictates that any reduction in ambient pressure will be associated with expansion of a given mass of gas. Bubbles associated with DCI will expand at altitude and have the potential to produce a deteriorating clinical picture. For this reason, divers are warned not to fly for 24 hours after diving, even in the absence of any symptoms.

Several studies suggest that divers may have suffered during air medical evacuation in this way. In the 2003 DAN Diving Report, 24 cases reported symptoms of DCI during or after a flight, suggesting flying may have contributed to the development of DCI (1). In a recent randomized trial of a nonsteroidal adjunctive treatment for DCI, of a total of 167 patients, flying was the most commonly reported event associated with worsening of symptoms (8/10 cases) [unpublished data]. Interestingly, however, in neither of these reports was any significant deterioration specifically noted during any dedicated air medical evacuation.

Reduced Partial Pressure of Oxygen Resulting in Further Tissue Ischaemia

A second potential reason for deterioration during transfer is the additional injury suffered to already compromised tissue by further hypoxia secondary to altitude exposure. As Figure 1 illustrates, even in commercial aircraft the partial pressure of oxygen may be significantly reduced if no supplemental oxygen is administered. For example, an airliner with a cabin pressure equivalent to 2,500 meters (approx 9,300 feet) above sea level will mean an inspired oxygen pressure of about 115 mmHg, rather than the sea level value of 160 mmHg. While this is of small consequence to a healthy individual, for an area already rendered ischaemic and oedematous secondary to bubble effects, this further insult may be enough to significantly impact on signs and symptoms.

For this reason alone, it would be inadvisable for any injured diver to fly without supplemental oxygen.

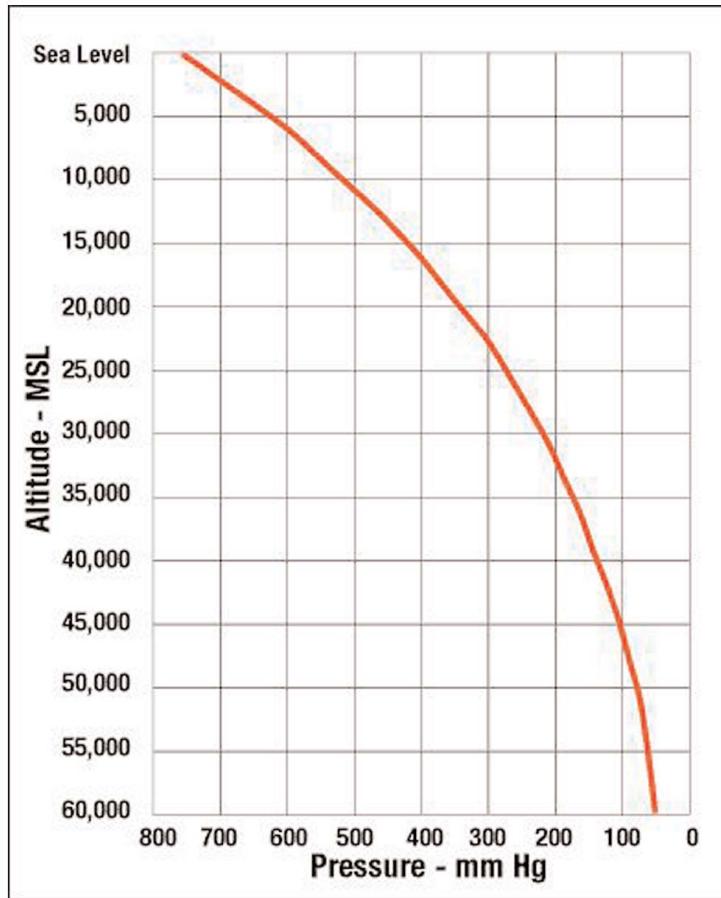


Figure 1. Reduction of atmospheric pressure with increasing altitude. The point indicated is roughly equivalent to a long-range commercial flight.

Vibration Characteristics

It has been suggested that the vibration characteristics, particularly of rotary wing aircraft, may promote bubble migration and produce new or changing symptoms or signs. An individual lying in a twin engine helicopter is typically subjected to vibration of moderate intensity between 6 and 34 Hertz, and this has been contrasted with the typically low magnitude, low frequency vibrations experienced by road passengers (0-5Hz) (4).

I am not aware of any data to support this assertion. Roughly one third of all DCI patients requiring retrieval to our unit do so by rotary wing aircraft, and the outcome of these patients does not differ from retrieved by other methods. The proportion of patients incompletely recovered after evacuation to our unit and a course of recompression treatments was 25 percent of those retrieved by rotary versus 23 percent of those retrieved by fixed wing and 33 percent of those retrieved by road ($p>0.05$) (5).

Financial Risks

Air ambulances, military flights and rescue helicopters are mighty expensive – someone has to bear that burden. If the individual is required to pay, this may be beyond his

or her means, or at least lead to a delay in execution of the flight with possible consequences. If insurance companies are to pay, this cost will be passed on to the purchasers of insurance. If society is to pay, we will all pay more tax.

We will not discuss financial considerations further.

Types of Aeromedical Transport

Any aeromedical transfer may involve one of two principle platforms – rotary wing or fixed wing aircraft. Both have their role and are associated with unique risks. Fixed wing transfers may involve dedicated, commercial or military aircraft.

In addition, aeromedical transports are qualitatively of different types – rescue, emergency facility-to-facility transfers for specialist treatment, and secondary non-emergency transfer of stable patients for social or medical convenience.

While the choice of platform is sometimes entirely constrained by availability, when alternatives are available, it is not always a simple matter to decide which option carries lower risk.

Choice of Transport Platform

Different modes of transport have different risk profiles. Table 1 contrasts some of the characteristics of road, and both fixed and rotary wing aircraft. It is adapted from a previously published analysis (6). The decision as to which mode is most appropriate in any given situation is often best made by close liaison between people familiar with the area at each end of the proposed transport route, along with expert advice from experienced retrieval medical personnel.

Transport Type	Response Time	Speed	Access	Weather	Availability	Altitude
Road	Minutes	60 km/hr	Good	Independent	Variable	Topographic
Fixed Wing	1 hour	550 km/hr	Poor	VFR/IFR	Good	Sea level
Rotary Wing	10 minutes	200 km/hr	Excellent	VFR/IFR	Variable	Day 100 m Night 1500 m

Table 1. A comparison of different transport platforms for retrieval.

The traditional approach to optimal transfer has been guided by three principles that can frequently be in conflict:

1. Minimising the interval between symptom onset and compression.
2. Minimising altitude stress during retrieval.
3. That all cases of DCI require compression.

It is the business of this workshop to challenge these assumptions. From the retrieval risk point of view, one should note a couple of important features illustrated in Table 1. With regard to speed, a fixed wing aircraft is usually the most rapid form of transfer through the air but will inevitably require longer preparing for flight and getting airborne than a dedicated EMS helicopter. Depending on the characteristics of the retrieval system, there will be a range over which the rotary wing aircraft will present a diver to the compression chamber more rapidly. Helicopters also have an advantage in access. Many hospitals have dedicated areas for EMS helicopters to land – and even when this is not the case, there is usually a sports field or similar nearby that will serve. Fixed wing aircraft must land at a designated airfield, perhaps quite remote from the diver, and the time taken to transfer to the airfield may be a significant factor.

On the other hand, helicopters are more likely to be affected by the weather, are less likely to be instrument capable and rarely pressurised. Transfer by helicopter may involve significant altitude stress, particularly at night when minimum safe altitude is commonly 1,500 metres. Finally, one should always be aware that road transfer is not equivalent to sea-level transfer. Topography may mean that helicopter retrieval over the sea is in fact at a lower altitude than a road ambulance driving through a mountain pass.

Conclusion

Retrieval is not risk free and should always be undertaken only after informed risk-benefit analysis. At the very least, it is expensive. Although air crashes are far less common than those experienced in road transfer, the consequences are more severe. In addition, there are specific risks, mainly to do with bubble expansion at altitude. It is by no means clear that outcome is negatively affected, but new symptoms do arise while at altitude.

If good data exists to suggest that mild cases of DCI have similar outcomes whether compressed or not, air transfer of such cases may not be in the best interests of the diver.

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DISCUSSION

RICHARD MOON: Mike, you've brought up the issue of PO₂ vs. bubble expansion. Do you have any observations that would shed some light on that – that is, cases where new symptoms have appeared during transport in the face of supplemental oxygen?

MICHAEL BENNETT: When we looked at that data, none of the new symptoms arose on oxygen, they were all in commercial aircraft, and of those who progressed, it was roughly a 50/50 split. In terms of the numbers in the trial, they were also roughly a 50/50 split. I don't want to dredge too much into data that wasn't the purpose of that study, but it's certainly our impression from looking at that data that you're less likely to do poorly during the transfer if you have oxygen. It was not related to the outcome as far as we can see. The administration of oxygen – whether flying or not – wasn't related.

JORDI DESOLA: About eight years ago, we asked the Catalan Aerospace Medical Association to study the effect of aircraft vibration on bubble formation. The opinion of the experts was that this mainly depended on aircraft type and especially engine type. Turbine engines produce higher frequency vibrations, while piston engines have lower vibrations. They agreed that the vibration problem was more important in an air ambulance even than in a helicopter. They believed that there was no reason to be concerned with aircraft engine vibrations. I also don't believe that data about emergency transfers in aircraft indicates greater risk than ground transport. Helicopter crashes during health transport are not more common than ground ambulance crashes, at least not in our area.

MICHAEL BENNETT: I'll accept that, Jordi. I didn't say it was my primary aim to compare whether we retrieve them by one method or another. I wanted to put forward to you the risks that we know in relation to air transfer, because I think that's the salient thing we're talking about today. I agree, and we could get some interesting data to show at what rate you suffer all sorts of outcomes by traveling by road. Absolutely, the overall data as I see it, though, is that events/crashes are far more common but less often result in serious injury or death. Having said that, the only one I've been personally involved with was a road ambulance, when I had to go and pick up the contents of an ambulance that had a nasty high-speed crash.

JORDI DESOLA: The problems of air transportation are more dependent on the type of aircraft than other conditions. There are wide differences among aircraft.

JOHN ROSS: Before the chamber opened in Orkney, the islands north of Scotland, people were flown down to Aberdeen by fixed-wing unpressurized aircraft on supplementary oxygen. We've compared those people with people subsequently treated in Orkney, and the treatment outcomes are pretty much the same. We didn't really see any deterioration in the aircraft that couldn't be explained just by the natural evolution of the disease. I think if you've got an air ambulance that's set up to provide transfer, it can be done successfully.

SIMON MITCHELL: With reference to the decision tree of Figure 1 in Introduction paper, let's say we have decided that recompression is needed on an emergency basis, that it can be provided on site, and that we are now in the position of having to repatriate the treated diver. At this point, we must confront the issue of flying home after onsite treatment. This is relevant to flying home after treatment at any facility, of course, whether it is in a remote location or not. I've always been fascinated over the diversity of recommendations. Recommendations vary from three days to six weeks, yet it has been difficult to make strong arguments to support one recommendation over another. There's now some data suggesting three days as a minimum period, and six weeks as too long. DAN is leading the way in monitoring this situation, and we have asked Dick Vann, Vice President of DAN Research, to speak on the subject. In his absence, Jake Freiberger will make the presentation.

THE RISK OF RELAPSE FROM FLYING AFTER RECOMPRESSION THERAPY FOR DECOMPRESSION ILLNESS: AN OVERVIEW

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Introduction

Flying after diving is recognized decompression illness risk factor. Divers who fly too soon after diving have an increased risk of developing decompression illness (1). Flying After Treatment (FAT) is a special case of flying after diving that occurs when a patient who has already been treated for decompression illness undergoes a secondary decompression stress from altitude exposure. The operative question is how long must a diver wait after being treated before he or she can fly on a commercial airliner. Although there are case reports describing relapses and recommendations for how long divers should wait, very little information is available, and the recommendations are based more on expert opinion and than on data. To summarize what is known, this report reviews published expert opinion, a select series of case reports, and a survey of FAT recommendations from hyperbaric chambers. This paper also presents the results of a small, internet-based survey of FAT relapse, and a 1998 abstract published in *Undersea and Hyperbaric Medicine* (2).

The specific questions we sought to answer were: (a) What are chambers recommending for flying after recompression? (b) Does flying after recompression predispose to relapse? (c) Is the relapse rate in patients flying after recompression affected by the pre-flight surface interval? The Hyperbaric Medicine Unit of the Royal Adelaide Hospital in Australia, the Diving Diseases Research Center (DDRC) in the United Kingdom, and Divers Alert Network in the United States contributed information for this review.

What are Chambers Recommending About Flying After Treatment?

DDRC Survey

The DDRC surveyed 19 chambers. Six of 19 chambers (32 percent) completed the questionnaire. Five chambers had guidelines concerning high altitude travel, but the guidelines were not evidence-based. Three chambers based their advice on local opinion, one on advice from DAN (three days), and one on unspecified research.

DAN Chamber Survey Data

Out of the 200 chambers queried by DAN, 17 responded, and only 14 reported having FAT treatment guidelines. The most common recommendation was three days. Four chambers distinguished between DCS-I and DCS-II in terms of their recommendations, with the recommended wait time being one day longer for the cases diagnosed as DCS-II. The range of the minimum recommended waits or pre-flight surface intervals (PFSI) for FAT from both surveys was from 24 hours to seven days. Although seven days was the maximum recommendation recorded in this brief survey, some centers suggest waiting much longer. Although unpublished in a peer-reviewed journal, it is reported that a study presented at the meeting of the Hyperbaric Technicians and Nurses Association in Townsville in 1998 indicated that there was a zero recurrence rate after a six-week delay in time to fly (Dr. Acott, personal communication). Some centers follow this conservative recommendation.

DAN Internet Diver Survey Data

Three hundred and 10 divers responded to an online DAN survey conducted during the winter and spring of 2004. Only 70 (25 percent) of the 310 respondents indicated that a specific wait time before flying had been suggested by their treating chambers. The recommended waits before flying after recompression therapy ranged from 15 to 2,160 hours (90 days). Figure 1 is a histogram of the recommended wait times. All recommendations greater than 200 hours were cut off to improve the resolution of the graphic in the more populated regions.

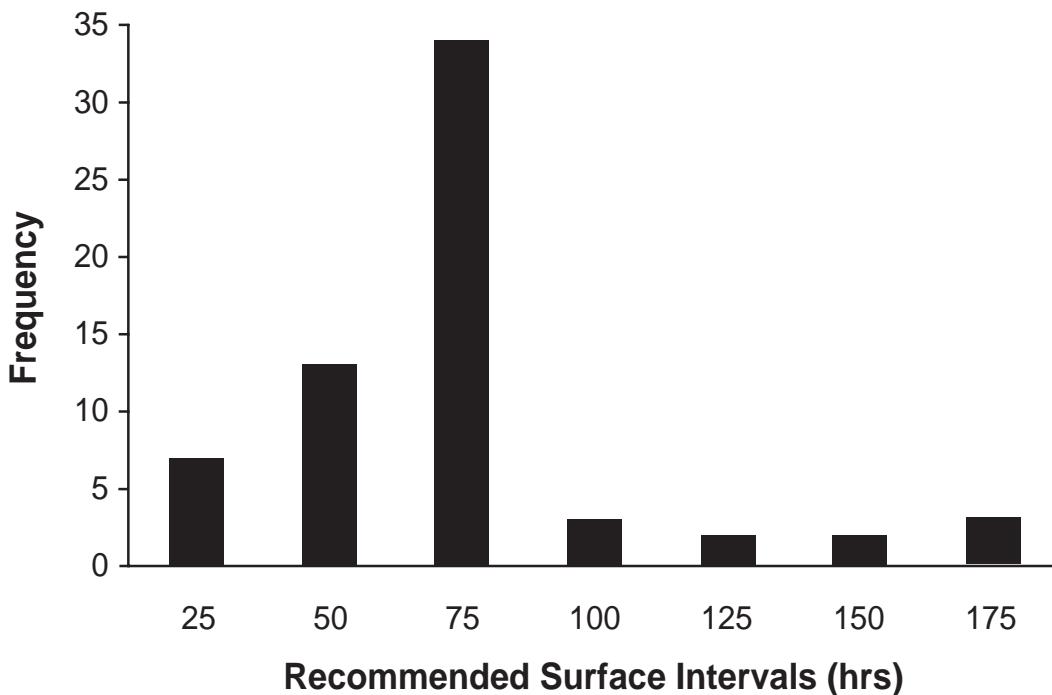


Figure 1. Distribution of preflight surface intervals recommended by chamber personnel to Internet survey responders.

Does Flying After Recompression Treatment Predispose to Relapse?

Previous Studies

If we are to understand the effect of flying on relapse rate, we must unambiguously know two things. First, we must know how often relapse occurs in the absence of flying. This is not currently well defined. Second, the definition of what constitutes a relapse must be firm. DCI symptoms are often very subtle, and diagnostic ambiguity can invalidate the results of even the most carefully designed study. This being said, there is some information in the literature that could be helpful.

Published Data

Earlier DAN data showed that FAT exacerbates persistent symptoms of DCI, but the data did not convincingly support a role for FAT for symptoms that relapse. In 1998, Uguccioni contacted 126 out of 151 divers in the DAN injury records who had been treated for decompression illness after diving in either Cozumel or Grand Cayman (2). She queried them as to initial relief of symptoms with hyperbaric treatment, recurrence of symptoms with flying, worsening of symptoms with flying, and the time of their flight in relation to the hyperbaric treatment. In the 95 out of the 126 divers called who had complete resolution of symptoms after initial hyperbaric treatments, she found an overall relapse rate of 9 percent. However, she found no difference attributable to their time of flight when she used 72 hours as a cutoff to categorize divers who flew early and those who flew late (Table 1).

Because the baseline relapse rate in this diving population is unknown, it cannot be stated that the relapse rate is any different in the flying versus the non-flying divers. Also, because there was no time effect or "dose response" (no difference in relapse rate in early versus late flying groups in her population subset), two interpretations are possible: (a) relapse was not affected by flying; or (b) the time to fly in the late flying group was not sufficiently long to demonstrate a difference.

Table 1. Patients with complete relief after initial recompressions before flight.

	Flight <72 hrs	Flight ≥ 72 hrs
Total Patients	54	41
# Who Relapsed During Flight	3	6
% Who Relapsed During Flight	5.6	14.6

p=0.13

In contrast to her results for divers who relapsed with flying, Uguccioni found that 31 out of the 126 divers had persistent symptoms after treatment. Of these 31 divers, 71 percent reported worsening of symptoms with flying. Table 2 shows that for the early flying group, symptoms were more likely to become worse (85 percent) than for the later flying group (45.5 percent). These findings suggest that flying with symptoms of DCI is likely to cause exacerbation.

Table 2. Patients with residual symptoms after initial recompressions before flight.

	Flight <72 hrs	Flight ≥ 72 hrs
Total Patients	20	11
# Who Worsened During Flight	17	5
% Who Worsened During Flight	85.0	45.5

p=0.02

Earlier work has reported that flying with symptoms increased the probability of residuals [Vann, 1993 #16; Freiberger, 2002 #15], a finding confirmed by another presentation at this workshop (Vann et al., 2004). However, readers should be cautioned that another interpretation exists. It is possible that divers who did not initially receive relief from hyperbaric therapy did not have decompression illness in the first place and that the physical discomforts they experienced were simply exacerbated by travel stress. Clearly, more study is needed in this area.

Case Reports

Case reports are often the basis of expert opinion, but because they do not represent

observations made under equivalent circumstances, they do not carry the weight of evidence of controlled studies. Also, symptoms attributable to DCI may have other etiologies. Of the 17 out of 200 chambers that replied to DAN's request for information, there were three FAT relapses (relapse during or after flight) and 12 non-FAT relapses reported. The PFSIs of the presumed relapsers were 10 hours, three days and 14 days. It is possible that the extremely low response rate for this survey represents a surrogate for the low perceived importance of the issue of FAT relapse among the chambers surveyed. Selected case reports are summarized in the appendix to this paper.

DAN Internet Survey of FAT Relapse

Methods

Three hundred and ten divers responded to the online DAN survey. After a careful reading of the comments, a diagnosis of DCI was considered questionable in 30 cases. These cases were removed from further consideration, leaving 280 cases for analysis.

Results

Two hundred of the 280 did not fly after treatment and, of these, 38.5 percent reported a relapse of symptoms. Of the 80 who did fly after treatment, 30 percent reported having relapsed. This difference was not statistically significant. Table 3 shows that there were no significant differences between divers who reported relapse and those who did not.

Table 3. The relationship of flying after treatment and relapse for the survey population.

	No Relapse	Relapse
Did Not Fly After Treatment	61.5% (123)	38.5% (77)
Flew After Treatment	70% (56)	30% (24)

A relapse rate of 38.5 percent for non-flying after treatment was an order of magnitude greater than the DAN chamber survey, where 12 of 229 non-flying cases relapsed (3.6 percent), and about four times greater than the 9 percent relapse rate found in the Ugugioni study [Ugugioni, 1998 #14].

Conclusions

The high relapse rate in the survey population might be explained by the motivations for answering an anonymous, self-selected survey. When reporting data from a self-selected survey, it is important that the results represent only those individuals who chose to respond. Frequently, respondents to a self-selected survey have a strong opinion about the issue being discussed, and they tailor their response in an attempt to affect the survey's outcome. Thus, the data are questionable.

Does Time to Fly Matter in FAT Relapse?

Both the Ugugioni abstract and the DAN internet survey did not show an effect of FAT on relapse. If these data are to be trusted, then FAT does not influence DCI risk, and the time delay before FAT is irrelevant. The Ugugioni abstract did show an

adverse effect of altitude exposure on persistent symptoms of DCI, and previously cited DAN research has indicated that residuals are more common in divers who fly with symptoms. Therefore, it is possible that there is an effect of time when symptoms persist before flying and assuring that the diver is adequately treated prior to any additional decompression stress can be claimed to be important with some certainty.

The DAN internet survey also speaks to this issue. Although the overall relapse rates are questionable, by plotting the rate of relapse by day of flight, an inference about the effect of time on symptom relapse can be made. Thus, Fig. 2 suggests that the cumulative rate of relapse with flying (the percent of the sample who reported return of symptoms up to a given day) stabilizes after three to four days. Even though the overall relapse rate in this self-reported internet study is higher than the more controlled Uguccioni study, it can be seen that flying within the first three days after treatment is associated with a higher rate of relapse, but after three days, additional waiting does not appear to improve the clinical situation.

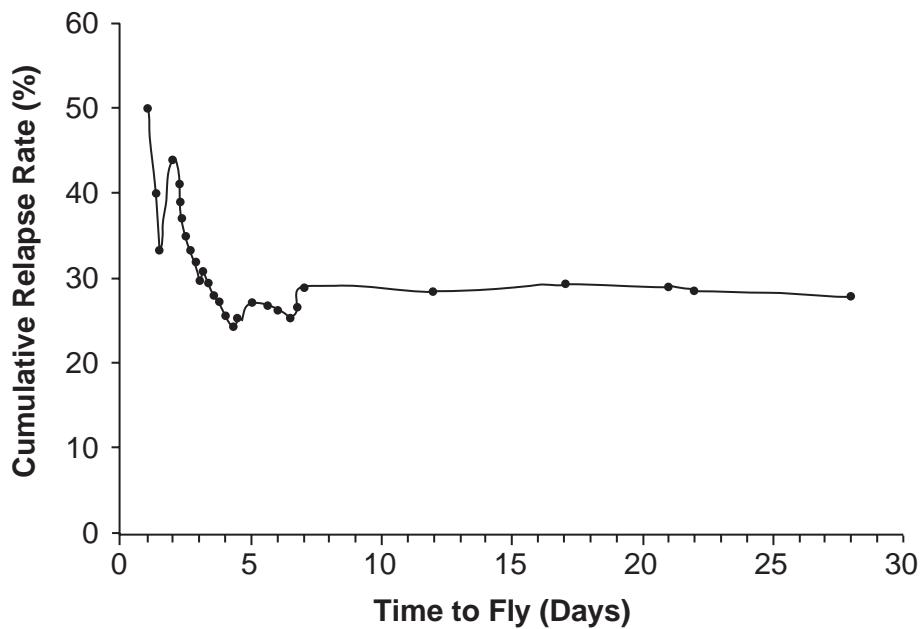


Figure 2. The relationship of time to fly to cumulative relapse rate.

Conclusion

The effect of flying on relapse after treatment is difficult to illustrate, particularly since the underlying relapse rate in the absence of flying is ill-defined. Recommendations from chambers about the appropriate PFSI or wait times are not uniform although, by convention, 72 hours predominates. Case reports of FAT DCI are uncommon, and published research does not unambiguously show that it exists independently of relapse in the absence of flying. Although the data are questionable, most of the relapses associated with FAT seem to occur with waits of less than three days before flying. A more definitive statement awaits a clearer understanding of: (a) the baseline relapse rate in the absence of flying; and (b) the effect of flying on the severity and persistence of symptoms that relapse in comparison with non-flying relapse.

As opposed to relapse after initial successful treatment, the issue of flying with existing symptoms is more clearly defined by the data. Divers who fly with symptoms risk either making them worse or more persistent and difficult to treat.

Appendix - Case Reports

The following case reports were provided by C. Acott, MBBS.

1. A 42-year-old man flew 14 hours after treatment and relapsed one hour after landing.
2. A 47-year-old female flew home 10 days after treatment and developed pain in her right arm and numbness and tingling in both arms and hands.
3. A 38-year-old male flew three days after recompression and developed pain in the right knee, elbow, wrist, and shoulders with tingling in the left ankle.

The following case reports are from DAN.

1. A 38-year-old overweight male made 14 dives in nine days [Vann, 2004 #17]. After his last dive to a depth of 170 fsw (52 msw) on air, which required decompression stops, he developed acute pain in his right knee, wrist and elbow, both shoulders, and left ankle. He also had numbness in right forearm and hand. He had complete resolution upon recompression with a Table 6. He flew at 72 hours after treatment. A first 1.5-hr flight was uneventful and was followed by a three-hour layover. One and a half hours into a second flight, pain recurred and did not resolve on landing. A neurological examination was normal and recompression on Table 6 provided partial relief. All symptoms resolved over the next 48 hours.
2. A 47-year-old female coughed twice to clear mucus from an airway after reaching a depth of 75 fsw (23 msw) [Vann, 2002 #18]. During ascent, she began to feel ill at 60 fsw (18 msw) and was disoriented on a safety stop. Post dive, she noted numbness in her left arm and leg, vertigo, confusion, and severe left side chest pain. A chest X-ray and EKG were normal, and she was treated on a Table 6 after which her only symptom was fatigue. Forty-eight hours later, she had decreased sensation in her face, arm, and leg on the left side and balance problems. There was no improvement after 90 minutes of oxygen at 45 fsw (13.6 msw), and a subsequent treatment on Table 5 was aborted due to claustrophobia with only slight improvement.

Six days after the last treatment, she flew and had acute exacerbation of her left-sided numbness. There was some improvement upon landing, but it worsened upon traveling over a mountain pass at 5,000 feet (1,524 meters). Her symptoms were worse the following day, and upon examination, she had decreased sharp to dull sensation on the left side of her face, motor weakness of the left arm, balance problems, and short-term memory problems. She received no additional hyperbaric therapy and continued to have problems with numbness after sitting after 12 months.

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DISCUSSION

DAVID DOOLETTE: With the chamber recommendations that you showed – some out to 90 days – did you get any information on what those chambers were basing those recommendations on?

JAKE FREIBERGER: I don't know. I always assumed that it was the personal experience of the treating physicians, but we didn't really get any firm explanation. We were hoping that the topic would be discussed during this conference.

GEORGE MACRIS: Did any of that data include actual flight durations? It seemed very sensitive and didn't differentiate between 30-minute and 15-hour flights.

JAKE FREIBERGER: That's an excellent point. We did not know the flight durations.

GEORGE MACRIS: In Guam, the average patient flies 3,800 miles for eight hours to get back to Honolulu at about 37,000 feet with a cabin altitude of about 8,000 feet. It's 15 hours if they go through Japan. We move lots of patients out – Japanese and others. I think the long-haul flights are probably where flying after diving problems would be most common. We hold them for 72 hours. That's about the longest we can hold somebody who's anxious to get home.

GLENN HAWKINS: Did you look at the number of flights they made?

JAKE FREIBERGER: I can't answer that. The survey was not designed to pick up those fine details.

JORDI DESOLA: The type of aircraft should be added to your questionnaire. There can be more than 1,500 meters difference in the cabin depending on the type of aircraft – Airbus, Lockheed, etc., and among the same type of aircraft, there may be 800 meters of cabin pressure variation in the same flight. The pressure in the cabin is difficult to know unless you have an altimeter. If not, the type of aircraft would make very interesting data.

FRED BOVE: There's a dimension missing in some of today's presentations, the probability of the diagnosis being DCI. I firmly believe that some of these cases are gas bubble and some of them aren't. Without knowing which are and which aren't, it's very difficult to make sense out of the data that we're hearing. Is there a methodology that would allow us to put a probability of a correct diagnosis on these cases? The data might be much more meaningful if we could tag the high probability cases and correlate them. Maybe DAN is the right place – is there a way we could start looking at probabilities?

JAKE FREIBERGER: I really appreciate you saying that. It is one of our more difficult problems. The tendency is to recompress everybody with symptoms after diving and classify them as decompression sickness so the treating physician feels good, the patient feels good, and the insurance companies pay. There's no doubt in my mind that many factors influence how we classify cases as I mentioned in my other talk. I believe it's critical for us to have a case definition of decompression illness based on signs and symptoms, exposure, and treatment outcome. I would choose a model similar to that used in the mental health profession with consensus definitions for the diagnosis of diseases with no laboratory tests. This would assist communication among practitioners. Cases that are not decompression illness will not respond to recompression therapy and will contaminate your database. You'll get the biases, confounding, and misinterpretations that I spoke about earlier. Epidemiological studies with such problems make it very difficult to detect small effects like a thousand meter change in altitude. We're almost forced to do lab studies instead of field studies for effects like these. Neal Pollock is running a series of flying-after-diving studies at DAN in which we control all the variables and varying the preflight surface interval to get a better idea of the risks.

EVOLVING CLINICAL PROBLEMS

*All Participants
Sydney, Australia*

Editorial note: The morning of Day Two consisted of working through two hypothetical evolving clinical problems concerning the management of decompression illness in a remote location. The two problems were a diver with severe symptoms, and a diver with mild symptoms. A premise of these hypothetical problems was that expert diving medical advice was available only by telephone. The purpose of these hypothetical problems was to stimulate discussion about the issues that were covered in the formal papers presented on Day One, and to generate debate around some of the issues that would be the subject of the consensus statement discussions later on Day Two. The discussion was structured by working through the decision-making tree (Introductory paper, Figure 1). Whereas the discussion included all workshop attendees, any controversial management decisions were put to a vote of the invited expert panel of Discussants.

This discussion has been edited in the interests of space and clarity as well as necessity, since recording quality was occasionally poor. Thus, not all statements conform to the exact spoken words. Where exact wording has been changed, the editors have taken great care not to change the intent of any contribution.

Hypothetical Case of Evolving Serious DCI in a Remote Area

DAVID DOOLETTE: This is a male 25-year-old diver who has no known medical problems. He's been diving for six years with a total of 50 dives, the deepest to 40 msw. He's trained to rescue diver level. There is no previous history of decompression illness or other diving-related medical problem, and he has a DAN Master Plan insurance policy.

The diver is on a remote island in the South Pacific. There is a small town with a medical clinic and an airport. The clinic doesn't have a full hyperbaric facility, but there is an old recompression chamber on the island – a four-person, twin lock chamber – that belongs to a diving company. There's a diver there who knows how to operate the chamber, but there's no doctor on this island with specific training in diving medicine, and there certainly isn't a doctor at this chamber. The nearest retrieval facility is Auckland, where there's a comprehensive recompression facility, and that's three hours' flight from this island.

It's the first day of diving, and the first dive of the day is on air dive to 45 msw for 12 minutes. The dive is uneventful during the bottom phase, but during ascent, the diver loses his weight belt and makes a rapid ascent to the surface. He is retrieved onto the boat relatively quickly, and within the first few minutes, notices transient shortness of breath and complains of this to the boat operator. Within 10 minutes, there's progressive numbness and weakness in his legs. The boat operator puts the diver onto 100 percent oxygen using an open circuit demand valve. There seems to be no relief of symptoms within the first 30 minutes. The patient reports feeling weak in both legs and can

move only with difficulty and feels numb up to the waist. The boat operator makes for shore and contacts you for medical advice via phone 45 minutes after the diver surfaced.

The first decision in the tree: is this a case of decompression illness? Let's have a show of hands for yes.

Editorial note: There is unanimous agreement that this is a case of DCI.

DAVID DOOLETTE: So we believe this is decompression illness. The next decision down the tree is whether recompression is required? Let's have a show of hands for required recompression.

Editorial note: There is unanimous agreement that recompression is required.

DAVID DOOLETTE: How quickly do we need to recompress this diver? Is this an emergency situation? Is there anyone who would suggest that recompression is not required on an emergency basis?

ALISON DREWRY: I agree that recompression is required and that this is an emergency situation, but this is possibly not somebody for whom I would consider in-water recompression. In my experience, these guys do pretty badly. He's obviously had a massive bubble load probably with some pulmonary involvement, flooding of his venous system with bubbles, venous hypertension, hemostasis in his spinal cord, he's now infarcting his spinal cord. I just might be a bit pessimistic about the immediate benefit of recompressing him in-water. I'm not convinced that there are an awful lot of bubbles in this situation necessarily but an awful lot of venous hypertension. This guy needs all sorts of things to manage his impending paraplegia. Recompression is certainly one of them, but I think he's got very special requirements for an in-water treatment.

SIMON MITCHELL: The identification of this patient as requiring emergency recompression does not commit us at this point of the tree to putting him in water. It's just saying this is a case that we need to access recompression early, not late.

ALISON DREWRY: In that case, I agree.

SIMON MITCHELL: So we're still unanimous.

CARL EDMONDS: I'm not talking about in-water at this stage. In your tree, you seem to have a choice between recompression and adjuvant treatment. Surely, what you really mean is emergency recompression plus adjuvant on one side and only adjuvant treatment on the other. So you should change the tree accordingly.

DAVID DOOLETTE: Yes. Thanks, Carl. It was not intended to exclude appropriate first aid measures from the recompression limb. Very good point. So we've decided on emergency recompression for this diver with appropriate first aid and adjuvant treatment as available and appropriate. As Alison pointed out, perhaps in-water recompre-

sion wouldn't be appropriate for this diver, but there is this recompression chamber on the island belonging to a commercial company. What would be your feeling about taking this diver to that chamber?

GEORGE MACRIS: If that chamber is operational and has been maintained and there's a physician there, even though he's not competent in diving medicine but can dialogue with somebody online and there are divers who can run that chamber, this is no different than a diving salvage rig or any type of operation. Let's not forget, divers are the ones who started treating people and did more treatments than many physicians. This man is at great risk for developing irreversible spinal cord injury. I would put him in that chamber and would consult if need be with an individual competent in diving medicine. We do this all the time when new chambers pop up in Yap or Ponapei or some of the outer islands. No delay.

FRED BOVE: It's an interesting exposure, because I'm trying to figure 45 meters for 12 minutes is not a massive gas load. It's not too far off the no-stop limits actually. The question is, unless this gentleman embolized at the same time, I would be really surprised that he had chokes. I'm thinking that he may have pulmonary barotrauma. He had some dyspnea. There's a risk that this guy may have a pneumothorax and, if you put him in this chamber with no support, you may have a problem. I would just put that in the soup to think about, because I really think there is a high likelihood that this is a combined lesion – that he's got gas bubble evolution, and he's also got a risk of pulmonary barotrauma from his rapid ascent.

DAVID ELLIOTT: If this is a commercial chamber – and I'm not quite sure what it's like in the South Pacific – but if the contractor is a member of the International Marine Contractors Association, they will have a retained doctor who will be competent. They will have the right emergency procedures. They will have the right equipment, even if they don't have a doctor there. I perfectly support the idea that having a doctor online under these circumstances is adequate. Unless they have, therefore, the proper contingency plans and a team of competent divers there, I think would be very concerned about how they would handle it if it becomes a much more difficult situation. But any competent commercial diving organization must be able to cope with this kind of accident.

JOHN LIPPMANN: There are many chambers – well, there are at least a few chambers – around the South Pacific that are not compliant with the kind of rules and regulations that you have stated. Around this part of the world, there's a lot of chambers lying down there that haven't had much use at all and aren't necessarily that well maintained, and aren't necessarily manned by divers that have lots of current experience. There may be medical officers associated loosely with them, but they may have rarely seen a case. So it's not quite a known situation. We have had situations with DAN with evacuations to such chambers and have been fearful about sending some divers. The other thing of note is that the New Zealand chamber is not that far away; we're talking

three hours, which is a bit further than what you'd like in a severe emerging case, but it isn't as far as many of the ones we have to deal with. Unless we could find more about that chamber, we, in our office, would have some reluctance to just send somebody there.

DAVID DOOLETTE: I'll just jump in with some more information. This is the Francis & Gorman Diving Company in receivership. It has been a little while since anything's been restocked in this chamber. We understand that the chamber is capable of a USN Table 6. There's definitely no diving medical officer, but there is the doctor at the clinic, and there's certainly no medical equipment or patient monitoring in this chamber.

JOHN ROSS: We've got some experience in dealing with people just like this. The time-to-treatment outcome issue in people like this is not strong. What this guy needs is not a chamber at this stage. He needs a doctor. He needs drips. He needs rehydration fast, and he needs transfer to a system of medical care which is going to be able to look after his rapidly dehydrating state and apply a competent rehydration scheme. If this chamber sticks to the manual, it's going to go like this. He goes into the chamber; he gets compressed. He has no response to treatment. He may even continue to become paralyzed. They go to 50 meters because that's the next thing in the U.S. Navy manual. He doesn't get any better at 50 meters, and they try to get him back from 50 meters on a Table 6A and he gets worse. He then gets stuck at 50 meters and goes into saturation. You've then got a major issue. That's what happens – we've seen it happen – with inexperienced crews.

JORDI DESOLA: From my point of view, maybe in this side of the world things may change a little, but you will have a transfer of three hours, which isn't much, assuming good fluid and pharmacological support in the meantime. There's no need to risk using this chamber. We don't know what to expect of the medical officer. We have the risk that the patient will not be helped in the first treatment and will need some further treatment. The patient needs a hospital as well as the chamber. I would recommend transferring this patient.

DAVID WILKINSON: I think what you're dealing with is a very difficult case. The Pacific, as John had made mentioned, is littered with many chambers that don't have full support and capability of doing difficult cases. This, as Alison has pointed out, is going to be a difficult case. I think it's highly unlikely that you're going to get by with a simple Table 6. You're talking about the necessity to be able to monitor that diver and to change your treatment profile. You are also looking at the probability of starting lignocaine. I don't think a remote location is the right place to handle this patient. This is a serious case and needs retrieval to a tertiary center to treat properly.

FRANS CRONJE: Essentially, we're getting into details, but there are really three principles to consider. The first is status known/unknown. The second is appropriate/inappropriate. The third is, is the liability greater or less if you use that facility? The rest of details are for the diving medical officer on other side of the phone to manage. Those are really the three things to think about. The rest are just details.

DAVID ELLIOTT: I have got a question that you might like to put for consensus opinion. You said there's an airport there, but you haven't said there was a plane there and whether it's going to take three hours for the plane to arrive. The question that I would pose for additional consensus is, would you actually do a Table 6 without anything else on that guy while waiting three hours for the plane to come in?

SIMON MITCHELL: That's a very good question, David. It was always our intention in writing this that there wasn't a plane there. That would certainly be the most typical situation. One of the guys like John Lippmann who deals with these all the time might like to comment. It may only be a three-hour flight to Auckland, but you've got to factor in the time it's going to take to organize an air ambulance as well. My experience is that these things can take another three, four, five hours, so this guy could be on the ground for quite sometime. I think your question about whether to use this chamber or not in the interim is a very good one. I hope you can see why we've written the problem like this. This is not an untypical situation, and we've tried to make these problems realistic. A long time on the ground waiting for a plane to be organized, let alone the flight time to Auckland, would be a typical situation.

JAMES FRANCIS: The choice we've got here is not a whole lot and not a whole lot plus recompression. From my point of view, this is a no-brainer. You put him under pressure – provided you use an oxygen table – and you can get him out as and when. I would use the chamber.

CARL EDMONDS: I agree thoroughly with you, James. I also think it's a no-brainer, but I disagree with some of my colleagues. I don't think this is going to be a disastrous case at all. I think this is a serious case that's eminently suitable for treatment. This guy is not too bad at this stage. If you've got a chamber plus someone competent to decide what to do with it, then why don't you put him in the chamber on oxygen – you don't have to give air breaks – while you're organizing your transport? It's beyond my comprehension why you wouldn't use, if you want to, to do a 9-meter oxygen table or, if you wanted, you could go onto a Table 6. But, either way, you should be doing something while the transport is getting there, and you should be trying to stop this thing from progressing. If you don't do this, it is going to progress, and it will become a dangerous case and will become hard to treat. By the way, no one – but no one – would advise a Table 6A.

KLAUS TORP: I would also put him in the chamber and, if the plane arrives before the Table 6 is up, so what? You can bring him out – you can bring a patient out any time.

JOHN LIPPmann: One of the issues that we face in dealing with unknown chambers [around the Asia-Pacific region] is how safe they are and, this being an unknown chamber, we still have a level of reluctance about treating in this chamber. Some who would say, "I'd rather go into a chamber," may change their mind when confronted with some

of the chambers. The other option is how well can you manage them on the surface with oxygen and fluids? Are some of those divers there that are working there capable of putting in IV fluids? Do they have normal saline? Can they manage them at one atmosphere on oxygen?

SIMON MITCHELL: As someone who's just expressed reluctance about this chamber, John, can I ask you what you would do if you were the diver, and you were in this location?

JOHN LIPPMANN: If I were the diver, it probably would depend on how the chamber looked, Simon. And the staff. We have put divers in some chambers and had a real bad reaction from the divers because they've felt that the staff inside the chamber and outside the chamber really did not know what they were doing. They felt very claustrophobic or freaked out because of the totally anxious faces of the staff inside the chamber and their inability to answer questions. This is reality.

DAVID ELLIOTT: I think it's important to distinguish between proper commercial chambers for commercial diving and commercial divers who are just hanging around and really don't do a damn thing. I took this to mean a commercial diving company; therefore, this is their base and, therefore, they would be sufficiently competent. I mean, that's why they've got the chamber there: to do this particular emergency procedure. But you have now put in a different category of chamber which is a rusty old thing, and it possibly is out of the back of a garbage dive shop, and although that technically might be referred to as commercial, I wouldn't touch it. So which of the two, please, were you talking about?

JOHN LIPPMANN: I was talking about the latter because we hear of quite a few chambers that have been donated somewhere like the Philippines and various other places, so they're sitting there and they're quite unknown.

DAVID DOOLETTE: Yes, it was previously a commercial chamber that is now not maintained.

WILLMA PADILLA: We know that the success of a treatment in a severe case is not just recompression therapy. It's rehydration, medications, and sometimes in a severe case a trained physician must be inside with the patient. We need not just a Table 6, we may need extensions and other decisions. Sometimes the patient is worse after the recompression. I'm thinking that we can recompress in the very closest chamber and the physician, the DMO, flies to see the patient.

BOB RAMSEY: Just a quick statement about chambers around this region. I'm wondering about the impression left behind of the South Pacific for the other people, the international people, here. I've got quite a lot to do with quite a few of them. Yes, there are some bad ones, but most chambers that accept this responsibility, do in fact provide detailed information about the capability of the system, the maintenance level, the training levels, the doctor support to people like DAN and other interested parties. This chamber obviously doesn't, so it's suspect – but there is a lot of information about a lot of the chambers.

FRANS CRONJE: Forgive me if I sound like a broken record, but we're all getting our adrenals squeezed about this particular case. I understood that what we're really trying to get at is principles. Again, the principles will be whether the status of this chamber is known or unknown; whether the chamber is appropriate or inappropriate, and that is going to be left up to the individual on the other side of the line making the call in terms of their experience; and, finally, whether liability is going to be increased or decreased by treating the person there. Many of you have addressed this indirectly, but that may involve consulting the patient as to the two options. I know that's laden with a lot of concerns, but fundamentally we're really making the decision on those three axes. I think that's really the way we should approach it for now. We're getting into details, and we're not going to get consensus on that.

BILL HAMILTON: I wanted this to be last after you had made the decision, but I would like to sharply slap the wrists of the dive planners on two counts. First, they should have given this guy another tank and another weight belt and let him go back and do his decompression, because that would have saved his life right then and there. Second, a part of a dive plan has to include treatment. You don't go diving to 45 meters unless you know how you're going to be treated when you get to the surface and need it.

STEFAN POMPLY: In this special case, I'm worried about one thing. Obviously, he has spinal DCS. But, second of all, he has pulmonary symptoms. He has pulmonary barotrauma, so he probably has pneumothorax. Maybe yes, maybe not. Well, I always thought that the pneumothorax was the only absolute contraindication to treatment, so this is the main point I'm worried about. I must rule out pneumothorax. Do I have a means to rule it out? Can I do an X-ray, a pulmonary X-ray?

PETAR DENOBLE: I agree. First, I would like to exclude pneumothorax; but then if there is any reason for recompression, this is a case where we can use it. There is no sense to delay his treatment for 24 hours and put him in a category that doesn't respond to treatment. In worst case, if you recompress within one hour, his chances of getting well are at least 70 percent. The chance of being blown up in the chamber because of ill maintenance of the chamber is maybe one in 10,000; so the benefit here is very obvious. Even if I don't use Table 6, I will compress him to 10 meters and give him oxygen and then see what's going on. This is not definitive treatment, but since we have at least six hours until evacuation, we have to do something.

KLAUS TORP: Pneumothorax is not a contraindication for recompression. It's only a contraindication for recompression if you can't do anything about it if it happens. As for X-rays for pneumothorax, we are poor at diagnosing pneumothorax from X-rays. If there is radiology, fine. If there's not, you're recompressing him for his neurologic symptoms.

FRED BOVE: I just wanted to ask Bill Hamilton a point of information. If this individual had a pulmonary barotrauma in addition to spinal cord decompression sickness, would you do an in-water recompression? That was my concern. I'm more concerned that this is two diseases really rather than one.

BILL HAMILTON: Fred, that's a good question, and I did not take the Carl Edmonds position. I didn't give this guy an oxygen tank and send him to 9 meters. I gave him a tank of air and sent him back to 45 to finish his dive immediately, then maybe he has barotrauma but....

FRED BOVE: No, I'm sorry. That's my question. If somebody has an air embolism with air in their brain from this ascent, would you consider that an incomplete dive? That's different than an incomplete dive to me.

BILL HAMILTON: It's true. I mean, it's a missed decompression if you consider it that. Then you go through a whole new algorithm of what you're supposed to do. I'm saying it's an incomplete dive in the sense that he just didn't finish it. But it has to be done immediately. You can't fool around and have a committee meeting while you decide what this guy's going to do.

FRED BOVE: The other point I wanted to make about pneumothorax is that I brought it up earlier only to be aware of the fact that if you do recompress this diver, which you should do, you want to make sure whoever's dealing with the diver is aware of the concern, so that if the diver has some trouble on the way back up that they know that there's a risk of pneumothorax and they have some plan to deal with it. I wouldn't limit the recompression because of that.

MARTIN SAYER: Based on the information you've given us here – you've only given us one BIB mask – does that actually make this chamber capable of providing the Table 6 or Table 6 with extensions? And would you, as an internal, go into that chamber if there's only one BIB mask?

JORDI DESOLA: In practice, not in theory, I wish to remind, first, that pneumothorax is a problem if it is a tension pneumothorax; if not, the problem is much less. But, the majority of you remember that pneumothorax is really rarely observed even in pulmonary barotrauma. Pneumomediastinum is 10 times more frequent in real practice.

DAVID DOOLETTE: Well, I think we can put this to a paper vote now and move on. Let's assume we were able to rule out the pneumothorax. We've got a chamber that looks like it's capable of doing the Table 6, but there's certainly no medical monitoring in it. So are we going to treat the diver in this chamber at all – whether that be an interim measure while we're waiting for retrieval or whether we are going to try and do definitive treatment in this chamber?

SIMON MITCHELL: While you're doing that, can I just make a comment, because I know Frans (Cronje) is a bit frustrated. I can see what he's trying to do. Frans has tried to provide us with a structured way of thinking about solving this problem with his three-axis approach (status known/unknown; greater risk/less risk; greater liability/less liability). I quite agree it's an ideal way to think about it, but the problem with that is that we don't actually have an objective way of resolving any of these axes

in a way that we could put it on paper. In a sense, each of the discussants is processing the available information along each of these axes as we have this discussion in their own way, and the outcomes of these personal deliberations are what we are interested in.

It comes down to what each one of you expert diving physicians and operators thinks along the kind of axes that Frans has proposed, and how these opinions are integrated into your final decisions. It's an integrated impression that you're all going to have to come up with and, at least at the end of this vote, we're going to know what a considered body of opinion is on the issue.

FRANS CRONJE: If we come up with a very detailed response to this, all we will have is a response to this particular case. And my understanding was that what we really want to get is, what are the fundamental principles in the decision-making process? And, in the end, it's going to be up to whoever is on the other side of the line.

GEOFF BAYLISS: One of the issues here – and I support the previous speaker – is that we're looking at issues that are evolving, and we don't seem to have made room for clinical judgment. If you're involved in this case or you're giving advice to this case over the phone or internet or whatever, you're getting an evolving picture. And this is a particular case, but it is illustrative, and it brings out a lot of points. But, in the final analysis, on the day, there may be a lot of other variables which throw all our discussion today into the scrap heap, because you could have a cyclone just runs right across the island and the whole thing becomes academic because you wouldn't go into the chamber anyway. You have a tidal wave that sort of sweeps over the beach or something of that sort. You can get guidelines, but they are just guidelines. They're not going to replace informed judgment on that particular day on that particular case.

SIMON MITCHELL: I understand that. But we've been careful to make these reasonably typical problems without things like cyclones and tidal waves because that would make it ridiculous. But as I've sat here and listened to the various discussants make their points – I thought, "That's a good point. That's a good point. That's a good point." And those points will be preserved in the transcript of this workshop; so I think that it's not a total loss. There's no easy way of doing this, but the idea of a representative evolving clinical problem is one way of drawing out some of the ideas that we should be thinking about, and that's what we're trying to do.

JAKE FREIBERGER: Just in defense of this entire process and trying to help everyone understand what's going on, what we are trying to do is, if I understand it correctly, to set policy; and policy is always based on inadequate information. That's why it's policy and not law essentially. So if we could try to look at the grander perspective and not get lost in the details, I think we might be able to come to some more useful understanding of the issues involved here. We can easily get tied up in what-ifs; but if we follow the rubric that's laid out here, I think that we will end up with a more useful product.

SIMON MITCHELL: There's one other point I'd make about the process. If the vote was to put this person in this chamber, it doesn't mean there's going to be some kind of decision or directive in the proceedings saying, "This is what you should do." That's not what has just happened here, and I want to put your mind at rest on that, Frans. This is just the opinion of this group at this time on this case. However, the kind of ideas that are being advanced this morning will help us, I hope, when we do try to formulate some policy this afternoon.

KARL HUGGINS: One of the points would be if you, as the hyperbaric physician, are talking directly to the local operator of the chamber or if you're dealing through the local medical personnel who's there and having that person actually be in charge of the orders that you're giving.

ALF BRUBAKK: I think this illustrates very well what the problem is, because we now have a committee meeting discussing what they're going to do with this guy and, while we're having that committee meeting, he's getting sicker and sicker. I believe from all I know that this is a real emergency, and I certainly agree with Bill here. I think that that problem could perhaps have been solved very easily or we could have prevented a lot of the problems if we had put him under pressure more or less immediately. But you have rapid access to a chamber. Of course, it's not risk-free, but still you get him on the pressure and the chances are that he will get better. Not 100 percent sure, but he is better off having pressure applied to him rapidly than having a committee discussing what we should do.

DAVID GRIFFITHS: No one's mentioned the review of how the patient's proceeding. In my experience, quite a number of patients with the sort of problem that's been presented will in fact improve on just the basic first aid that's been provided. And, if the individual is improving, I believe there's a lot less urgency to get this individual under treatment. On the other hand, if after two or three hours – and that's how long it usually takes to get them to this [local] facility, wherever it is – if the individual's still deteriorating, then I'd be in favor of treating. But if they're improving, then you may well want to wait and evacuate the individual almost at leisure.

DAVID DOOLETTE: I'll announce the outcome of the vote. Someone sat on the fence and said "maybe." There were two "no's", so two people didn't want to treat in this chamber. And 22 people put "yes," they'd put the diver in the local chamber.

DAVID ELLIOTT: I put "maybe," and the reason I put maybe is you were just saying, "Would you recompress?" And I think when you say "Yes," there's a question of "To what depth?" And my attitude would be to hold him at 9 meters until – I think what David Griffiths said about progression, of course, is very relevant here – until you know what the airplane is doing and all the rest of it. And it wasn't, therefore, to give a Table 6. Hence, my reservation.

DAVID DOOLETTE: So we decided to treat in this local chamber, and let's say that the symptoms resolve after two treatments. The next question we come to now is, how

does this diver get home? And as we continue down our decision tree, having treated this person, there's the issue of flying this person from this island back to Auckland. How long do we have to wait?

GEORGE MACRIS: I think this is a very easy answer. If it's a one-atmosphere aircraft, immediately. And if it's not, you wait at least three days.

DAVID DOOLETTE: To wind up this problem, let us assume we have gone down the road of not bringing an air ambulance, so we're talking about sending him home on a commercial aircraft, so three days.

JOHN ROSS: Being on the receiving end of this kind of situation, I'm not clear how long you wait before you send these people home. We don't have to make that kind of decision. But it would be really useful if these people were put in contact with a chamber at the other end of the flight – at least with a telephone number they could phone – so that if they do have a problem, they know what to do and where to go. And if the doctor at the other end also had some intimation that somebody was coming in, that would be extraordinarily helpful as well.

DAVID DOOLETTE: Good point, John. Does anyone here working with those phone lines know what happens to the people they talk to over them when they get home?

ROWAN SANDERSON: Just in regards to the question for follow-up on patients, we've got five recompression chambers in our network and anyone that sort of gets treated in any of our chambers, we normally do a follow-up where they'll go to Bangkok or they'll go to a hospital where they'll do follow-up with a diving medical officer. If they're actually going back overseas, we'll always give them the details of the Diving Disease Research Center in the U.K. or contacts in Australia or America as well. And normally a lot of our patients email us for advice afterwards as well.

CARL EDMONDS: I have been in this situation many, many times and, Fred, my attitude is that if I believe the person has bubbles in their body, there's no way I'll send them back on commercial aircraft. And the reason I say this is that if you really have done a good treatment, the person is now asymptomatic and then you've now given them an extra four to six hours on [surface] oxygen, I cannot believe there are any bubbles or excess dissolved nitrogen in that person's body at all. I see no reason why you can't fly them back immediately.

JOHN LIPPMANN: We get faced with these questions not uncommonly from members that have been treated in a particular place and want to go home. They ask the chamber that's treating them. Sometimes they're confused and unhappy with the advice, and sometimes they'll call us for an opinion. And the situation I'm often faced with there is explaining any difference in advice they have been given. But not only that, I do make sure, as was mentioned before, that they do know whether or not there's a chamber in the destination and whether or not they can contact that chamber. I also

suggest they monitor themselves during the flight and, if they do get concerned about changes and unwanted symptoms, that they ask for some oxygen, because it might just be a bit of hypoxia. I have had people getting oxygen on the plane – just the standard oxygen – and it seems to help them through the trip.

JAKE FREIBERGER: The data that I presented yesterday, if the diver is asymptomatic after the treatment, he seems to have less of a negative response or adverse response to flying early. And if he continues to have symptoms, then the flying should be delayed. But we would need to be able to determine these things before we were able to make an informed decision on how to advise this person.

FRED BOVE: I was surprised at the outcome you put on the board (in the evolving problem), because these kinds of cases with a significant gas load and a risk for embolization are often refractory to treatment, and you end up with very little change in the chamber. That's why I was sort of interested in how you picked your outcome. I would have thought that the outcome could have either been simple or very complex with very little change in therapy because of this combined injury. So you'd still have to keep in mind the idea that this could be difficult to treat; and, even though you'd go in the chamber the first time knowing there was a risk of not getting much response, you'd have plans for medevac while the chamber was being used at the same time.

SIMON MITCHELL: Thank you, Fred. We've heard that from you and several of the discussants, and I'll take that on board. I think that also has relevance to Carl's comment about not closing our minds to the possibility of evacuating the diver in an air ambulance after the first treatment in that chamber, especially if they had ongoing symptoms.

DAVID DOOLETTE: We'll move on, and really what we want to do is introduce another scenario about this case. So, the case is actually changed now. Let's say that that chamber wasn't there onsite but the diver was a much more experienced diver than we initially suggested, and he's actually diving there with a group of technical divers who have a large quantity of open circuit oxygen and several oxygen rebreathers which they're using during their diving. They're doing in-water oxygen decompression as part of the diving that they're doing. This team of people, being used to using oxygen underwater – they do it routinely – don't see a problem with putting this diver back in the water and treating him themselves. They're suggesting they do that. What's your response over the phone?

CARL EDMONDS: Simon, you did promise me that I could make some comments about some of the misunderstandings that have been developed regarding underwater oxygen during the last 48 hours. Firstly, could I clarify something? I have never treated anyone with underwater oxygen at a depth of greater than 9 meters. Most of them are either 9 meters or less; they're usually off the end of a wharf. And also, although you took about two to three hours – this will influence your voting and your attitude – you're talking about two to three hours; but in fact, if you get the cases early, like the abalone divers and the pearl divers and the technical divers do, then you're often talk-

ing treatment within one hour. So that's the first of a number of things I'd like to point out. Secondly, the weather. People keep talking about the weather and how that's going to influence everything. But really, with underwater oxygen, if you're on the end of the wharf, the weather doesn't matter a great deal. Even in shallow water, the weather is not that important. And, in fact, if you've really got terrible weather that's going to influence your decision to put them underwater, then that terrible weather is going to influence your decision to medevac as well.

Now the next point that I think was raised yesterday, which I found unbelievable, was that somehow or other these little islands are not going to have any oxygen. Well now, look. This is nonsense. Most of these islands we're talking about have got dive operations. They've got compressors. They've got dive boats. They've got motor vehicles. They've got garages and they've got machinery that looks after the infrastructure. They'll all have oxy-welding machines, so they'll all have industrial oxygen, which is quite adequate. They'll all have regulators which they'll put onto their oxy-welding machines which are quite adequate. And they'll have hoses, high-pressure hoses, which are quite adequate. All you have to do is add in a demand valve with a jubilee clip on it. So we're not talking about islands that are so remote and so poor that taking their bottle of oxygen from the hospital is going to kill them. You don't have to use the bottle of oxygen from the hospital.

Now the next thing that was brought up yesterday and today – and I really can't believe this – this discussion of pneumothorax and mediastinal emphysema. Look. Many, many people have gone in chambers with pneumothoraces. This is a way of getting rid of the pneumothorax. I'm going to promise you that breathing oxygen at 2 atmospheres if you've got a pneumothorax is a hell of a lot nicer than breathing air on the surface. And really, you know, even when I was back in the Flying Doctors service, if you wanted to get rid of a pneumothorax, what you did was you gave people oxygen. So you get rid of it in hours instead of days and weeks. So pneumothorax and mediastinal emphysema are not reasons for not putting people back under pressure or in the water, which is the same thing. And, in fact, I would much prefer to be treated for my pneumothorax under pressure onsite than to have someone attack me, attack my thorax, with a knife...

SIMON MITCHELL (interrupts): ...which is probably going to happen soon, I think Carl...

CARL EDMONDS: People have been questioning about whether the environments are going to have any influence. Well, look. Hell, OK, if they get their bends while they're diving at night, they're used to night diving as these fellows will be. If they got their bends while they were diving in cold water, they'll be able to protect themselves. We had no trouble using this treatment in the Antarctic.

The other thing is there's some idea that you're hanging off a rope as if you're dangling from a trapeze. This is nonsense. In the water, you're neutrally buoyant. Hell, you don't have to hold yourself there. But if you do want comfort – you know, on Thursday

Island, they actually used to put a chair at the end of the wharf and they'd just drop the chair down underwater and you could sit on it – you don't have to hang onto the rope for three hours.

So the last point I'll make is that this was originally developed as a way of preventing mild cases becoming severe while you were waiting for transport. Now, it is true that most of the cases end up being treated very adequately so you don't need the transport, but that doesn't stop you organizing it. And the whole concept of the underwater oxygen was to prevent a mild case from getting worse. So it's prevention as well as treatment. And also, by the way, in that last case, any comment I make must be made on the presumption that I would not be using a Table 6 under these conditions.

SIMON MITCHELL: What about this case, Carl, if I can draw your attention to that?

CARL EDMONDS: This case is obvious. You know? The guys know how to do it; let them do it. It'll clear up the symptoms very quickly. But if you leave it and wait for a couple of hours later or six hours or 12 hours, then, yes, you're going to have to keep putting them back in and giving treatment after treatment after treatment. Remember that the pearl divers and the abalone divers, if they get this sort of syndrome, they'll probably be diving tomorrow, because they treat themselves very rapidly. These guys can treat themselves rapidly; let them go ahead. They don't need a doctor to tell them what to do.

GEORGE MACRIS: Now this boat had no radio, so my question is if you're going to do in-water treatment, I guess it's going to be at the dockside [45 minutes after the dive]? I think it's noble to consider in-water treatment, but I would have dispatched that air ambulance and been in contact. I'm sure he's going to be oxygenated, hydrated, someone's going to respiratory excursions, listen to his apexes, maybe get a chest X-ray, and that air ambulance would be on its way. I would say with only three hours away and the ability to have copious amounts of oxygen and some type of medical support and hydration that I would opt to not put him in the water, use all your adjuvant therapy modalities, and get him to a chamber as soon as possible.

MICHAEL BENNETT: While not basically disagreeing with you, George, we're saying it's three hours flying from Auckland that's going to take six or seven hours to get there. I'm with Carl for some in-water recompression with these guys.

GEORGE MACRIS: But going back to what was up there, he began, as I recall, on oxygen. He had some improving symptoms.

DAVID DOOLETTE: No, we had him not improving on oxygen.

GEORGE MACRIS: OK. If he's not getting worse, I would continue the more conservative approach of waiting for adequate recompression therapy.

SIMON MITCHELL: Can I just ask if any of the few technical divers in this audience, if any one of them would like to make some comment about whether or not they would be keen to do this under these circumstances?

JERRY CHIA: I'll say that this sort of situation happens quite regularly – maybe not to the extent of this particular victim – and it's never reported. And also the profile of the diver does not fit a technical diver. But, yes, I think straight back in the water, definitely. No doubt about it. In the group of divers that I dive with, we don't have this sort of problem occurring regularly, but there's no reason not. The facilities are there. There is reasonable expertise to do it. And it's never reported.

GLENN HAWKINS: I think there are a couple of things. If they're on the boat, he came up, they'd have no hesitation in throwing him straight back in the water. If there's a delay of sort of an hour or so before we're considering putting him back in the water, you've got a whole pile of other issues coming up with inflammation. You're going to put a guy in the water who's going to be dehydrated, hard access to get him any more fluids into him in reality, and you're going to get him breathing for several hours on dry oxygen. So, I mean, this guy's going to come out of the water dehydrated to hell and probably a lot sicker.

JAMES FRANCIS: Could I just come back to this issue of pneumothorax? Pneumothorax is not a contraindication for compression; it's a contraindication for decompression. So putting somebody back under pressure – be it in the water or be it in the chamber – is not going to do them any serious harm. The question is, what happens when they're back under pressure, and how can you bring them back out again? If the pneumothorax seals off and you've got them on 100 percent O₂ and they're down at 9 meters, I agree with Carl. There should be no problem; you should be able to get them out. If it doesn't seal off, that is when you may have a problem. And if I had a pneumothorax and I was back under pressure, I'd be much happier in the chamber, where you can stop the decompression at any time, than in the water.

CATHY MEEHAN: I think in a situation like that with technical divers, you'll probably find he's already back in the water with part of the group while they're making the phone call.

CUAUHTEMOC SANCHEZ: There is no ideal solution in this case, because we don't have all the elements. Just deal with what you have and solve that problem; and then if you have a pneumothorax or a tension pneumothorax, you have a new problem, and you solve that problem. But your main problem is to treat this guy as quickly as you can with what is available. But the ideal [treatment] is something different.

CHRIS WACHHOLZ: First of all, it takes a lot longer to organize an evacuation than the time it takes to fly both ways. You have to put the bids out. You have to receive the bids. You have to choose the company and they have to find the crew and then the plane has to go. So a three-hour trip could end up being 12 hours. The second thing is it's not that in-water oxygen in this situation is going to work or not; it's the reliability of what you're hearing on the phone that you can trust that these people really can do it. And it's the same thing as relying on the examiner at the local clinic. And I don't believe that institutes like DAN, DDRC, or the DES are going to consistently be able to have confidence that these people are going to be able to do it.

DAVID DOOLETTE: Let's put this to a vote. The question is, these divers ask and seem willing to put this diver back in the water – say they know how to do it – would you say, "Yes," treat them in-water while you're organizing medevac if that's necessary, or "No," only treat them on the surface with oxygen while you're organizing medevac. And we will take some more comments during the vote.

JORDI DESOLA: Again, I comment based not on theory but in practice, in observation experience. We have all seen or heard of cases of in-water compression which resulted in the diver becoming worse, much worse than it was before. And, secondly, is the distance. If the transfer could be six hours instead of three, the result would be exactly the same.

MARK BROWN: As a member of the group of technical divers, here is some information for the rest of the group. The last line "they would want to recompress," it would actually be "very eager to recompress," as you were saying before around if he wasn't already back in the water. Second would be my comment on hydration. Most of us train during decompression training, etc., to rehydrate whether it's taking sports bottles or whatever. So the difficulty of rehydration while underwater for an hour or two isn't too much of an issue, especially on the rebreathers which is quite moist air. The third one would be that an hour, like Dr. Edmonds was saying, an hour in-water at 9 meters on oxygen, for a technical diver they don't even give that a second thought. As long as they're warm enough before they go back in.

FRED BOVE: If the surface first aid caused a resolution of symptoms, I guess my question would be, would there still be a compelling need to do in-water recompression if surface first aid resolved the symptoms?

SIMON MITCHELL: What do you think, Fred?

FRED BOVE: I think I'd leave them alone if surface first aid resolved the symptoms.

ALF BRUBAKK: Well, I think everybody would. I think this is a totally unrealistic question. First of all, I think that these guys would probably never call anybody. And I think one of the reasons why we see so little decompression sickness, or alleged decompression sickness, in technical divers is that they do this all the time without ever telling anybody. So I think the only thing that you'd get a situation like this is they could have called you and said, "Hey, we have this guy in the water and he's been in the water for an hour and he still has a bit of pain in his shoulder. Should we do something? Should we leave him there? What's your advice? What should we do when we get him up?" The more realistic question is, if you're not technical divers and you're sitting there and you have someone getting quite ill, what should you do then?

Secondly, the question about hydration. Everybody says how important that is. However, in all the studies that I know, no one has been able to show that dehydration is really a serious problem. Dehydration – I'm not saying that if you're seriously dehydrated – but you think you have to be very dehydrated, an unrealistic form of dehy-

dration, before you actually are able to measure that it will make the outcome worse. I mean, theoretically, I would expect that to make sense to be well hydrated; but I don't think the problem has this kind of magnitude.

DAVID DOOLETTE: I think we'll stop there and look at this vote, because we need to move on to the next problem. As far as using in-water oxygen treatment, we had six no's and 19 yeses.

Editorial note: Summary of key voted decisions. It must be noted that these decisions cannot be interpreted as "policy" arising from the workshop. They are valid only in respect of the present case of remote progressive neurological DCI. Nevertheless, they serve as an interesting indication of the position of a diverse panel of international diving medicine experts on these issues.

1. All voting Discussants agreed that this was a case of decompression illness.
2. The overwhelming majority of the voting discussants supported the use of a local recompression chamber capable of a USN Table 6 but whose maintenance and other characteristics were otherwise only vaguely known.
3. More than 75% of the voting discussants supported the use of in-water recompression on oxygen administered by an expert technical diving group.

Hypothetical Case of Evolving Mild DCI in a Remote Area

SIMON MITCHELL: This is a 25-year-old male, normally well – no known medical problems. A diver for six years; not very experienced. Fifty dives, deepest 40 meters. Trained to rescue diver level. Never had a diving-related illness and, again, has the DAN Master Plan insurance policy.

This time we're at a diving-oriented resort in the Solomon Islands. There's no landing strip and no medical facilities at the resort itself, but it's a one-hour boat trip away from the capital, Honiara, where there is a hospital of sorts and an airport. There's no hyperbaric chamber at all. The nearest one is Townsville – that's the nearest comprehensive unit – approximately a three-hour flight away.

The resort is technical diving-oriented. This diver is not a technical diver, as I pointed out, but there is a lot of technical diving that goes on here. They have lots of oxygen. They have full-face masks at the wharf for in-water oxygen recompression which occurs at this place quite frequently. The owner proclaims himself an expert at it. And a similar arrangement exists in Honiara itself.

We are at day four of a five-day stay. Fairly typical. This diver has done nine air dives to 13 to 40 meters over three days, so this is now the fourth day. All of these dives were essentially unremarkable. All profiles within the limits prescribed by an AirX dive computer. Some of them were close to the no-decompression limit, and they did do safety stops on all the dives. There were no no-decompression limit violations, no

rapid ascents, or other incidents. And so what this amounts to is a very typical picture. The last dive was a night dive finishing at 2130 the previous day. That dive was 16 meters for 45 minutes total, but it was within the limits of the computer. The diver went to bed tired but otherwise well at about 2230 without drinking any alcohol.

At 0730 on the fourth day, approximately 10 hours after that last night dive, the diver woke and felt unrested, unusually tired, had a mild headache, a mild ache about 3 out of 10 in his right elbow, and a perception at that time of vague tingling in the right hand which felt as though it was over the whole hand, not on any particular distribution. The tingling is now subsiding, and it's now 0930. The patient has attributed the tingling to sleeping on his arm. There are no other symptoms and no obvious organ system dysfunction to anyone who was looking or interacting with this diver. He's been on oxygen by demand valve for 30 minutes because he reported these symptoms to the dive operator, and they said, "You'd better breathe some oxygen." There's been little change; maybe a little bit of improvement, but that's highly subjective. They're worried it might be decompression illness. There's been no particular precipitant that would provide a more plausible explanation for the right elbow pain.

So the first step in our tree is to ask, is this decompression illness? And I've given you three options: yes, uncertain, or no. Is there anyone here who would say, "No," so that we could rule out decompression illness in this patient at this point? Nobody. So we're all going to be either yes or uncertain.

Just out of interest, how many would actually say – and I'll poll the whole room here – how many would actually say "Absolutely yes," this is decompression illness? There were a few saying yes. So we're either yes or uncertain. And I think it's fair to say that in a situation like this that moves us down the tree that you've got in front of you down the yes branch. We have to give it the benefit of the doubt at this point and move down the yes arm, and probably that should say yes or uncertain on that tree, I should think.

You need more information at this point before we get into it, because I know these questions will come up on the recompression required question. So the patient is taken to Honiara by boat. They're breathing oxygen still. And they're seen by a doctor at the hospital. The pain's now improved on oxygen to 2 out of 10 from 3 out of 10, so that's a pretty small and subjective improvement. The tingly is barely perceptible, but the patient says, "Well, I think I can feel it some of the time." The headache has improved, but it's still there mildly. And the patient still feels fatigued. The doctor can find no abnormal clinical findings on examination and the neurological examination, in particular, is normal.

It's now 16 hours after that last dive. The patient's been on oxygen for four hours. The symptom picture is as it was before, but improved slightly on oxygen. And we're still faced with this decision about whether it's decompression illness, so I'd say none of that information I've given you would have changed your views on it. It's probably still a "yes or unsure." Is anyone going to say "no?"

JOHN ROSS: So this guy is fetched up at the local emergency room effectively? And he's been seen by the doctor who works there, but there's an issue here that we see all the time. This doctor will probably not have got him off the trolley. So if you get these guys, you need to ask the doctor, "Have you had him walking? Can he do heel-toe walking? Have you tested his balance?" Because emergency room doctors don't like getting people off trolleys because the floor's dirty; there's other things going on. And it's a major issue, I think.

SIMON MITCHELL: I absolutely agree with John, and it's something that we have often had to do. Let's say that's been done and this doctor can find no abnormal clinical signs. So we're at "yes or unsure" to what we would probably call mild decompression illness. Now the question is, is recompression required? Now bear in mind, on the tree the option here is, if recompression is not required, we would provide adjuvant treatment.

CARL EDMONDS: I can't see why you'd even consider the possibility of recompression, because the man has now been well over six hours after his symptoms have developed. They're not getting worse. They're not progressing. He's got no major symptoms. You're giving him oxygen which is going to get rid of the bubble; it's just going to take a bit longer than if you put him under pressure and gave him oxygen. I don't even know that I'd bother putting him in a chamber if I had one near. I'd just use surface oxygen.

KLAUS TORP: Well, one comment you mentioned – he woke up with symptoms. So this is I think one part that that we see a lot is we basically have no idea when the symptoms came on, which may or may not be pertinent here. You mentioned that they do have in-water recompression in Honiara and a full-face mask. I would recompress him.

GEOFF BAYLISS: Going back a step in this patient, the thing that concerns me is we have these symptoms that have come on towards the end of his holiday. But we haven't had any information on what his normal level of activity is. I mean, is he an office worker who is not terribly active and here he's gone into a fairly active recreational pursuit? The reason I raise this as an issue is we may just be looking at a straight fatigue factor here. Those people quite often do have this group of symptoms that you outlined because they're not normally physically very active in their day-to-day work.

SIMON MITCHELL: I agree with you, but if I told you that he was normally a sedentary office worker, would that help you rule in or rule out decompression illness?

GEOFF BAYLISS: It would help me; it would broaden the diagnostic scope, and I would look at fatigue factors generally. And, as there hasn't been anything that has really focused on decompression sickness, apart from the fact he's been in the water but he's followed all the rules. I'm trying to keep a fairly wide-angle lens view of the management of this patient.

CATHY MEEHAN: This is a story that we see quite frequently [in Cairns]. And I think that my opinion's always been that if any symptom occurs after diving and there isn't any other plausible explanation, you have to assume that there is a possibility it could be DCI.

BILL HAMILTON: I'd like to expand on the concept of fatigue. And addressing also what Dr. Bayliss said, this diver woke up tired. That's inappropriate fatigue.

Inappropriate fatigue is a clear-cut symptom of subclinical decompression illness. I'm not a technical diver, Lord knows; but I see a lot of these guys. I send them out with decompression tables and they tell me what happens. They use their fatigue, their feeling of well-being – we called it constitution yesterday – as a major item in judging whether their decompression was adequate. The fact that they don't have any joint pain or tingling or rash or anything is secondary. Their major thermometer as to whether they've been properly decompressed is how well they feel. And that has to do with the fatigue and inappropriate fatigue. So we have to keep this as a symptom, not as a side issue.

PHIL BRYSON: We had a similar case, slightly worse, in the depths of Cornwall three months ago. We treated him on surface oxygen in Clarin Hospital down in Penzance in the southern tip of Cornwall. He did very well. The key thing was to follow him up. We did not treat him [with recompression]. He came to see us something like 24 hours later. We were on the phone to him roughly every six hours. He stayed overnight in the hospital on oxygen for a maximum of 10 hours and made continual and steady improvement. He was watched all the time to make sure that he didn't relapse or deteriorate, and he got his fluids, he got his oxygen, and did very well. He did not require recompression and did not get worse and saved a lot of money.

FRANS CRONJE: I think the issue depends on how you address the question "does he need" versus "would he benefit," because "does he need" versus "would he benefit" bespeaks the issue of availability, and I think that may influence your decision.

SIMON MITCHELL: Frans, before you leave the microphone, if I said to you, "Can you tell me your interpretation of 'does he need' at this point," what would you say?

FRANS CRONJE: How I would understand that is, "Would these symptoms resolve in the absence of recompression?" And my answer is, I believe they would. If the question is, "Do you think he would benefit from recompression?" I would say, yes, I think he will.

MR. PATKIN: Two things that I think are important to consider. One is, what is the likelihood of him getting worse or having any permanent impairments subsequently? And, second of all, what is the liability to the physicians for not treating him?

SIMON MITCHELL: Well, one of those issues was addressed yesterday. We had two presentations of relevance to that. One was Jake's presentation on the effect of delay to treatment, and one of them was David Elliott's. David, would you like to comment on the likelihood of this diver at this point going on to develop serious symptoms?

DAVID ELLIOTT: I entirely support the wait-and-see process, and I think what Phil has described is a perfect example of how it should be done. Things can still happen later. I'd just hold on the surface. On the balance of probabilities, which is a useful term with a lawyer present, I think he'll be OK.

SIMON MITCHELL: You would not at this point say, "Don't worry about it. Go away and enjoy your holiday"?

DAVID ELLIOTT: Oh, no way.

SIMON MITCHELL: You would keep your eye on him?

DAVID ELLIOTT: Absolutely, yes.

FRED BOVE: This is a very non-specific presentation, and I think if one were to talk to a whole group of divers who are on a diving trip and asked them specifically the questions about what this individual had, I think you'd find an awful lot of people recounting similar symptoms that either were diving or weren't diving. These are very, very common symptoms. So the question is, you take one person out of a picture with a ubiquitous set of symptoms and try to decide whether that's bubble disease or not, it's very difficult.

I would agree that if this is resolving and if you're uncertain about whether it's bubble disease or not and the symptoms are gone, I, for one, would not treat this individual, because I'm not sure what I'm treating. To me, again, it would be really important to try to understand how much of this is related to the person's environment, you know? Was it a poorly-conditioned individual who wasn't used to exercising, wasn't used to working all day long, and woke up tired because a lot of people wake up tired from that first couple of days of diving?

The other question I wanted to ask – and maybe Richard Moon could answer this – DAN was doing a survey of some diving medical programs just asking about these ubiquitous symptoms. I think Donna was doing that a while back. I don't know whether you guys have analyzed that data or not, but it would be really interesting to see some of that information. Do you recall whether it was collected? Because I think that would be the right way to do this. Take a whole group of divers and ask them across the board specifically what their feelings are – not symptoms, but feelings – to get an idea of how much of this is representative of the whole group or whether it's unique in one individual.

RICHARD MOON: Well, only to say that I haven't really looked at the data, and I wouldn't want to comment in the absence of Donna's input.

JAKE FREIBERGER: We don't have specific information [at DAN] on the distribution of symptoms in people who do not dive because that's what you need. You need a prior probability of having the tingling and minor pain that was described in this case. We have been collecting data only on people who dive, so we don't have that, but it

would be an excellent idea to do that. We were discussing this in the Decompression Diagnosis Symposium approximately three weeks ago, and one of the suggestions made was to apply one of the scoring systems – I believe it's the sandhog criteria – to people who have not been in the water. That way you would get a prior probability of developing symptoms such as these and would be able to adequately analyze the effect of diving isolated from the effect of the general distribution of these non-specific symptoms.

DAVID DOOLETTE: Regarding my diver health survey (a one-page questionnaire of symptoms that I use to evaluate outcome with diving), I've given it to non-divers, but all the divers involved complete it on days when they don't dive as well. So, I do have similar sort of data for that. It's very variable person to person, but you can identify a baseline within each person. You actually have to analyze from that baseline. But there are these symptoms reported. People do report them when they're not diving.

JAKE FREIBERGER: This is exactly true. When we do our flying after diving studies or any of the studies that involve the possibility decompression disease symptoms at DAN or at Duke, we always emphasize to the participants that they take a survey prior to undergoing the pressure exposure to self-survey the extent of any joint or muscle pains that they might have prior to the exposure. That way, we're able to subtract that from anything that would appear after the exposure, and it has considerably decreased the confusion around this issue.

SIMON MITCHELL: There's no question you're right about there being lots of these kinds of cases out there that probably never get reported, in divers and non-divers. But the reason this case has been presented is that divers do report these symptoms to us, and we have to make decisions about them. Those decisions are often difficult. That's why this case is here.

WILLMA PADILLA: We know that symptoms of decompression illness could improve by itself breathing or not breathing oxygen, could be stable, or could be progressing. But the problem is that we don't have a crystal ball. We don't know which patient will be which. If we have any doubts about if it's decompression or not, it's better to recompress.

SIMON MITCHELL: I think David Elliott's comment about watching this patient is very important in this context.

KARL HUGGINS: You might look at changing this to look at recompression "recommended" and then start bringing the patient into the decision-making process.

SIMON MITCHELL: That issue was addressed to some extent by Alison Drewry yesterday, who did bring up some very valid concerns about it. I'm actually a big fan of that approach, but there are some concerns about that. We may come back to that.

CATHY MEEHAN: I think you'll find that most of the divers at that resort all have the same symptoms; but the fact that that particular person actually felt that it was impor-

tant enough to sort of make a spectacle of himself or seek advice means that his symptoms are very relevant and need to be taken seriously.

SIMON MITCHELL: Let's move on with this clinical problem. The picture is of resolving mild elbow pain, resolving paraesthesia, mild headache and fatigue, and a normal clinical examination. The question we're asking ourselves is, "Is recompression required?" We're getting close to the point where I think we can take a vote on that.

The question you're asking here is not, "Does this person require some treatment or not?" It's just whether to recompress or not. If we say "no," it doesn't mean to say we're going to deny them any of the normal treatments; in fact, that's the next thing we will discuss, because that's what comes up on the tree. If you're not going to recompress, we have to then look at adjuvant treatment. Does anyone want to make any more comments on whether or not we recompress this patient prior to taking a vote on it?

RICHARD MOON: Could you clarify, Simon, whether the [word] "required" is in the context of this [overall geographic] situation or generally with mild elbow pain and parasthesia 16 hours after a dive?

SIMON MITCHELL: This is in the context of this isolated situation and this clinical history. You are on the end of the phone providing advice on this case. What would you substitute in there? Would "essential" be better?

RICHARD MOON: No, I don't think so, because I think we heard yesterday that the probability of a long-term adverse outcome from this, even if it is decompression illness, is virtually zero. The problem will resolve eventually within hours or days. The physical exam is normal, so we're not concerned about piano players or violin players and sensory problems of that sort. If you rephrase the question, "Will recompression accelerate the resolution of the symptoms?" then that's a valid question.

SIMON MITCHELL: I agree with that, but at some point, you're going to have to make a decision on this case, whether you recompress them or not.

RICHARD MOON: When you say "required" or "recommended," are you saying, "Should this patient be evacuated by air to a definitive recompression therapy?" Is that what you're asking?

SIMON MITCHELL: Ultimately, that will be the question. If you look at the tree, that would become the question if you decide not to recompress onsite. You are more or less committing yourself to some kind of evacuation further down the tree.

JAMES FRANCIS: There's just one extra word that needs to go in there, and that is "emergency" recompression. Are you going to treat this as an emergency recompression? Either put them back in the water or fly them as a matter of priority to a chamber.

SIMON MITCHELL: Well, no. Emergency compression is the next step. What you're saying is, take step two [of the decision tree] out completely. Just take it out and just say, "Is emergency recompression required?" But where then in your decision tree are you going to opt to not recompress at all? Because that seems to be the way a lot of you are going with this case.

MICHAEL BENNETT: I think the only problem we've got is a semantic one. I'm a little confused, as many of us are, with the use of the word "required." We're trying to decide whether you really mean, "Would I want to recompress this person?" which is a different thing from, "Is it absolutely necessary?" The nuances between the two would change my answer; and I see some nodding around. Unfortunately, I'm looking for a slightly different statement than, "Is it required?" Maybe, "Is it optimal?" Would that work?

SIMON MITCHELL: The problem with "optimal," at some point in this scenario, you have to decide whether this patient is going to be recompressed or not.

DAVID ELLIOTT: I've already answered this. I've put down, "Essential? No. A good idea? Yes." As both Phil and I and others have already said, wait and observe and have the plans there in case you need it. There's not a direct answer. It's a question of time of management. But you've got that option next.

SIMON MITCHELL: What about, "Recompression required at this point"?

CARL EDMONDS: Surely, this is being submitted to someone who is going to have to make advice on this particular case. Surely the question is, "Are you going to advise recompression in this case right now?"

SIMON MITCHELL: Yes. David's right. Everyone's jumping further down the tree. This tree takes you to that point, Carl. What we're trying to do is break it down into small steps. I think David's point is fair, I think by putting "now" there, you can say no. Then you go to adjuvant treatment and observe. That's what you're saying, isn't it? Is everybody happy with that? Does that satisfy everyone's concerns? OK. Well, let's try that then. Does anyone want to make any further comments about whether recompression is required for this patient now?

DEBBIE PASTEL: If we go with recompression required now and say no, you've got the next step would be efficacy of adjuvant treatments. I then think you would need a dotted line to non-urgent evacuation, because you're still got to have the option open to yourself, but at some point if he stabilizes but doesn't continue to improve or unexpectedly rarely deteriorates, then you need to have that option open to go back to evacuation.

SIMON MITCHELL: Yes. I agree with you, and we may need to put a line back from that box to Box 2 to reassess whether recompression is required now if there is deterioration. I agree with that. I must point out that this diagram isn't really supposed to form a template for universal management of decompression illness; it was more a

way of us thinking about the steps that we all take in making these decisions and identifying the issues that needed to be discussed in the papers yesterday. I think we came up with a reasonable program of discussion based on these decisions, but I can see the problem we're getting into here by making you follow this tree. It's now becoming semantically difficult at some points, and this is one of them. I think "Recompression required now?" is a reasonable question, but it conflicts with Step 3 [in the decision tree]. If you say yes, then the next step in this tree is "emergency recompression?" That is little different from "recompression required now?"

But let's vote on this. I think the conflict we're getting into here is whether we're trying to resolve this clinical problem, or whether we're trying to validate this tree. That's not really the point of the discussion. What I'd like to do is work through this case. If asking "recompression required now?" helps you answer this question, I think I'm happy to run with it.

DEBBIE PASTEL: The reason I brought that point up is because one of the concerns we're experiencing is that if we make it black and white and say yes/no anywhere on the decision tree, we feel like we've locked ourselves into that pathway. Whereas, if we can continue to use clinical judgment as we go along, it gives us the option of going back into the decision tree down a different route if in fact something unexpected happens.

SIMON MITCHELL: I have no problems with that. I think what I'll do at lunchtime is put in those pathways you suggest and make sure that everybody's happy with it. However, we've got to have a point where we can actually opt not to recompress. That's the function of this point in the decision tree. We don't want to word it so that it takes you away from that option. We've got to have a point where you can say, "Look, this case is not one that we need to recompress."

CHRIS WACHHOLZ: Would it help if instead of, "Recompress now: yes or no?" that we say, "Adjunctive therapy and monitor?"

SIMON MITCHELL: Well, in fact, you'll see on my next slide if we go down the "no" route is oxygen, fluids, other drugs, observation, and with the implication of observation being that you would then alter your management if the patient deteriorated or something happened that you weren't expecting. If things went according to plan, you would repatriate them by whatever means was appropriate. That was something we were going to discuss on the next slide. The problem is, we're all trying to jump too far down [the decision tree]. We're not breaking these decisions down into the smaller chunks that we've intended them to be.

PETER MUELLER: Simon, I think [you risk] getting off the track, which you have been following nicely so far. The ones who are getting called, those are all physicians. We either prescribe hyperbaric oxygen or we don't. The question for me as a physician is, "Do I prescribe it in this case or not?" The question is perfectly good as is. But we should have a contingency plan. Well, we always have that available.

SIMON MITCHELL: Yes. I suppose "Recompression required at this point" is fair. "Now" is kind of a time imperative thing. In fact, "recompression indicated" is a better way of putting it.

PHIL BRYSON: Can I take sort of a slightly different approach here? In the case that I dealt with, recompression wasn't potentially indicated. He was miles away from our chamber. If he had been next door to us in Plymouth Casualty, I would have treated him. This is the same for you guys in the South Pacific. I would say recompression is indicated, but the logistics of transfer, the response to surface oxygen and fluids, and everything else that goes around the case shows that recompression now is not required. We can adopt a wait-and-see policy. That's better than "indicated" because, yes, I think we'd all say if this guy was right next to us, let's get him to our chamber. We would probably put him in.

But the difference we've got here is the scenario you have. Peter's quite right. We make a simple decision; it's semantics. Yes or no? I would say absolutely not. We wouldn't fly him thousands of miles, put him in an ambulance for thousands of miles. We see he was doing well there and monitor him. If he needs to do something different, then we'd change that, and your arrows on your decision tree would extend as you said.

FRANS CRONJE: Next attempt. "Recompression essential" would force the decision whether or not at that point you would go towards adjuvants or whether you would follow the tree down of scenarios of emergency, in-water, etc. But it would remove the ambiguity about "required," which is what we're all getting hung up on. We would need something, a qualifier, that will force a decision that the patient's outcome will be dependent on receiving recompression at some time or another or not. "Essential" would commit yes or no.

SIMON MITCHELL: I like "essential." Does anyone have any major objections to "essential" as opposed to "indicated" in the context?

UNIDENTIFIED: It's clearer.

SIMON MITCHELL: "Essential" was clearer? Yes, I think you're right.

DAVID SMART: I also like Frans's modification, but I'm just querying the way the tree's set up, because when you're dealing with remote area calls, the decision would precede this one which would be, "Do we evacuate to another recompression facility or do we leave the patient onsite?"

SIMON MITCHELL: I disagree, David. I think that before you decide to evacuate for recompression, you have to decide whether it's required or essential. That's what this does. You work your way down the tree. It's all there.

DAVID SMART: Well, the evacuation is based on the clinical urgency of the situation.

SIMON MITCHELL: Agreed, but the tree gives a logical structure to a process that you might mentally traverse in two picoseconds. In a serious case you would be thinking, "This is a guy with spinal DCI." Yes, recompression is essential. Yes, emergency recompression is required. Is it available onsite? No, so we have to have air ambulance evacuation. So the tree does it.

MICHAEL LANG: Simon and David, I just want to congratulate you on a very difficult job you're trying to do. If you don't stick with the plan that you set out in this decision tree, you're going to invalidate what we just did for the severe case, and you're going to want to compare the two. So stick with it. What you're trying to do is get them to say yes or no. You can't be a little bit pregnant. Either you're pregnant or you're not. That's what we want to find out here.

SIMON MITCHELL: I think "essential" is still a good modification. I'm still happier with that.

CATHY MEEHAN: I think we're talking about mild symptoms, mild decompression illness, so saying recompression is essential or an emergency is probably down the wrong track. We should say, "Would they benefit from recompression?"

SEVERAL: No.

SIMON MITCHELL: No, you can't say "benefit," Cathy, because they will benefit. You've got to have an option in here that allows you to say no. We're faced with trying to decide whether it is essential to spend \$50,000 on a Lear jet to evacuate a headache, a tingling hand, and a sore elbow from this place to a place where they might benefit from recompression. This is the decision we're trying to make. What you're looking at is a tree for ideal management. I'm not. I'm looking for a tree for pragmatic remote management. The problem with the argument for "benefit" is that it would become a meaningless point in the tree, because it would almost never be no. I mean, if someone's got decompression illness, they're almost always going to benefit from recompression if you can provide it.

RICHARD MOON: This argument is pointing out that in real life, these decisions carry along with them a large amount of contextual baggage. In this particular case, the baggage overwhelms the medical decision or the physiologic decision, if you like. There are really two types of questions. One is the real-life choice, in which case you're not asking that question. What you're asking is, which of the following four or five options are you going to choose? However, if you ask the question that you've got up there, it's a medical prognosis question. If you make that clear, I think you're doing fine.

SIMON MITCHELL: Yes. I think it can actually be both; but if you want it to be the second one, Richard, we'll make it the second one. I don't actually see that there's a huge distinction between the two, provided you take the time to go down the rest of the tree and make sure that you understand what we're doing further down the track. I think we should leave it as "essential" and let us work through this case and see how it pans out.

Again, to qualify this tree; we're not going to be publishing this as the UHMS version of "How to Manage Remote DCI." This tree was a template for approaching the discussion and for deciding on the topics for yesterday's papers. What we're trying to come out of this workshop with is the consensus decisions that are going to be made this afternoon, and this tree isn't really part of that. It's helped us discuss it, but it's not really part of it.

BILL HAMILTON: May I try to summarize and offer a couple of new words? We're all in agreement that this patient would benefit from treatment, from being repressurized, and given oxygen under pressure. There's no question about that. The issue is, is it worth it in this situation? That's really what we're trying to decide. Is it worth it? Recompression: is it worth it? I didn't say also that if we don't treat, the patient is not going to deteriorate. The patient will eventually get well. So the question is, "Is it worth it to go to the trouble of doing the recompression at this point?"

GEOFF BAYLISS: Yes, just following on from what Bill has said and keeping the wide-angle lens view in perspective, I think we really need to accept – and this is what's coming through to me in the discussion – is that different doctors are going to treat the same case in different ways with a very satisfactory outcome. We are trying to set up guidelines, and I think guidelines are very useful, but they are just that. They're guidelines, as you yourself have said, Simon.

ED KAY: I wanted to agree with Bill that this treatment option here is not essential, and it changed. When you had it as "indicated," then my vote was yes. I thought that it was a case that could be treated, because it was indicated; but many of these cases get better on their own with adjuvant therapy, and so changing it to "essential" turned my vote to no.

FRED BOVE: I'd like to disagree with Bill Hamilton in the sense that I'm not sure we all agree that this was gas bubble disease. I think there's a significant degree of uncertainty that this is gas bubble disease, and that's weighing into the decision process here. I don't have a problem with saying, "if in doubt, treat," because that's the way we've been trained. But in this situation where the option to treat is so difficult, you need to bring in the uncertainty of whether this is truly gas bubble disease or not. If there's a significant amount of uncertainty, it makes the decision to not treat a little bit easier. You can find very similar pictures in many, many people who have never been diving before who are going on vacation sailing. It's a very common symptom complex in non-divers. I don't know for sure whether I would be convinced that this was gas bubble disease, and that alters the management of the case. I'm not saying it isn't. I'm just saying that you need to build in that uncertainty into the decision-making process, because this is a very non-specific symptom picture and common in many, many people.

SIMON MITCHELL: We need to move on. Let me put a question to you. Would you be happy if we leave this as "recompression essential" and put an arrow from the "no" / adjuvants option back to the Box 2 ("recompression essential") with a label on that

arrow saying, "on the basis of review or monitoring," which gives you the option of going back to reviewing whether recompression is "essential" in the case of a relapsing or deteriorating patient?

All right, that's what we'll do. That's the context in which we're going to run this vote. Voting crew, what we want to know is, under those circumstances where the "no" option means that you're going to give adjuvants and monitor and possibly modify your response on the basis of what happens over the next 24 hours, we want you to vote for whether recompression is essential at this point. Yes or no?

Editorial Note: There is a unanimous vote that recompression is not essential.

SIMON MITCHELL: That was the decision I expected, and it doesn't preclude us from changing that response if things change. OK, let's go to the next slide. Here is the situation we now find ourselves in. We're in Honiara. We're in a small peripheral hospital where there is oxygen, fluids, and probably the other drugs that we would want to give. We can observe this patient and then we'll be faced with repatriating him. I invite comments on adjuvant treatment. The things I'm interested in are an oxygen regimen for this patient, whether or not you would give other drugs, and how long we should keep him under observation. Also, any comments on what we should do if these symptoms don't resolve, and how long we should wait for symptoms to resolve before we do something else about it.

FRED BOVE: The first thing that you might want to do is give him some ibuprofen, because that'll get rid of all his symptoms. Then you've got your problem solved altogether. It may be that that's the right answer because if he's got a local elbow injury, the ibuprofen will take care of it. It sounds like the parasthesias are going away and nobody's quite sure, because isolated hand distribution of paresthesia is a very bizarre presentation. I would opt to give him intermittent oxygen for another few hours. By then, it would be 24 hours after the dive. Give him some non-steroidals, let him go back to his normal day having a meal and doing whatever else he wants to do. Then the question about repatriation, because most of these folks are on a dive vacation, they want to go back to diving.

I might not even tell them not to dive. If another day goes by and the ibuprofen works and the oxygen is finished and the symptoms are gone, it's pretty hard to tell them not to dive again. I'd almost even opt to say, "Just go back and finish your week."

MICHAEL BENNETT: I'd like to agree, Fred, with what you've said but add that, in my experience, many of these divers become hyper-vigilant. My emphasis in my discussions with them and the people who are looking after them would be to try and get some realism into the situation and point out exactly the kind of things that Fred was saying. It's very important to get that person back to a more or less normal holiday pattern, though maybe not to get off his face [drunk] every night, and maybe not return to diving if you can persuade him. Normalize his life and try to avoid that hyper-vigilance that I'm sure many of us have seen.

EDWIN LOW: I would probably do the same thing except for the non-steroidals because, in this case, there is some uncertainty to the diagnosis still. If you do give a non-steroidal, you'll be masking the pain for maybe six hours. By the time it comes back, that might be into the night. I would probably, since it's only a 3 out of 10, which is not very severe, leave him be and see how he is the next day or until the observation period is over.

SIMON MITCHELL: What specifically do you see is the problem with masking the pain in musculoskeletal decompression illness?

EDWIN LOW: I think the thing about it is, the moment he gets worse – let's say it becomes a 5 out of 10 – at least I'll know early rather than have to wait until after the effects of the non-steroidals.

FRED BOVE: In our state and in a lot of states in the United States, we're not allowed to let people live with pain. We're supposed to treat pain. There are laws out there now when we do a physical exam or history, we have to mark off whether the patient has pain and what the degree is. We're obligated not to let a patient continue with pain. I'm sort of used to doing something to relieve pain. Even with masking, the non-steroidals last four to five hours. You could stop them and see what's going on in between if you needed to.

JOHN LIPPMANN: The problem I have is not with giving the oxygen. That's great, and we see it all the time in the field, and it's not necessarily with the non-steroidals. If the symptoms do abate, the advice on whether or not they can go diving again causes concern because, not uncommonly, we've come across people who have mild symptoms that could be DCI, breathe oxygen, symptoms go, and the next day they go diving, and they come up with more symptoms. That is where I think it gets a bit tricky about whether you advise them to get on with their normal holiday. I would suggest they do not return to diving during the holiday.

FRANS CRONJE: Remember that our working diagnosis at this stage is, in fact, decompression illness, and we have determined that it is non-essential to recompress. It's not about masking symptoms. We accept provisionally that they are indeed symptoms of decompression illness, and we're actively treating them. Therefore, we shouldn't continue managing this person as if he didn't have decompression illness and allow them back to diving. He should still be managed as a case of decompression illness unless we refute the diagnosis and follow a different path of the tree.

DAVID GRIFFITHS: Simon, you asked if the oxygen regime needs to be considered. I'm assuming that 100 percent oxygen has been given up until this time with minimal air breaks. If that is so, I would agree that you need to at this stage consider intermittent oxygen, but up until this point, I would be very much in favor of true 100 percent oxygen with breaks only to drink, communicate, and eat food, and use the toilet.

SIMON MITCHELL: Let's say we're at 16 hours and we're going to go out to 24 hours, David. What intermittent regimen would you recommend?

DAVID GRIFFITHS: Well, if the diver has not yet developed any respiratory symptoms, I think you probably need to give them something on the order of two hours on and perhaps half an hour off – just a limited period off. This will depend to some extent on how much oxygen you have available or whether you have an oxygen concentrator which is unlikely to give you 100 percent.

JOHN ROSS: You're going to give this guy oxygen, fluids and non-steroidals and probably everything's going to settle down, and you're going to want him to go away. The information you've got to give him now is that when the non-steroidals wear off, he has not had another episode of acute decompression sickness. I've found that these people come to you every six hours saying "I've got the bends again." What kind of regime for non-steroidals are you going to put this guy on? That's more important than the oxygen regime, because you're going to stop that quite soon.

ED KAY: Continuing on the non-steroidal theme for a moment, aspirin with its anti-platelet effect could potentially convert a non-hemorrhagic problem into a bleed. Is there any opinion on whether aspirin should be included in the anti-inflammatory regimen?

RICHARD MOON: Well, using a non-specific COX inhibitor like ibuprofen has about the same effect on platelets as aspirin does. I can only answer the question in that only certain types of decompression illness are associated with hemorrhagic components. For example, frank spinal cord bends or inner ear bends, and in this case, we have neither one. I don't know what the effect of aspirin or ibuprofen are on spinal cord hemorrhage, however, in the setting of major head injury, stroke, or hemorrhagic stroke where there is leg weakness and, therefore, concern for deep vein thrombosis. Doctors who treat such patients don't have any hesitation in using a low molecular weight heparin. I think probably the risk of hemorrhage using aspirin or ibuprofen is probably overstated in decompression illness.

SIMON MITCHELL: If you had a choice of aspirin or ibuprofen, which would you choose, Richard?

RICHARD MOON: I would choose ibuprofen on the basis of your and Mike's study on COX inhibition, but arguably, they would have similar effect.

Editorial notes: A short period of discussion at the end of this session was lost from the recording and therefore the transcript.

Summary of Key Voted Decisions. It must be noted that these decisions cannot be interpreted as "policy" arising from the workshop. They are valid only in respect of the present case of remote static mild DCI. Nevertheless, they serve as an interesting indication of the position of a diverse panel of international diving medicine experts on these issues.

All voting discussants agreed that recompression was not essential in this equivocal case of mild remitting musculoskeletal, neurological and constitutional DCI.

Modification of the Decision Tree. The modifications to the decision tree (originally presented in Figure 1 of the Introduction paper) that were proposed and accepted in the above discussion are incorporated and presented below. In relation to a point made by Dr Edmonds in the severe case discussion, it is tacitly accepted that any diver suspected of having DCI ("yes or unsure" at decision point 1) will be offered standard first aid management for DCI appropriate to the level of severity. For clarity and simplicity, this has not been included on the tree. In this regard, the reader is reminded that this tree was generated to give structure to the discussions in this workshop rather than as a template for definitive management of DCI.

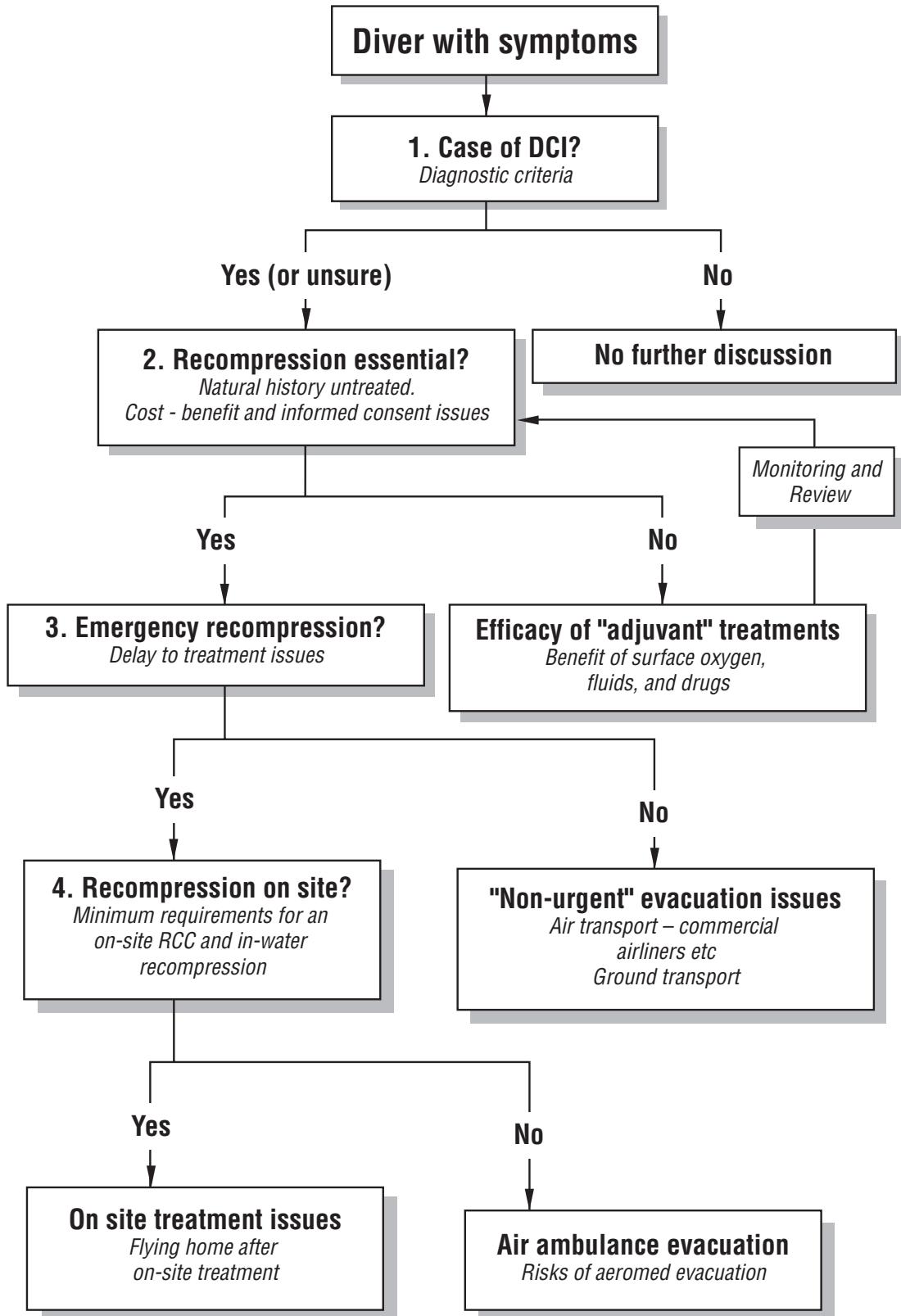


Figure 1. Updated decision tree.

THE LAWYER'S VIEW ON REMOTE MANAGEMENT OF MILD DCI

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I am an avid diver. My wife dives, and my three kids started diving at 12, 12 and 10 years of age. We dive everywhere. It's my job, it's our love, and I care a lot about the industry and about making it better. What I've heard so far in this workshop is a first step toward solving a problem. I hope I can contribute to that effort.

I've been a lawyer for 30 years, and almost all of it has been in water sports. Our firm has focused almost exclusively on diving cases since 1985. We've defended recreational, commercial and technical diving. I've lectured DEMA (Diving Equipment and Marketing Association) about all aspects of risk management, and served on its Board of Directors for five years.

I've tried to figure out what happened in 2,500 to 3,000 dive accidents – some of them horrible, some of them phony – and I've developed a healthy cynicism about dive claims. Many cost a fortune, and they are a reality we must deal with. I'm going to talk about how we manage these accidents and pay for the insurance that covers them within the American legal system. Here are some examples of diving lawsuits.

1) A diver claimed the inflator on his buoyancy compensator fell apart and bubbles spewed out from everywhere. (In reality, only the oral inflator assembly was missing, so there was no place for bubbles to come from.) He claimed that he panicked when he saw the bubbles, dropped his weight belt, and ascended from 24 feet (7 meters) after a 10-minute dive. When I deposed him, I asked what symptoms he had. He replied he was tired and scared, nothing else. Our diving medicine consultant concluded that this wasn't gas embolism.

Six months later, the diver added a page and a half of symptoms to his deposition that included paralysis in his arms and legs, black and white vision, and double vision. He said he didn't remember these symptoms during the first deposition because he was brain damaged. When the diving consultant reviewed the second deposition, he noted that a third of the new symptoms were consistent with gas embolism while the other two-thirds were consistent with Type II decompression sickness, which you generally don't get in 24 feet of water for 10 minutes. The diver went to see another doctor and finally made his symptoms consistent with gas embolism. That's the way he presented his injury in court.

2) A current case involves a student diver who spent 30 minutes at 40 feet (12 meters) followed by an hour on the surface. Five to 10 minutes into a second dive at 28 feet (8.5 meters), he claimed he ran out of air and ascended. Back on the boat, he stomped around, mad as hell because his tank was empty. He was apparently asymptomatic when he went to the dive shop where they told him to go to the chamber if he had any

symptoms. He began to get symptoms – tingling, numbness and more – so off he went to a chamber where they diagnosed Type II decompression sickness, treated him, and charged him \$15,000.

The diver filed a lawsuit against the instructor, training agency and dive store asking for lots of money. My guess is he'll try to settle for \$150-200,000. There's nothing wrong with him. The only medical records I've seen are from the first day of treatment where the chamber said his symptoms seemed to resolve. He claims residual injury and says he no longer can play the guitar.

Many of the claims we get are not medically logical. This diver did not have Type II decompression sickness after these shallow dives, but explaining this to a jury is expensive, and insurance companies often settle because trials cost too much. "Do we want to fight this? We should give this guy a couple of hundred grand for his DCS because it's clear he wasn't recompressed." This perpetuates the next case.

I recall a motor car company that discovered a rear collision in one of their car models could cause the gas tank to explode and the passengers to burn up. A company memo presented in court concluded it would cost less to let a few cars burn than to pay \$20 million to recall all the cars. The punitive damages were about \$100 million. That's not the kind of cost-benefit analysis that U.S. courts like to see a company make.

Care is required to avoid appearances of this sort. Someone said earlier, I might testify, "We didn't treat this person because we didn't want to pay overtime to our operators and because I was on the back nine and having a great day." Bad answer. Was the result of the treatment the same? Sure it was, but the injured diver's lawyer will tell you, "My client was writhing on the ground outside the chamber while the diving doctor was on the golf course." They will play it up, and they do play it up. And it sells.

There was some discussion about divers in Malaysia who harvested trees underwater. These divers are very different from people on liveaboards (generally Americans) who have lots of money and are very litigious. If they have a problem, they expect someone to pay for it. They bought insurance for evacuation. They're not going say, "Well, OK, it'll resolve." They'll say, "I want my one atmosphere plane. I paid for that insurance. It's bad faith if you don't fly me out of here." A hotline doctor can't say, "Hey, shut up, you're going to get well." The client's lawyer will reply, "Now my poor client can't play the piano."

We're not dealing with medical issues, we're dealing with perception. People will say anything in a trial to get money. It doesn't matter if the symptoms are medically inconsistent. Their point is, "They did it to me. They didn't give me the treatment I needed. Here's the book. You show me where it says you don't need to treat DCI."

If you wait 12 hours to decide whether to transport an injured diver, the plaintiff's lawyers, who know the current diving medical literature says to evacuate someone

with DCI immediately, will ask you, "Why didn't you evacuate at once?" You will answer, "Well, it was mild." "He didn't get better, he got worse," the lawyer will say. "He has to live with this. You don't."

Fortunately, the courts often accept waivers as acknowledgement of obvious risk, and we use them to great advantage, even in the states that don't recognize a complete liability release. When a diver signs a statement that he understands scuba diving can kill him and then he dies, a jury will often hold him responsible. This is important in defending cases where somebody has elected not to buy insurance or to buy insurance with limited coverage.

When we discussed the decision tree in the Introductory session (Figure 1, Introduction paper) and the examples of remote DCI, I wondered who would be the first doctor to say a diver with symptoms that might be mild DCI didn't need recompression? This doctor is likely to be asked by a lawyer why his client wasn't recompressed when all the literature says that recompression is the treatment for DCI? His poor client was an accountant making \$130,000 a year, but now he is disabled, can't think, can't work his adding machine, and wants lots of money. Until the diving medical literature says different, there is no good answer in court.

You WILL be second-guessed. That's what the American legal system is all about. Monday morning quarterbacking is the tradition. They will find something wrong with what you did. You will have to justify what you did and how you did it. "Isn't Bennett & Elliott the definitive text on treatment? Doesn't it say, 'Get thee to a chamber?' You didn't do that, did you?" "No," you say, "because it wasn't serious." A simple "no" is the answer they want, because it's hard to explain. You are in trouble.

Right now, the literature cites recompression as the only treatment for DCI. If we're going to conclude that not all people with mild symptoms of DCI need to be recompressed, we must establish and publish a medical basis that is defensible in court. The published proceedings of this workshop could provide that support. The idea is not defensible without documented support in the literature. The next step would be to involve the dive training agencies so they begin to teach new divers that not every mild symptom consistent with DCI need be treated in a chamber.

The other problem is that it is ethically impossible to run a study in which some divers with mild DCI are treated in a chamber while others in the group are deliberately not treated so the end results can be compared. Instead, you are limited to examining cases where divers with mild DCI are not treated or are treated after long delays because of circumstance (refused treatment, transport or functioning chamber unavailable, etc.). These outcomes have to be studied after the fact. Based on the evidence presented here, however, it seems that chamber treatment for mild DCI usually had little effect on the outcome after a certain delay.

It gets the attention of diving insurers when it costs \$20,000 to fly a person with a sore elbow out of a remote location. Maybe insurance will need to cost more for diving in remote locations. Many divers are knowledgeable people, particularly tech divers who understand gas management and frequently do in-water recompression. Perhaps there should be separate levels of insurance for decompression illness. Mild DCI might have limited coverage with full coverage for serious DCI.

In summary, while more data are certainly needed, the available data seem to support the conclusion that symptoms consistent with mild decompression illness will resolve without recompression. This concept needs to be in the literature, and the training agencies need to start teaching it to new divers. If divers understand that recompression is not necessarily mandatory in mild cases of DCI, the decision not to recompress will be easier to defend in court. Until support for a decision not to recompress is published, a decision not to recommend recompression will be difficult to defend. This conference has been an important step to this end and is very good for the diving industry.

DISCUSSION

SIMON MITCHELL: You made reference many times to getting these opinions and these data out into the literature. What you see here in front of you are two, three, or four rows of some of what we think are the best brains in this business. There's more of them out there in the general audience as well. They've all contributed to this workshop which will be published as a proceedings. When expert contemporary testimony at workshops like these get published and endorsed by organizations like UHMS, this might take precedence over the earlier literature. I think we are taking the correct first steps at this workshop.

GEOFF BAYLISS: We have very similar issues on this side of the Pacific. One of your strong messages is the need to operate within the legal framework of the jurisdiction where you're diving. Telemedicine is making this a worldwide issue. In Sydney, we have at this moment a teleradiology service where films can be beamed from anywhere to U.S.A. and then back to Australia for a radiologist to read because he's in his normal daytime cycle. He sends the report back to the U.S.A. which sends it back to the parent country, which could be Indonesia, Thailand, Southeast Asia, or anywhere. This is creating an issue for our legal people, who ask, who has the responsibility for decision-making? I know I should never ask a lawyer a question like this without his legal library behind him, but I'm interested in your thoughts as to where the jurisdiction lies.

RICK LESSER: Jurisdiction is a whole different seminar, but for the most part, Americans who go overseas and get hurt in remote locations tend to sue back in the United States because juries there tend to give them more money. Because they have a tough time bringing in people from distant lands just because of the jurisdiction, they don't go after the doctor who read the film by CD-ROM in Thailand who they will also

claim may be an agent of the dive shop who sent him there. They sue the dive shop and say, "You sent me out to this resort. They didn't have any money. They didn't know what they were doing." They always look for the deepest pockets. In another case, the same lawyers who represented the guy I referred to who ran out of air and can't play guitar filed a different lawsuit for someone who hurt his ears diving. They first sued the dive boat and, when they didn't have any insurance or money, sued the dive instructor, but the instructor had quit instructing and no longer had insurance. They wound up suing the training agency just to get at somebody who had money. They'll go where the money is and say, "Well, that person was really working for you roundabout."

DAVID ELLIOTT: When the North Sea opened up, I think a lot of us Brit doctors were concerned about the number of American divers who might go home and sue under the Jones Act. The official reply was, "Don't worry, you Brit doctors don't have enough money to bother about."

RICK LESSER: No, but the diving companies do.

DAVID ELLIOTT: My question relates to a phone call in the middle of the night from a diver who had a problem somewhere in the southern hemisphere. I was given the diagnosis by a local doctor and was asked about treatment facilities. I had no knowledge of the competency of that doctor or of the chamber. I give my advice that, "This should be done and that should be done." But, of course, I do not feel that I have responsibility for what actually happens in that remote part of the world. What are your comments on that potential liability?

RICK LESSER: I think they're going to have a hard time tracking you down and suing you there.

DAVID ELLIOTT: Well, that's reassuring, but as an awful lot of people are hotline doctors, we need to have some sort of caveat that's rather like fitness-to-dive, "I know of no reason why this person should not dive at this moment." Don't say, "You're fit to dive for the next year."

RICK LESSER: A good way to do it is you send back by fax or email a disclaimer saying, "It's based on the information that you have here."

DAVID ELLIOTT: How much do you charge for writing a disclaimer that we can all have?

RICK LESSER: A lot!

CHRIS WACHHOLZ: Rick, thanks for coming all this way, being one of the few people that didn't have to already be here. You came on your own time to help us, and we really appreciate that. Two of your suggestions – changing the literature and changing expectations – are very long-term strategies.

RICK LESSER: True.

CHRIS WACHHOLZ: First, what research areas to improve the literature would you suggest? Second, what kinds of mistakes in documentation do on-call people typically make? How would you advise on-call physicians and on-call staff to avoid mistakes or do better?

RICK LESSER: As to the first, I think distributing the proceedings of this workshop as fast and broadly as possible pretty much gets that ball rolling. DAN is in a perfect position to get it out and say to the training agencies – there ain't that many of 'em – "Guys, this is important stuff. Let's start putting it into your open water training books. Let's start 'em off with the understanding that not all mild DCI may need recompression. It's gonna make your life easier. It's gonna make your insurance cheaper." That'll get their attention.

CHRIS WACHHOLZ: I meant research for the diving medical literature. What areas of research would enhance our knowledge that you could use to defend us?

RICK LESSER: This seminar. Am I missing your question?

CHRIS WACHHOLZ: I think yes. What would be the first priority, more information on delay to recompression, for example?

RICK LESSER: I think the key here is a decision not to recompress. Unfortunately, we've shown that no one knows how important delay is. That's the problem. Is it gonna make a difference? We don't think so, but there are statistical outliers that the lawyers will always find and say, "Well, isn't it true that Dr. Elliott had this guy with mild symptoms and, all of a sudden, a month later, he's in the chamber and can't walk?" They always will line up with the odd one. The traditional literature holds that delay is a bad thing, and I don't think I heard anything here that really changes that too much. At the same time, I have heard that maybe not all DCI needs recompression. That's the most important observation.

CHRIS WACHHOLZ: OK. Perhaps you can give that some thought for the paper you're going to provide for the proceedings. What about documentation mistakes or mistakes on the telephone?

RICK LESSER: I think you can do it by way of caveats when you're on the phone. You might also have a prerecorded message that says, "This information is based on current knowledge. New knowledge might change this information." That needs to go into everything – emails, faxes, etc. You've got to qualify it by saying it is a recommendation based on present knowledge. Generally, that'll be right.

FRED BOVE: There's a lot of telephone and email banter among experts in responding to people who ask questions. I heard you say that putting disclaimers in the emails and telephone conversations is a reasonable thing to do. Another question is, where does the good Samaritan concept fit into answering a phone call from a sick diver asking for help?

RICK LESSER: I think it varies from state to state, but I don't even want to opine on that, because I just don't know.

ALF BRUBAKK: Well, I come from a country where the lawyers aren't as smart as the American lawyers yet, so we have few problems like this, but I'm a bit confused about how far my responsibilities go in answering questions. I ask this because I happened to be a passenger on a flight from Houston to London where someone had a cerebral hemorrhage. We landed in London, and he was put in a bed with nothing done for him. The man later sued. I was standing in the middle of this saying, "Why didn't you make sure that the emergency service in London put this guy in the right hospital?" It didn't even cross my mind that I should have done that. When I recommend that he should go to a hospital and be treated, is it my responsibility to make sure that that hospital actually knows what they're doing? How far do you have to go? It is very difficult to make a general statement to say, "Decompression sickness." Now, we used to say, "Recompression with oxygen is the primary way that we treat decompression sickness, period." It's very difficult to say, "Well, in some cases, recompression is not needed," because that's a judgment. The problem is that judgment should be backed up by literature and experience. It would be very difficult to get a clear-cut legal case.

RICK LESSER: I think your plane flight is the quintessential good Samaritan where you're on board. "Is there a doctor on board? Come help out." You're not stepping into any liability.

CAROLINE FIFE: I'm protected because I'm a university physician, but I have been asked to do some telemedicine outside of my university practice and found I was completely unable to get medical liability insurance for any activity that didn't involve physically seeing a patient. That can be a real issue in the United States. You're basically naked unless you're covered through another institution.

RICK LESSER: Or you pay the price for the insurance.

CAROLINE FIFE: Exactly. If you can find the insurance, which you can't. I've been asked many times after I've treated the patient to sign a form that says, "They're now released to return to diving." It may be someone who's had a significant neurologic event and is now normal by exam, or it may be a minor issue. What are your thoughts are on our liability when we sign the form that says, "Yep, you're OK. Go for it."?

RICK LESSER: You got it. You're on. You're signing 'em off. Here's an egregious example. A first-time diver weighed 350 pounds. He had sky-high blood pressure. He was taking every medication. He was a closet alcoholic. The doctor said, "He can go scuba diving. No problem." The guy goes out, swims out on a lake and dies from a heart attack. They sued the doctor and collected because he did nothing to check him out. On the other hand, I've seen trials where doctors had approved people to dive, and because juries tend to like doctors, they said, "Well, the guy was going scuba diving. You know? He knew what he was doing. There's risk there, and we won't blame the doctor because he died." You've got something on your side. You also should do a

standard physical exam, such as the PADI or RSTC form. In the case I described, the doctor had signed him off saying, "Well, he wanted to go diving. I thought it was good for his psyche." The doctor never looked at him. It also depends on what the guy dies from.

KLAUS TORP: How big of a problem are those minor symptoms that become blown out of proportion? How many lawsuits do you have compared to the millions of divers that we have and the thousands that we treat and that don't resort to litigation?

RICK LESSER: Well, first, I think that it is much more of a DAN / Chris Wachholz problem to discuss, but it makes the insurance unaffordable because of the potential for everybody with a minor problem getting a \$20,000 evacuation. So the people who really need it can't buy it.

It's relatively rare. Right now, the protocol is to recompress them. Should we do a change on that and say, "Guess what? Minor DCI, we're not gonna put 'em in a chamber."? I think you will see more litigation. Opportunistic, it may well be, unmeritorious though it may be, it'll be there. It'll be like silicone implants and Johns-Manville. Plaintiffs' lawyers will find something to attack, a change that's not supported by literature of medicine, for example, particularly when you've got the buzzwords, "We're doing a cost-benefit analysis." That makes people salivate.

GEORGE MACRIS: I think it's good to put that in the literature. Practically speaking, it's very difficult to say no to a person who's traveled to your chamber. Not only should it be changed in the literature, but also in the emergency call systems. When a person thinks they're bent, they get on the phone and call DAN or SOS. DAN or SOS locates the local expert if possible. Rather than have them programmed to say, "We're gonna get you to a chamber to be treated," perhaps they should say, "Maybe they'll get you to the chamber and decide whether or not you'll be treated," or something to that effect. As it is now, divers show up ready to go, and it's almost as if you have to fight them to say no. Maybe if we start by letting the 24-hour services defer to the regional talent to help with more real-time analysis, it would be easier to make a conservative decision about treatment rather than have the mindset that they're gonna get the platinum plan back to a chamber and stay in the Hyatt to recover.

RICK LESSER: Remember, it's a function of education. There was a time when people would have lots of DCI, but they didn't want to talk about it because they're macho. There was a time when there was no O2 on boats. These things have come in. It's an education process. Maybe it will get to a point where people will say, "Hey, I've got a sore elbow. I need some O2 and some ibuprofen." Not, "Get me to a chamber." And most importantly, it will be the right diagnosis.

GEORGE MACRIS: Well, right now the DAN and SOS people are here and could start tomorrow.

CONSENSUS DISCUSSION

*All Participants
Sydney, Australia*

Editorial Preamble by Dr. Simon Mitchell

This discussion has been edited in the interests of space and clarity, and of necessity (because of occasional poor recording quality), so that not all statements will conform to the exact words spoken. The editors have taken great care not to change the meaning or intent of any contributions.

The format of the consensus session deserves some clarification. It has been the editors' experience that attempts to generate consensus statements from scratch among large groups of discussants are often frustrated by inertia and circular argument. Accordingly, a series of draft statements were proposed by Drs. Mitchell and Doolette to be used as a "straw man" to generate consensus. These draft statements were not an attempt to advance a particular agenda. Rather, they were based substantially on the discussion that had taken place on the first day of the workshop. They provided a starting point for focused debate and dispensed with the very time consuming process of composing statements de novo. The consensus session, then, took the form of a sequential discussion in which all statements were thoroughly debated. None were accepted in their original form. This can be readily appreciated by consideration of the original statements (see below) and the final wording presented at beginning of these proceedings. Several statements were rejected entirely.

This session was chaired by Professor Des Gorman. Dr. Gorman is Professor of Medicine at the University of Auckland, Auckland, New Zealand. He is widely recognized for his seminal research work on arterial gas embolism and his extensive experience in clinical diving and hyperbaric medicine.

Introductory Comments by Professor Des Gorman

In a minute, Simon will display the draft consensus statements which we'll show you in their entirety before we begin to debate them. Clearly, any form of consensus requires that there be a draft at the outset if there's to be any real likelihood of arriving at agreement or consensus. In that regard, I guess "consensus" may not be the right word, because many of these statements may simply, at the end of the day, have been held by a majority of people or not held by a majority. In fact, opinions may be equally divided, and so be it. I don't think there's ever a problem with these sorts of workshops identifying those things where there's strong agreement and those things where there's strong debate.

We need to focus ourselves on what today's consensus is about, and the words "remote" and "mild" need to be clearly emblazoned in our consciousness as we conduct this debate. We are talking about remote cases, and we're talking about mild cases. We must retain that focus.

In terms of the purpose of the workshop, when Simon first approached me, I thought, "This sounds like an insurer's exercise in reducing their cost or their liability across time." And I think that's partly what it is. But there is a substantive medical basis for this workshop, and that is to avoid risk and harm that arises from inappropriate care. So, in that context, there's a very legitimate ethical, medical rationale for this debate, and I don't think we need to see it in purely cynical fiscal terms.

What I do need to do, though, is declare my own bias before we start, because I don't think my bias should influence the debate today. I've been listening to the debate for the last couple of days and haven't expressed any particular point of view because my point of view is changing, and quite significantly. I find myself wondering about the clinical utility of the concept of mild decompression illness, and in considering this, I'm reminded of several things.

First of all, if we step outside diving medicine and look at medicine in general, the vast majority of human symptomatic expression is not rational in the context of organ system disease. Why should mild DCI be any different? We take people with headache (but no clinical signs of neural disease), and we investigate them with the most sophisticated techniques available. Maybe one in a hundred will be shown to have an explicable basis for their headaches. If we investigate chest pain, we may find five to 10 people out of a hundred with chest pain prove to have ischemic heart disease or some other form of heart disease. If we investigate dyspnoea, we may find five in a hundred have an identifiable organ system disease which explains their symptomatic expression. The reality is, in every other field of medicine, if people have symptoms but no demonstrable clinical signs, for the vast majority, there is no organ system disease basis for their discomfort. The consequence of medicalizing somatiform disorders or some somatiform symptoms is profound iatrogenesis (the process of inducing imagined ailments by autosuggestion based on a physician's words or actions during an exam).

I'm also reminded as we talk about this mild syndrome of decompression illness, we need to put it in the context of the outcome for brain injuries from other causes, which is my major research interest. When we look at people who have brain injuries where we find no demonstrable physical signs, the major determinants of their outcome are:

- Were they depressed before the head injury?
- How much did they like their job before the head injury?
- How did they cope emotionally with crises in their life before the head injury?

The actual head injury itself is a sentinel event which causes a decompensation. You can drive yourself mad trying to work out the utility of interventions for this subject group. You can drive yourself mad trying to find a dose-response for the head injury and outcome when, in fact, it's largely determined by non-head injury premorbid factors. Why should mild decompression illness be any different?

In this context, we also need to remember, as we discuss this syndrome and what we should do about these patients, that we have a treatment, and we're debating why we

shouldn't use it. In every other area of medicine, we debate why we should use treatments. We should find a substantive basis for intervention, not a substantive basis for not intervening.

The final thing I'd like to say in terms of this mild syndrome before I talk about my own views on decompression illness is that when we survey the sorts of communities we're talking about – and I'm now excluding indigenous diving populations such as the pearl fisherman and fish collectors and so on – every index of health that we have for the industrialized world shows that we are healthier than we have ever been in the history of this planet. And every index that we have also shows that we are more worried about our health than we have ever been in the history of this planet. We are literally well-worried-sick. Every time I think about the mild syndrome of decompression illness, this concept of well-worried-sick starts rattling around inside my cage, and I see the word "iatrogenesis" written in large 48-font bold uppercase.

I increasingly see decompression illness as an artificial, categorical construction imposed on a spectrum of outcome. If we take the premise that most dives and certainly most compressed gas dives produce bubbles, and if we take the premise that bubbles will induce adverse effects or "disease," then we arrive at reasonably logical conclusion that diving causes disease, and that there is a spectrum of outcome in symptomatic terms from death at one of the spectrum to being remarkably well at the other end of the spectrum with everything else in between.

Decompression illness, then, is an artificial, categorical construction imposed on one end of that spectrum. That's all it is. And the boundary between disease / no disease will vary according to anxiety, denial, proximity to a chamber, distance from a chamber, insured / not insured, but it's actually an absolutely artificial construction. It only exists because we've defined it. The whole concept of mild decompression illness is, if you like, a subcategory of a category which we can define any way we choose, frankly.

So where does this leave clinicians? It leaves us, as it does in most areas of clinical medicine, as uncertain as hell. But with all due respect, the nature of clinical medicine is uncertainty. The environment in which we practice is an environment of uncertainty. We abhor that, our patients abhor it more than we do, and we spend our whole lives trying to define areas of certainty into areas of great unknown. And that's what I've heard for the last two days – people frantically redefining these profound areas of uncertainty to give themselves some comfort and their patients some comfort, because the reality is we're having this debate today in the absence of any absolute risk data. We do not know the number needed to treat. We do not know the number needed to harm. That's the beginning, the middle, and the end of the objective scientific argument.

So, let's be honest. What we're going to do today is to resort to expert opinion. We're going to base our clinical behavior and recommendations on that expert opinion, and that's all it is. That still has some merit, because it's the highest form of evidence we have, and it's better than none whatsoever. Anecdote will rule. I expect to hear and see

you exhibit the dogmatic views that you brought with you, and I expect most of you to leave with them unchallenged! I would hate to see us waste valuable time today debating the need for future research and collecting data. The Society's been discussing that for 30 or 40 years and has done very little at all about it, so let's not pretend this is an area which defines sensible data collection because, quite frankly, we do not have a case definition of mild decompression illness. In the absence of such a case definition, sensible research will always be handicapped.

So, as a clinician, I'm much happier with the severe spectrum of disease, but we're about to talk about people who are not like that today. We're talking about the well-worried-sick, some of whom may well have a disease related to bubbles.

So, that's my own personal bias. I promise that I won't interject that bias any further into the debate, but at least you know where your chairman's coming from. Alison said the longer she stays in diving medicine, the more uncertain she becomes. Well, some of us have been involved two to three times longer than you, Alison, and consequently are two to three times more confused.

Draft Consensus Statements

The eight statements below will serve to start the debate. Each statement will be considered separately.

- **Statement 1.** With respect to decompression illness, the workshop defines a mild presentation as one or more of the following symptoms only: (a) pain; (b) constitutional symptoms; (c) subjective patchy, non-dermatomal sensory change; and (d) urticarial rash (not cutis marmorata) where objective neurological dysfunction has been excluded by medical examination.
- **Statement 2.** The workshop recognizes the possibility of progression and evolution of mild symptoms. Patients must be monitored carefully over the first 24 hours following diving, and management plans should include provisions for such progression.
- **Statement 3.** The workshop accepts that mild symptoms are highly unlikely to progress after (one of) 12 or 24 hours.
- **Statement 4.** The workshop recognizes that a delay of up to (one of) 24, 48, 72 hours prior to recompression for a patient with mild decompression illness is unlikely to be associated with any worsening of outcome.
- **Statement 5.** The workshop acknowledges that where evacuation for recompression implies significant logistical difficulties, cost, or hazard, some patients with mild decompression illness can be adequately treated locally with oxygen at one atmosphere.
- **Statement 6.** The workshop recognizes that there will be some groups of divers competent in the appropriate use of 100 percent oxygen in diving whose members are willing to accept the risk of in-water oxygen treatment for mild decompression illness.

- **Statement 7** (one of two options).
 - The workshop consensus is that patients with stable or remitting mild decompression illness can be transported for recompression by commercial airliner after a surface interval of 24 hours or more.
 - The workshop acknowledges that transport of patients with stable or remitting mild decompression illness by commercial airliner after a surface interval of 24 hours or more is unlikely to be associated with worsening of outcome.
- **Statement 8.** The workshop endorses repatriation on commercial airliners after treatment – that is, recompression and hyperbaric oxygen – and complete recovery for mild decompression illness after a post-treatment wait of three days minimum.

DISCUSSION

DES GORMAN: I think you'll see then that these consensus statements are as non-controversial as they can be made, which gives them a reasonable chance of being debated sensibly. What I hope we can do in the next hour or so is get to a point where we either have a sense of widespread agreement, profound disagreement, or where there are one or two clear objections.

You have to see Statement 1 in the context of Statement 2. I'll just give you a few more seconds just to have a think about these first two, because perhaps we should debate these first two Statements together because I think they hang neatly. While you are thinking about that, I should note that David Elliott has just asked to make the point that we are talking about recreational divers. I understand your sensitivity in that regard, David, because this shouldn't be extrapolated beyond the population which we are considering. I agree with that totally.

So here we are. Statement 1, then, aims to define a symptom complex. It puts that symptom complex into the context of no objective signs. It then provides a further comment about the possibility of progression. And so what we're trying to do here is define a subset of symptoms, which may present after a dive which we will call mild, if it is due to decompression illness. That's what this particular consensus statement hopes to achieve.

KLAUS TORP: I think David Elliott brought up the issue of pain that can range anywhere from mild pain to very severe pain. So should we include, if it's a mild DCI, is it mild pain or severe pain?

DES GORMAN: We can come back to that later on. The reality is that there's never been a correlation shown between the experience of pain and the extent of disease. Pain is a subjective emotional experience which people have which bears little relationship to the nature of underlying disease. That's true in every single disease state in which it's been considered. There's no difference here.

RICHARD MOON: Des, I have a couple of comments. One is that I would narrow pain down to articular / peri-articular pain and differentiate that from girdle pain.

Secondly, I brought this up yesterday, I'm not convinced that it makes any difference whether the sensory change is subjective or is associated with any objective change. Hyperesthesia in isolation I would still classify as a mild case. Thirdly, urticarial rash, in my experience, is extremely uncommon as a manifestation of decompression illness. I think it only really occurs in the setting of gas switches during heliox diving. Urticaria in diving is much more likely to be an allergic sort of reaction. I don't think it really matters whether it's cutis marmorata or anything else. As long as that is the only manifestation and is stable, there's no particular urgency or sense that that needs to be treated any differently than any other minor symptom.

DES GORMAN: My own perspective is that Statement 1 (d) should just read "rash."

RICHARD MOON: Yes. I would agree.

FRED BOVE: Yeah, I think I'm gonna say pretty much what Richard said. The pain needs to have some other concept added to it, because articular pain is very specific for DCI, whereas, a lot of the cases are not articular. So the question is, do you sort out those two or just leave it as limb pain whatever the limb pain is? In addition, regarding the rash. I think if you biopsied true urticaria, under the microscope it would look exactly like what we call cutis marmorata. So you get the same sort of inflammatory, vasodilatory, cellular infiltrates in both of those types of skin lesions, I think.

DES GORMAN: Before you go, Fred, the reason for limb pain being expressed as non-specifically is that, as you implied before, if you do a point-prevalent study of pain expression in any community at any time, you'll find something like 10-20 percent, even as high as 50 percent, of people may be experiencing pain somewhere in the limb or the back over a 48-hour period. It's an almost meaningless finding.

FRED BOVE: Right. That's right.

DAVID ELLIOTT: I agree with both previous speakers and was going to suggest both their modifications. Concerning sensory change, I'm quite happy with that, but at the same time, I wonder whether or not it's worth adding to limb pain, or preferably peri-articular pain, "...even if localized sensory changes or localized muscle guarding is present," because muscle guarding can be associated with the word "weakness" and then you jump into another category.

DES GORMAN: You would see that as a footnote, David?

DAVID ELLIOTT: Yeah. You can put it in as a little footnote if you like.

DES GORMAN: Before you go, in terms of the sensory change, do you think the words "patchy" and "non-dermatomal" add anything?

DAVID ELLIOTT: I think the non-dermatomal is definitely needed.

DES GORMAN: Well, most doctors wouldn't know what a dermatomal was if it walked up and bit them.

DAVID ELLIOTT: Well, yeah. OK. The other thing that I'd like to see, but I wasn't going to raise at this stage, at some time you've got to include the time element, that is, observing over time for change.

DES GORMAN: Have a look at Statement 2, David. Does that resolve this?

DAVID ELLIOTT: OK. I was a little bit concerned about the hypothetical case we had this morning that at the end of 24 hours you could pretty well write it off. I think there's enough occasional cases of deterioration after 24 hours that I think the word over at least the first 24 hours might be the tactful way of putting it, because the first 24 hours is undoubtedly the most important, but there are a few that come and kick you up the backside later.

ALISON DREWRY: I was also going to comment on the fact that although I think that perhaps this label of mild DCI is a bit of a nonsense, it definitely has a time factor in it. This is almost a retrospective description. All you're saying is, "These are what we consider minor symptoms that may be associated with decompression illness." From my point of view, it can't be mild DCI until at least 24 hours have elapsed since diving. I mean, if the guy's got those within two hours, I wouldn't call it mild decompression illness because in four hours, he might be a completely different presentation. All you're describing here is minor symptoms.

DES GORMAN: That's the reason why we chose, and correct me if I'm wrong, the words "mild presentation" –

SIMON MITCHELL: Correct.

DES GORMAN: – rather than "mild disease."

ALISON DREWRY: I don't think you should use the same words then. You should say it defines a presentation, that these are minor symptoms of a presentation, but you can't say a mild presentation.

SIMON MITCHELL: The problem was that we actually had it the way you wanted it initially. We said you can't diagnose mild decompression illness until after 24 hours. Then we received a lot of feedback yesterday along the lines of "Well, that's no use to me, because it means that none of this really becomes relevant until I've had the patient in my hands for 24 hours."

ALISON DREWRY: Exactly.

SIMON MITCHELL: So we reworded it –

ALISON DREWRY: So what we can say is that – perhaps we can say that we would consider these minor symptoms, but I don't want to get mild symptoms mixed up with mild DCI if you're going to end up with a syndrome that you're going to call mild DCI.

DES GORMAN: So what you're arguing is that with respect to decompression illness, the workshop defines the following symptoms as being mild.

ALISON DREWRY: As being minor.

DES GORMAN: Being minor? Well, we'll think of that, because that's an interesting alternative to it. It doesn't change the sense of this at all, but as you know, these things can live and die often on that sort of semantic.

JOHN LIPPMAN: My concern (but it's a concern with full understanding of why the second part of that statement regarding exclusion of signs by examination is there) is that from the dive boat's point of view, when they're out in a remote location, they're usually going to have to evacuate a patient somewhere where there can be an objective neurological examination from an appropriately trained person. So quite often that means evacuation to a chamber anyhow, where they're going to end up being treated if they've got symptoms. So, it doesn't seem as though it's going to change things much at all from the situation we face at the moment.

SIMON MITCHELL: I don't think that's true, John. The problem is that what we're trying to create here is a definition that we can work with when we're the doctors on the end of the phone distant from where the patient is. We cannot make the assumption of "mild" without an examination. All of us have seen patients that are presented to us on the phone as mild, and when they get to us, they've got significant neurological problems – so we cannot work with anything that calls a patient "mild" until the patient's been examined. That came through very clearly in David Elliott's presentation, and I believe that Frans Cronje was instrumental in pushing that view at the Thailand workshop. I just don't think we can get away from it, unfortunately.

JOHN LIPPMAN: No. I said I understand it. I've seen the same situation, but I just don't think it's going to make any difference now to a large extent to any of the practices that we're currently doing.

DES GORMAN: What I'd like to do in terms of the expert group is ask you to address two specific issues for us then, please. One is whether we should be rationalizing Statement 1 (c) about sensory change and making it far less specific and far less distracting. In other words, say subjective sensory change and not worry about implying anything else. The other thing is the issue that Alison raised, which I think we do need to discuss: whether we should be rewording this to say, "With respect to decompression illness, the workshop defines the following symptoms as being minor." That's a very important and viable alternative, and I'd welcome your comment on that, because that actually doesn't change the overall thrust of this argument but may present a consensus statement which actually has more rigor.

MALE SPEAKER: I completely agree that rash is a minor symptom, but in my experience rash plus lymphedema does deserve some respect, because often it involves more severe symptoms associated with a PFO and so on. What happened with this classification for lymphedema? Is it included or not?

DES GORMAN: I think the bottom line is this: The predictive power of lymph swelling, or any other sort of swelling, plus rash for bad outcome in decompression illness is almost immeasurably low. It's almost a meaningless finding in terms of predictive power.

JAKE FREIBERGER: I have a little problem with this in that these symptoms can be lots of things. They don't necessarily have to be DCI. Wouldn't it be easier to define what severe DCI is and let everything else be mild?

SIMON MITCHELL: No.

DES GORMAN: I think in terms of this decision tree, we are talking about mild or minor symptoms, and I think that's where our orientation should remain. Otherwise, we'll find we very quickly have lost complete track of what we were supposed to be talking about which are those things which we see in terms of predictive powers being minor predictors of poor outcome. That's what we're really talking about today.

JAKE FREIBERGER: But this adds to ambiguity because it can be many other things.

DES GORMAN: Who cares? In terms of intervention, who cares? Because I think what they're saying is that in respect of decompression illness, these things are minor symptoms with poor predictive power for bad outcome. That's what they're saying.

JAKE FREIBERGER: Exactly.

DES GORMAN: As to whether they are confounded by the diagnosis, of course they are. In fact, the likelihood of that sort of presentation being decompression illness is very low.

JAKE FREIBERGER: Very low.

SIMON MITCHELL: Jake, if you tried to do it from the other end and come down in severity until you've decided who you do have to treat, you'll hit exactly the same problems but just coming from the other direction. What we're going to do with this definition is go on to use it in applying some of the following statements, so we've got to have a definition (or the other statements become meaningless). It doesn't matter if we are embracing some patients who don't have decompression illness, because we still have to deal with them in the real world.

JAKE FREIBERGER: OK.

DES GORMAN: Now, Wordsworth, we really would appreciate your commentary on the two issues about the sensory symptoms and the suggestion that Alison made about a different orientation for Statement 1 (c).

JAMES FRANCIS: A mild symptom is only mild if it's static or getting better. If you've got any of those things that are actually getting worse in front of you, I don't think you're dealing with mild disease. Second point is at the bottom of Statement 1, we've

got "has been excluded by medical examination" with no qualifiers as to who has done the exam, and I think maybe we should address that.

DES GORMAN: You would want the word "competent" inserted there, whatever that means?

JAMES FRANCIS: It's a value judgment, but something needs to be said.

DES GORMAN: Oh, I accept that, but that's why the word "excluded" is there. This is what clinical medicine's about, James, and those sorts of value judgments can't be written out by semantic terms like "competent."

JAMES FRANCIS: That's why I didn't say it, but it's an issue that concerns me.

DAVID ELLIOTT: To resolve Alison's point, which I think is perfectly valid, you could just say that the workshop defines mild symptoms as one or more of the following only. You get rid of the word "presentation" entirely. I accept everything that I think almost everybody's said, that we've got to put in a progression comment on this, maybe on the next page. The other thing that really stood up is, I think you, Des, suggested should we get rid of the "patchy" and "non-dermatomal." It immediately occurred to me the phone call you do get in the middle of the morning, the guy's at the phone in the railway station and says, "My feet are going numb," and, if both feet are going numb, that's not mild.

KLAUS TORP: I'm wondering who's going to read those statements and then tell somebody with severe pain, "You have mild disease." I think a qualifier that those symptoms are less likely to progress to paralysis and so forth, would be nice to put in.

DES GORMAN: You want the word "mild" in front of the pain? Well, I mean, I would personally think that's a nonsensical situation, but I'm more than happy to take any further debate on that. I mean, there is no evidence anywhere that severity of pain correlates with significance of disease; and so I think that's a bit distracting.

KLAUS TORP: No, that's not what I meant. I meant, when we draw this up that we put in there that even severe pain is not likely to progress to some severe disease.

DES GORMAN: I would agree that there should be a footnote, Simon, where we define what we mean as minor or mild, something which has a low prediction of poor outcome. I've got no problems with that. But the minute you start trying to link outcome to severity of pain, I think you're in Never-Never Land.

MICHAEL BENNETT: Just trying to help you shorten it up, Des. The sensory business is going to be probably quite difficult to get consensus, but I'm tempted to just leave it as sensory change. Impending paraplegia is progressing, and that will be excluded from being mild. I think that's how we catch that. So I'm saying you don't even need subjective in there, because if you've got objective sensory loss that's ruled out by the qualifier at the bottom, so I think all you need there is sensory change. We understand that in the next statement, we're talking about it being static.

DES GORMAN: David, do you want to have some feedback on that?

DAVID ELLIOTT: OK.

DES GORMAN: OK. So long as that Statement 2 is a qualifier of Statement 1. OK, Richard?

RICHARD MOON: One more comment on sensory. What I can see happening here is that at the end of all of this, one's decision on whether to call in the air ambulance is going to hang on whether somebody's sensory exam is positive or negative. As we all know, that's the most difficult part of any neurological exam, and I'm not sure that there's any difference between sensory exams with objective changes or without.

DES GORMAN: The point I'd like you to think about in Statement 2 is the word "excluded." This is an exclusion exercise, not an inclusion exercise. This is an exercise where you have some confidence after your assessment that there is no neurological deficit rather than the other way around.

RICHARD MOON: But we haven't heard any evidence in the last couple of days that sensory changes with objective changes behave any differently than purely subjective changes. So why are we making that differentiation here?

DES GORMAN: Richard, we haven't heard much evidence in the last couple of days! Before I ask if there's any sort of burning input from the invited discussants, are we getting to a point with those first two Statements – the first Statement with its qualifier and the second Statement – close to something that you want to pass some sort of judgment upon?

DAVID ELLIOTT: Subject to the next Statement being as Mike has suggested that we put a time phrase into the sensory change. I'm still very concerned about the guy – and I'm sure everybody's had one – who starts off getting numbness in both feet, cotton wool feeling in both. That is sensory change, but it is not mild. The thing that bothers me – and I'm so glad that Rick Lesser is here, because I know perfectly well what these attorneys do, they'll just present you with Statement 1 and keep Statement 2 tucked away – so that each statement needs to be self-contained. I would like to go back to Statement 1, please, and just ask us to look at sensory change and to specify "patchy" or something like that, because of the specific problem of the way in which we see the onset of spinal cord paraplegia.

DES GORMAN: David, the very first vote we'll take will be on that specific issue.

GEORGE MACRIS: My comment is simplistic in that we don't want to be married to something which obviously is evolving, and do we really need "only" in Statement 1? Just eliminate that.

DES GORMAN: No. With the change in terminology, "only" is now redundant. It should go.

CARL EDMONDS: I don't disagree with anything that Des has said or will say in the future. However, it does worry me. I'm a bit like David. I am worried about the guy with two numb feet. I am worried about the guy with a hemidysesthesia, and I am worried about the guy with homonymous hemianopia, and I am worried a little bit about the guy who's just lost his hearing because that will come under sensory changes.

SIMON MITCHELL: Yes, but they're objective.

DES GORMAN: I would hope, Carl, that they'll be picked up by that second Statement. But the very first vote we'll take, Carl and David, will be on the way in which sensory change is expressed here. That's the first thing we'll vote on, because there seems to be reasonable consensus about the rest – so we'll vote on that first, but then we'll vote on them as total comments.

MICHAEL BENNETT: I'm probably just going to make the same point that the chap who rings us up from the airport (with the progressive numbness in his feet) is not going to have been examined and can't possibly fall into this description. That's my point.

DES GORMAN: Before we take the first vote, I'd invite people from the wider audience to pass any sort of opinion or comment or illustration they'd like of these first two statements. Bob, I'd like you to see them together as a conjoint. One of the things, David, we may need to talk about later on is actually merging them, so that they're actually not two statements but one statement and one qualifies the other, which I think would preclude that division that sort of the forces of darkness might present to us in the legal setting.

BOB WEBB: In terms of the second part of Statement 1, I see this as a beginning to changing the way that we deal with the divers out there. We will be working with the dive industry, and I can see that if that second part is such a critical part of the definition, we might look at ways of trying to get some sort of neurological examination done where the diver is. Whether that means training our people, or whether we train divemasters.... I'm wondering whether the term "medical" is going to limit us to a particular avenue. Maybe we should change it to "clinical" or some other term which allows us to use other avenues to exclude that neurological dysfunction.

DES GORMAN: The Americans in the audience will tell you that the United States Navy has had just that sort of approach in their divemasters for a long, long time. They've actually taught them, I thought, quite a sensible neurological examination which focused on the important things like gait which are where all the clues are anyway.

GLENN HAWKINS: One thing that I was concerned about was lack of progression. Shouldn't there be in part of the second statement that the symptom is not progressing? Because regardless of what you've got, if the person's constitutionally getting

sicker and sicker, you're going to treat them, aren't you, while they're going into the serious things? So where it says "objective neurological dysfunction has been excluded by medical examination and is not progressing" – does progression put them from mild into a more serious category?

DES GORMAN: The issue I think that David and Carl were both raising was that those are signs and harbingers of spinal cord disease, and very shortly after, the person won't be able to stand up, will have trouble passing urine, and so on. That's the point they're making, that you might be missing an early intervention point for those sorts of disease. Am I correct, David and Carl, as to the point you're making?

NEIL HAMPSON: As long as everyone's doing picky wordsmithing on this statement, rash is not a symptom, but it's a sign.

ALF BRUBAKK: The problem hinges on the second part of this statement because it depends a lot on how good you are on doing medical examination. If you're very good, you're probably in a large number of individuals that are classically called Type I or mild or whatever you use. They will have subtle neurological signs. Do we believe that those with difficult detectable clinical signs are mild, like for instance some small changes in reflexes or something? I think we have to say that unless we want to get into a lot of trouble, if you have a trained neurologist on board, I'm sure that the definition will change.

DES GORMAN: I'm not sure that's right. Many of us have had the experience with people trained in classical neurology of describing what we'd consider to be quite sick divers as being completely normal because they're used to crappy, crumbly old buggers, not fit young athletes. Very frequently, I've seen people described as having normal power actually have quite significantly reduced power. The point now I'd make, though, is you already make this decision. Someone rings you up and says, "I've examined this person. They're well." You will make a value judgment on the nature of that doctor's ability and sometimes you'll ignore it, and that's what you're doing today, I'd suggest. So we make those sorts of value judgments about the quality of assessment all the time, and every one of us has the experience, I've no doubt, of people coming to us who we're told confidently were free of signs and who were anything but free of signs. And we're generous and say, "Maybe the disease has evolved."

ALF BRUBAKK: Yes, but you're not saying mild DCI can only be called mild DCI if there is a competent doctor present at the dive site. If there is not, all other cases are regarded as severe accordingly. It's not how we should read this.

DES GORMAN: That's the default option. You're absolutely right.

SIMON MITCHELL: Can I just make a point though? It's really for the purposes of applying the statements that we're going to subsequently go on and discuss that we're making this definition now. You don't have to use this statement to define mild decompression illness in the rest of your practice.

FRANS CRONJE: Would the use of the word "physical" rather than "medical" include the one without excluding the other possibilities: "physical" examination?

MIKE GERNHART: I'm a little troubled by the words "one or more of the following" and if you had a patient with pain in both elbows, both shoulders, truncal sensory changes, rashes all over...

DES GORMAN: No, no, no. You're right. Since that Statement has been changed, that needs to be re-wordsmithed and "one or more" no longer is applicable. You're quite right. It's just an inclusive list now, it's no longer a definition of disease.

MIKE GERNHART: You might think in terms of single sites maybe.

DES GORMAN: So you can take out "one or more," Simon. So the first thing I'll ask you to do then is the comment on the sensory change, please. Are you happy with it as it is? Yes or no? That it just reflects sensory change. Does anyone feel unhappy with that term "sensory change"? And you would prefer...?

FRED BOVE: I think we heard the word "subjective." The issue is that the patient might be complaining of the sensory change, but the doctor can't detect it.

ALISON DREWRY: No, I'm sorry. I mean if a patient had any spinal disease or sensory symptoms due to spinal disease, they are more often tight or band-like feelings – odd things that don't necessarily reflect on actual skin sensation. It doesn't make any difference whether it's subjective or objective, but what they do need to be is patchy and non-dermatomal.

DES GORMAN: Well, I think what we might do there, Simon, is just put a footnote by that, and that's going to require a couple of explanatory sentences, because I don't think any of us can be happy with one or two words inserted or extracted there. What we probably need for this particular one is a footnote which describes exactly what all of us are trying to express, and that is that we recognize that there are some sensory findings, like numb feet, for example, which are harbinger. There are some things like classic girdle pain which actually worry us. So I think if we actually make that into a couple of well-constructed sentences as a footnote, that might solve the problem of trying to find one or two words which bring us some comfort. Go ahead and read through it again now, Simon, both as it's been revised now. It's now a single statement, is that correct? Noting that the words "sensory change" will have an explanatory footnote to pick up on the issues that we're talking about.

SIMON MITCHELL: OK. Statement 1: "With respect to decompression illness, the workshop defines mild symptoms and signs as follows – limb pain [peri-articular], constitutional symptoms, sensory change, rash – where objective neurological dysfunction has been excluded by medical examination. The workshop recognizes the possibility of progression and evolution of mild symptoms such that patients must be monitored carefully over at least the first 24 hours following diving and management plans should include provisions for such progression."

JAMES FRANCIS: We've gone from the first half of this, which is defining what we're talking about, to embarking on part of a management plan here.

DES GORMAN: Thanks, James. Well, you're right, but so what again. I mean, no one's pretending we're defining a disease state here. We've said these are mild symptoms. We've got these two qualifiers: a normal examination and major commentary to effect recognition of progression.

JAMES FRANCIS: We're recognizing the possibility of progression and evolution of mild symptoms, i.e., they're still mild. If you've got progressive symptoms, I don't think they're mild.

DES GORMAN: I agree with that, James. I think the word "mild" should go in line 3. I'd take out "and evolution of symptoms" also. OK. Any final comments from the panel before we vote? Well, here we have Statement 1. There is a Statement and two qualifiers. It's now defining a set of symptoms as minor or mild. It's recognizing that there are two provisos in this: one, that there should be no objective signs and, secondly, that there's a recognition that what is, may not be, and there's a need for ongoing review.

Before we have a hands-up, does anyone want to have any final feedback or comment on this as it now stands, bearing in mind, Carl and David, that we will insert a couple of sentences describing a series of illustrative sensory changes which would indicate significant disease? Well, how does the expert panel feel about this? Who would find objection with Statement 1 as it's now written? Anybody amongst the expert panel?

ALISON DREWRY: Yes. I think that there are sensory changes which I would not regard as mild at all, even in the absence of objective neurological dysfunction.

DES GORMAN: And you're talking about girdle pain, etc.?

ALISON DREWRY: I'm talking about things that suggest spinal cord involvement.

DES GORMAN: What about non-dermatomal? Would that do it?

ALISON DREWRY: No, because that doesn't include – oh, it might include girdle pain, I suppose.

DES GORMAN: I take your point. It's the same point that both Carl and David have raised – that there are subsets of sensory change which you would be reluctant to describe as mild, and what we're trying to find is a catchy phrase to describe these – and I'm not sure that "patchy non-dermatomal" does it for me. In fact, that's why I'm suggesting a footnote to qualify sensory change.

ALISON DREWRY: Or do you have a bracket "[not spinal syndrome]" or something like that? I don't know.

DAVID ELLIOTT: I'm happy with a footnote, as long as it is not read out of context. That's why I'd like to see the cutaneous patchy in the sensory change and still have the footnote.

CARL EDMONDS: I was just worried about the central nervous system sensory changes that we're going to miss.

FRED BOVE: I think what we're really talking about here is skin sensory changes, cutaneous sensory changes, because the girdle pain is not cutaneous and nor is partial blindness cutaneous. So I just wonder if what we're talking about are cutaneous sensory changes only and whether that might help to solve some of these other problems.

DES GORMAN: Well, what I'd ask your indulgence to do is we recognize that we need to do some work on that. I don't think it's going to be possible to have a simple, brief statement which reflects our concerns. I suspect we simply need to illustrate that with some explanatory commentary. This reflects the fact that there are sensory changes which are harbingers of more significant disease. What we'll do is email it to make sure, Simon, that the group are happy with the exact wordings and to make sure that the series of illustrations we provide – we don't have to be exclusive – but if we have two or three illustrations of what would be a significant sensory problem, I think that would do it. Well, very good. Let's take Statement 1 as accepted then and let's move on to what was number 3 and is now 2 please.

SIMON MITCHELL: Statement 2 reads, "The workshop accepts that mild symptoms are highly unlikely to progress after 12/24 hours," bearing in mind we refer to "mild" symptoms as we have just defined them.

DES GORMAN: What I'd invite you to do now, please, is to comment on this in generic terms, and then specifically, I'd like your comment on whether you think we should be going for 12 or 24 hours in view of those cumulative symptom exposure curves, which may provide the basis for this comment?

FRED BOVE: Well, you know the safest way is to make it 24 hours, because we know that for any presentation, the likelihood of progression is very low beyond 24 hours. I have to ask the folks who presented the data where the boundary would be: 12 or 24 hours. The safest boundary would be at 24 hours.

DES GORMAN: Is there any utility for 12 hours? Would it achieve anything?

FRED BOVE: The case we talked about this morning suggested 24 hours because the diver didn't complain for a whole day. The utility would be for deciding when to start planning a medevac based on progression at a certain point. For example, you might say, "We're going to wait 12 hours before considering medevac." But, as I said, the safest thing to do would be to wait 24 hours because it's more conservative.

JAMES FRANCIS: I prefer 24 hours, but 24 hours after what? Is it from the time you've left the water, or is it after the onset of the first symptom?

DES GORMAN: I'd like you to consider whether it should be 12 or 24 hours and from symptom onset or from leaving the water. In fact, given that symptom onset is generally quick, it's reasonably an academic argument.

DAVID ELLIOTT: I suggest leaving in the word "highly," because we can't put a mathematical probability on the likelihood of progression. However, the time of the dive is known, whereas the time of onset is subjective and further obfuscated by denial, etc. Twenty-four hours is a pretty long time anyway, so OK.

WILLMA PADILLA: Sometimes if a patient is wearing oxygen, the symptoms are stable, but as soon as you remove the oxygen, the symptoms may return, perhaps worse. The statement does not account for this.

FRED BOVE: I was thinking of this more as a pathophysiologic statement rather than a treatment statement. We're talking about whether symptoms are going to progress, not what the treatment's going to do. I'd be satisfied with leaving the statement as is.

DES GORMAN: So, Fred, if you put that "in the absence of treatment," would that remove the objection completely?

FRED BOVE: I think so, yes.

NEIL HAMPSON: These statements are all the beliefs of the workshop, and so to make this a simpler document to read, I might suggest removing "The workshop accepts that..." These are bullet points of what you believe, right? Same thing in the last one with regard to mild symptoms: "The workshop feels..." This is the consensus of the workshop.

SIMON MITCHELL: We considered that. I've just seen other workshops worded in similar ways. The reason for expressions like "accepts" or "believes" or "recommends" or "the consensus is," is that they have different meanings and provide the opportunity to give some strength or take some strength off the statement.

DES GORMAN: You're absolutely right, Neil. We can revise these to have a common stem where appropriate. With regard to the treatment issue, you don't need to qualify what treatment. The statement simply says that mild DCI, in its native state, is likely to behave in this way.

PIERS ROBERTSON: Since Rick Lesser (Solicitor) has raised the point that this document may be a very important one to be put into the literature, it'd be useful to have his input on some of this wording from a legal point of view. So, having "the workshop..." in may be advantageous.

DAVID SMART: I suggest that we remove "in the absence of treatment" and replace with "untreated."

RICK LESSER: I like it the way it is. I think calling it "the workshop" gives it a focus of where it came from. Leave it the way it is.

DES GORMAN: Thank you. Does anyone find any objection to this particular statement amongst the expert group? Very good. Let's move on, Simon. Let's look at number 3.

SIMON MITCHELL: Statement 3 reads "the workshop recognizes that a delay of up to [whatever we specify] hours prior to recompression for a patient with mild decompression illness is unlikely to be associated with any worsening of outcome."

DES GORMAN: This may be one of the consensus statements where we end up with very divided opinions. This is a slightly more contentious issue, because there are slightly deeper implications with this particular commentary.

FRED BOVE: I was surprised that there wasn't another slash with the infinity sign there as well, because one of the issues we're raising is, do we treat at all? This statement implies that we can't conclude that some of these cases don't need to be treated. My question is, does this statement preclude the possibility of us deciding we don't have to treat any of these? I thought we were moving toward the point where at some time in some cases, we wouldn't need to treat them at all.

DES GORMAN: Fred, I think it's a totally valid argument.

ALISON DREWRY: What about the delay prior to recompression?

EDWIN LOW: Can I just check whether you mean long-term outcome?

SIMON MITCHELL: Long-term's probably right.

RICK LESSER: I think where we were going was to say a delay or omission of recompression.

DES GORMAN: Well, that's the point Fred makes, Rick. It's a very important point because this statement is one step towards saying exactly that.

RICK LESSER: We're just saying what we said when we walked in the door, which is we've still got to pay to fly somebody out there. We've still got to do this, and do we do it fast or do we do it slow?

DES GORMAN: We are currently discussing Statement 3. Your concerns are addressed in Statement 4, so let's look at that now. We may need to consider these together.

SIMON MITCHELL: Statement 4 reads: "The workshop acknowledges that where evacuation for recompression implies significant logistical difficulties, cost, or hazard, some patients with mild DCI can be adequately treated locally with oxygen at 1 ATA (+/-other strategies)."

FRED BOVE: Let me expand on that. If I get somebody in Philadelphia with this collection of symptoms, and I have a chamber 15 minutes away, I might still argue that I wouldn't treat that patient if it fits this model. I think that's where we're moving. It

will ultimately move toward the non-remote patient as well, because I think that's what we're implying here is, if you don't treat these patients, no harm will be done. If that's the case, the "remote" even disappears from the consideration at some point.

DAVID ELLIOTT: I think that's fine, but as far as non-recompression is concerned, we've got to acknowledge that if you don't treat, the guy could be in agony or pain for hours. I think it's been well-demonstrated historically for as long as eight to 12 weeks. So we mustn't imply, therefore, that recompression is not necessary; it's just that if it's not available, the long-term effect is not going to be too bad.

DES GORMAN: I asked Simon to make one minor change to Statement 3 which addresses the point that you were raising a minute ago, James, and it reflects the point I was making before about how we're now taking a stance that we've got to show we shouldn't be using intervention. Well, that's unusual medical practice. We should substantiate an intervention, not the absence of an intervention. You want to read it out now, Simon?

SIMON MITCHELL: Statement 3. "The workshop recognizes that there are no data to show that a delay prior to recompression for a patient with mild decompression illness is likely to be associated with any worsening of long-term outcome."

DES GORMAN: There we are. That's getting close to something people can feel more comfortable with, but I welcome your comments on this revised version.

DAVID GRIFFITHS: Once again, it comes back to who is examining the individual? You've pointed out, Des, that we may not treat people at five in the morning, but I'll still get out of bed and go and see the diver. So the issue becomes, does the diver have mild DCI, or is there something more serious? If it's something more serious, of course we will treat.

DES GORMAN: I think we've covered that issue in the previous statements. So remember that these ones hang on Statements 1 and 2. These make no sense at all unless you take those first statements into account.

DAVID GRIFFITHS: The delay to treatment then becomes a different issue from the delay to treatment of someone who has a more serious condition. The statement is fine if they've already been examined by someone appropriate.

DES GORMAN: This statement only is remotely sensible if you take those first commentaries on what is a mild or minor symptom.

ALF BRUBAKK: Would it be very bad to say that the reason there are no data to show that delay doesn't make any difference is that there are actually very little data at all? We haven't really looked. If you combine this with the other statements, we're actually saying that cost does matter. The next step would obviously be that no one with what you define as mild symptoms will be treated in the chamber at all because they'll say, "Hell, it is too costly to take him." They have said that. Then the first sentence can say that you don't need recompression at all.

DES GORMAN: Alf, I think the point that Alison was alluding to yesterday was that there's an inappropriate assumption that hyperbaric treatments do not cause harm. For presentations related to hypervigilance, adjustment disorders, anxiety, depression, that's not true. For some somatoform disorders, that's not true.

Editorial note: Professor Gorman's reference to "harm" is in relation to the potential for reinforcing illness-behavior by intervening with recompression in these patients. The harm is psychological rather than physical.

The medicalization of these vague aches and pains carries harm which we currently don't measure except when we do psychometric studies. Carl and I are to blame for one such study in 1984. I didn't want to do it, but Carl made me publish on the long-term outcome of people with aches and pains. I think we were measuring the effect of hospitalization quite frankly. Illness and other issues hugely confound tests of cognitive function. I think both Carl and I now would more than happily withdraw that misleading reference in the literature, frankly.

ALF BRUBAKK: I would like to agree that it wouldn't make a difference if you do not recompress at all, because I think one of the effects of this stance would be that a lot of patients who are not presently treated will at least be treated with oxygen. I think that divers avoid reporting minor symptoms because too many things can happen – helicopters will come, etc. So now we're saying, "OK, if you treat very quickly for these minor symptoms and your symptoms go away, we accept that you don't have to be sent somewhere for further treatment." I think it will probably improve treatment for these minor symptoms.

RICHARD MOON: I think we can be a little bit stronger on Statement 3. Jake Freiberger presented data to show that indeed there is no effect on long-term outcome. It's not just the lack of data to show the converse. We actually have data to show the positive.

DES GORMAN: The only trouble there, Richard, was that study wasn't the most robust epidemiological study of all time. It would be a very strong statement based on one study with the response rate reported. This is a more conservative statement, isn't it? We can address that further if you want, but this is one we may be able to get some consensus on.

RICK LESSER: I think that Statements 3 and 4 are really the whole point of why we are here. If I understand what we are trying to do, we would want Statement 3 to suggest that a delay or omission of recompression is not likely to cause any worsening of outcome. In Statement 4, I would suggest you say, "The workshop acknowledges that some patients with mild DCI can be adequately treated locally with oxygen 1 ATA and other strategies," and take out the part about logistical difficulties, costs, or hazard. That is the lawyer's full-employment statement in there.

JAKE FREIBERGER: I appreciate the confidence in this study, but I also would like to see a confirmatory study before we make such a strong statement. However, I believe that study will be forthcoming.

RICHARD MOON: It's fair enough to include "omission" perhaps, but we didn't really address that yesterday or this morning at all. I don't think we have any evidence other than a few personal anecdotes.

SIMON MITCHELL: We did decide that we wouldn't recompress a patient like this in our evolving clinical problem this morning.

DAVID SMART: The abalone industry in Tasmania is going to absolutely love UHMS for coming out with a statement that supports what they've done for the last 20 years, which is not treat DCI or not present with symptoms. Just remove a couple of words: "likely to be" I think can be removed without any major effect and make it a bit tighter.

FRED BOVE: In the UHMS Adjunctive Treatments workshop, we were using the American Heart Association definitions of levels of evidence. As Richard pointed out, there is a level of evidence here – it's probably C – that supports the statement that there is no long-term outcome problem. I wonder if we ought to change this to say "some data show" and then put in the level of evidence, whatever we think it is, because there are standards for making statements like that.

Editorial note: The American Heart Association descriptors for levels of evidence categorize "a single randomized trial or non-randomized studies" as level B and "consensus opinion of experts" as level C. Thus, the evidence for the effect of delay to treatment presented by Dr. Freiberger is probably best described as level B. It also falls into level B as defined by the American Academy of Family Practice whose guidelines were referred to in the final consensus statements. Thus, the references to "level C" data in the following discussion are potentially inaccurate, and some (if not all) should refer to level B instead.

DES GORMAN: Except this is a different sort of statement, isn't it? It's saying that there's actually no data. This is a slightly more inclusive comment than that.

FRED BOVE: Well, what I'm saying is there are some data, but the level of evidence is not very strong. But you can make that statement – that the level of evidence is C – on the data that we have if you wanted to do it that way.

DES GORMAN: So rather than this negative statement, you'd suggest saying "there are level C data to show that delay is unlikely to" so you return it back into that affirmation again? OK.

DAVID ELLIOTT: I'm quite happy to put forward that the statement should apply to "a patient with static or improving mild disease," because we must not put anybody who is actually deteriorating in there. If they're still having mild disease and it's getting worse, then it's not a suitable statement.

DES GORMAN: We'll put it there for discussion. What do other people think about that last inclusion? I understand why you want it there, but I wonder if we've already defined what we mean by mild, if we need to do that.

KLAUS TORP: Are we are happy with the term "omission?" As Richard Moon pointed out, I don't think we have addressed that issue.

DES GORMAN: We'll just change this into an affirmation and see how it looks and see if this sits more comfortably with you.

PETER MUELLER: I don't think we should take that out. First of all, it was recommended by the lawyer to leave it in for our friends from the U.S. There may be some important point, even for you, Klaus. Second, I think we've discussed that the last two days quite a bit. We've been talking about 24, 48, 72 hours. So if you extend that, where do you want to cut off to say, "We omitted or we didn't omit recompression"? So if we put it in there, we cover that.

DES GORMAN: No, Peter, we can't leave it in there with level C data attached to it. There's going to have to be two statements. If we go to an affirmation, we will have to say, "There are level C data to show that a delay makes no difference," and that there are no data to comment on omission of recompression because, in fact, the data only refers to a delay.

ALF BRUBAKK: I still believe that the previous statement is better because it simply does not go too close. It is a broader statement and, I think, a better statement because it says there are no data to indicate that there is a risk. I think that's a better statement than saying this. I also think that, just as Peter Mueller said, I believe that we have to have in the omission thing because that's exactly what we're trying to say.

DES GORMAN: This won't preclude that, but –

ALF BRUBAKK: No, that does, and that's why I believe that the other statement is both, the non-data statement and the omission is important to keep in there.

DES GORMAN: Thank you. So we've got a choice, wise people, between a statement that there are no data to show the delay or omission or an affirmative that there are level C data to show it doesn't make a difference for delay. You'd have to make a secondary statement that there are no data to provide any commentary or show efficacy of recompression at all.

SIMON MITCHELL: We address the omission of recompression issue in Statement 4.

JAKE FREIBERGER: The stance that there is no data to show that delay worsens outcome sounds more legally defensible to me.

JAMES FRANCIS: I support you entirely about that. I think the double negative is better in this situation.

MICHAEL BENNETT: I'd support the statement that has the level C data statement in. There's no data to show that giving them half a dozen milkshakes won't make them better. There's no data to show that sending them on a three-week vacation to Disneyland won't make them better. There's lots of things there's no data about. That's all there is data about, so that's the more useful statement medically at least.

DES GORMAN: There's some division of opinion here, so I'll just keep this debate rolling.

ALF BRUBAKK: Can't we have both and say, "There are no data to support," and then at the end say, "There are level C data to indicate that the opposite is true," or something like that?

DES GORMAN: Simon's point here, and I think he's quite right, Statement 4 (see earlier) deals with the omission of recompression issue. Let's flick to Statement 4, please, Simon. We can modify Statement 4 to a large extent to reflect your concerns about omitting recompression. I think we can deal with the omitted recompression issue in Statement 4 and leave 3 to deal with delay. Maybe by separating those out, it might make it a bit easier for us. Let's leave Statement 4 hanging for a few minutes until we debate it. Statement 4 is the omission statement, and 3 is the delay statement. Now, if there are level C data that show delay doesn't make a difference, we should say so.

ALF BRUBAKK: But I think those are totally different statements. In one, you're saying that, in these particular cases, you do not have to treat at all, period. In the second statement (Statement 4), we're saying, "Well, you should treat, but if it costs too much to do it, you don't have to do it."

DES GORMAN: No, Alf. In number 4 we'll revisit the issue of omission in a minute and we'll modify that quite significantly.

ALF BRUBAKK: OK. Fair enough.

DES GORMAN: Let's just deal with this one.

KARL HUGGINS: That was my concern. Whether with the "omission" in there, treating somebody with mild decompression illness would be construed as inappropriate.

DES GORMAN: I think we need to start changing our terminology. You're talking about treating someone with mild symptoms after diving. I think we need to get a paradigm shift in what we're talking about. Every time you call it mild decompression illness, you're making a huge presumptive statement, and it implies an inevitable recourse to treatment.

NEIL HAMPSON: I don't think the first two lines make grammatical sense, and I would suggest just saying, "Level C data suggest that a delay..."

DES GORMAN: Very good. Well, let's wrap this statement up. Is there anyone in the voting mass that has a problem with this statement as it currently now stands, or can

we move on to try to thrash out Statement 4? Does anyone have a particular problem with this? (*Editorial note: no response from invited expert group.*)

Very good. Well, let's look at Statement 4 then, Simon. As it stands, this implies that under some circumstances, if you believe that logistical difficulties, the costs or potential harm exceed the likely benefit, you will say that this disease can be adequately treated without recompression. An alternative perspective would be to say, "The workshop acknowledges that some patients with mild DCI can be adequately treated locally with oxygen 1 atmosphere," and leave the rest of it out.

SIMON MITCHELL: The rest of it is in there because the focus of this workshop is on remote decompression illness, and those are the things that may characterize a remote case and justify a decision not to recompress.

DES GORMAN: I've got no problems with that, Simon. All I'm saying is that one alternative is to go to a more succinct statement, and I invite your comments now. Do we want a statement similar to that shown with commentary weighing up the risks and costs and implying that they outweigh the benefit, or a simpler statement that acknowledges some patients with mild DCI can be adequately treated without recompression?

CUAUHTEMOC SANCHEZ: I'd prefer the short one, because by implying that the transfer is difficult, costly, and something like that might invite legal problems. There will be a huge difference because evacuations might be difficult in remote areas. So, no patient will be transferred.

FRED BOVE: We've had numerous ethical discussions regarding the position of caring for a patient building in global costs as part of the decision-making process. Right now it's probably not ethical to do that in an individual patient care situation. I don't think we ought to imply that we're making clinical care decisions based on the global cost. I mean, I hate to say it that way, but that's an ethical issue that's sitting out there right now. Those are societal issues that physicians shouldn't be factoring in. When we're taking care of patients – I mean, it sounds crazy – but we're not supposed to look at cost in the individual patient care.

DES GORMAN: No, you're quite right, Fred. In fact, most ethical arguments would say that you have implicit advocacy obligation.

DAVID ELLIOTT: Nevertheless, if we do feel, as a consensus, we want to get into that, there's a very useful phrase in U.K. health and safety law which is the phrase, "reasonably practicable." Therefore, it would be, "Where it is not reasonably practicable to evacuate the patient, then..."

GEORGE MACRIS: I tend to agree with Dr. Bove. I would leave it short and not imply costs in any way because, if you go back to the earlier statements where it says, "A delay may not have a problem," there may be individuals who will insist, "Well, I'll just stay here for another week, and you can bring that air ambulance in at your leisure to

treat me because it won't be a problem later." But I'm a little uncomfortable because I want to be certain that DAN and everyone else look at this as letting the physician make that decision, not acting as an insurance company and saying, "Based on the verbiage here, you are denied the right to treat this patient." That's the other area I feel uncomfortable with. I think costs should be mentioned anywhere, because I believe in what the attorney says. "You'll be eaten up alive there."

MALE SPEAKER: Just for consistency with Statement 3, should you add in the static and non-progressive mild DCI?

NEIL HAMSON: Neil Hamson, Seattle. Do you need the word "locally" in the next statement?

DES GORMAN: Nope.

CARL HUGGINS: That acknowledges that while awaiting transport, some patients with static, and so forth, and transportation could be construed however you wanted to.

RICK LESSER: I'll do now exactly what I said I wasn't going to do, talk about the law part and not the medicine part. From what I've heard over the last two days, this statement is really what this whole workshop's about. Either patients can be treated without recompression to get well, or they can't. That's what we were here to determine because, otherwise, all you're doing is shuffling around the cost of recompression. You're delaying it. You're moving it out. You're changing the transport. But you're back where you started. The question is, for you medical guys – because I don't know the answer – can DCI that's mild be treated other than through recompression? That's the question. If you guys all believe it, that's the statement. If you don't, don't buy the statement.

HENRIK NIMB: I think the short statement here is really the whole basis for what you recommended that we change the text in the old manuals, etc. The shorter and the clearer it is, the easier it is for the training agencies to go ahead and change it.

ALISON DREWRY: I like the statement the way it is. Part of the reason is that in managing some patients who may have static or remitting very mild DCI but who desperately want to be treated or are absolutely certain that the symptoms from which they're suffering are due to DCI and recompression is the only option, I would refer them for treatment regardless of my better clinical judgment. This is on the basis that those patients, in my experience, tend to have a rather poor outcome if you don't recompress them because they continue to ruminate and vigilate and all the rest of it.

ALF BRUBAKK: I suggest another change that might make it even clearer. Why don't you say, "Remitting mild DCI may be treated adequately at 1 atmosphere" or "treated adequately without recompression." That says it clearly. Not what kind of treatment you're going to use.

DES GORMAN: In fact, that statement can be edited potentially in two ways. By qualifying it with "some" patients, I think you can take out "static" or "remitting," because you don't need it. We've already qualified this as a subgroup. You're quite right, "treated adequately at 1 atmosphere," also works better. I don't think you need to specify elements of the care package you deliver. The point you're making, Alf, is that the key element to this statement is that they don't need recompression?

ALF BRUBAKK: Exactly.

DES GORMAN: OK. So we should say that. I think that becomes a slightly more succinct and perhaps coherent statement.

DAVID SMART: At the risk of saying, "The emperor's wearing no clothes," we have had the whole paradigm shift here. We were talking about remote area retrievals and modifying our approach to treatment based on the fact that logistic issues were preventing us from taking the patient to recompression. We've now gone to a statement which can be construed by most industry as that regardless of where you are, you can treat DCI without recompression, and we really have no evidence to suggest that that's an appropriate response. Based on data presented yesterday, we've got a 70 percent success rate treating it with recompression. Do we want to go this sort of length?

DES GORMAN: I think, David, that's not quite right. There is extensive anecdote about atmospheric treatment of divers with decompression illness. There's an incredible experience about the self-limiting nature of this symptom complex irrespective of what's causing it. I think the qualification of "some" there is the appropriate thing. This is leaving it very much to your clinical judgment.

JOHN ROSS: Why do you say, "can be treated adequately at 1 atmosphere," when you mean without recourse to recompression?

DES GORMAN: You think it should be explicit?

JOHN ROSS: Yes. What's 1 atmosphere? I mean, the guy may be at the Dead Sea or he may be halfway up a mountain, but he's getting better. You don't want to change his atmospheric conditions.

DES GORMAN: Without recourse for recompression is the Scot's version.

CARL EDMONDS: I'm also a bit concerned that this might be interpreted as meaning "don't recompress," and I just wonder if you shouldn't add, "Recompression can, however, reduce the duration of symptoms," or something like that just so that you don't exclude recompression treatment as an option.

DES GORMAN: Carl, would you be happy if that appeared again as a footnote to this statement?

CARL EDMONDS: Of course.

ROBIN WALKER: I just wonder why we need "adequately?" What does "adequately" mean? I mean, now they can be treated without recompression, but what does "adequately" add to it?

FRANS CRONJE: I want to raise the issue of whether we wanted "mild DCI" or "mild signs and symptoms" because previously we wanted to avoid the judgment of mild disease.

DES GORMAN: Yes, I would support that. If we do a "global replace" here and take out "mild DCI" and put "mild symptoms and signs after diving," that would be explicit about what we're talking about, wouldn't it? What we're saying is that when we have anything beyond that, we're confident in the diagnosis. Short of that, we are talking about mild symptoms and signs after diving, which is not quite the same thing.

RICK LESSER: The reason the word "adequately" is in there is because you can always treat them, but the argument's going to be it wasn't adequate because you didn't recompress them. That's why it's in there.

PASQUALE LONGOBARDI: I'm deeply worried because before there was the sentence implying difficult logistics and so on. The current statement could apply to a patient, for example, near a large hyperbaric center. For me, it's important to state that this is applicable for remote locations and not when a good hyperbaric center is available.

DES GORMAN: Well, we've got to a point with Statement 4 where we're probably going to start doing those never-ending circles. Does anyone in the panel feel the need to change Statement 4 beyond its current construction?

JOHN LIPPMAN: The only concern I have is I don't want divers in the field to make the decision that DCI is only mild. I think there might be a proviso somewhere, a footnote, that "appropriate medical consultation should be used in conjunction with this."

DES GORMAN: I agree, there needs to be a clear indication that these subsequent statements are subservient to the first ones, because none of this makes any sense unless you accept the opening statements. You want it clearly specified that statements cannot be plucked out and quoted in isolation.

JOHN LIPPMAN: Yes.

DES GORMAN: So, Simon, each of the statements following on from 1 needs to be qualified as such. Otherwise, they could be used quite harmfully. I agree.

SIMON MITCHELL: Done.

KLAUS TORP: We just could make this one statement on one page so we don't have Statement 1, 2, 3, 4.

DES GORMAN: Yeah, sure. But the ability of people to take things out of context is legendary. If we preface each of these statements with, "Given concordance with Statements 1 and 2." But we can do that later on and then circulate that. Last question and then we'll move on.

EYKE BETINGHAUSEN: With regard to the healthcare system in Germany, there is significant emphasis on the UHMS regulations. By these statements, the German healthcare system, whether public or civilian, will draw the conclusion, "My DCI must not be treated by HBO," and, therefore, they will not pay for it. I think it would be very good to define remote as if treatment by HBO is not possible within three or four or six hours, then these regulations can be valid.

DES GORMAN: Presently, it is implicit in this statement that a diagnosis has been made and is robust. How does the panel feel? There are two ways we can present the statement. One is "mild symptoms and signs of DCI," which is an assumptive statement. The other one is "mild symptoms and signs after diving," which is not an assumptive statement, it's an observational statement. Which does the panel prefer, because there's no doubt that the issue you just raised about the problems in Germany are addressed by or worsened by an assumption of diagnosis here? Whereas, if we take a slightly more empiric view and say we're talking about "mild symptoms and signs after diving," this makes it a statement which puts you in a slightly less compromising position.

JAMES FRANCIS: I think this should be phrased in the same way as the first statement.

DES GORMAN: After diving.

JAMES FRANCIS: Yes. We should have consistent phrasing throughout these things with the first statement.

DAVID ELLIOTT: All I wanted to do with the business of the resolution without recompression was to add the proviso "but the recovery may be slower" or similar because if you can recompress, you can treat the pain. So "without recompression, but resolution may take a longer period of time."

DAVID SMART: This workshop is about remote area decompression illness. Nowhere in these four statements have we got any comment about remote decompression illness. We're now making a complete paradigm shift to making a statement about treatment of mild decompression illness in all cases anywhere. We need to define it.

GEORGE MACRIS: Again, in the context of being careful about other third-party payers determining this to be an exclusion of benefits, we have to make sure our language is clear that the provider or the caregiver or the experienced physician makes the determination who is to be treated and who's not to be treated. Otherwise, they're

going to take this and use it to deny care, deny benefits. That's my concern. I think we're moving in the right direction, but we have to make sure who is in command – who is in the position to make that determination that we can treat them with just oxygen.

RICK LESSER: First of all, I think the word "patients" indicates that they've already been medically intervened. Secondly, I think that if you stick that comment on the end (David Elliott's suggestion regarding slower recovery), you sort of unwind what you're trying to do, because you're putting it back to saying, "Gee, you're not adequately treating if they have to suffer and recover slower." I go back to my original statement. Either the workshop buys into the notion that "You can treat people without recompression or you can't." If we can't, we can't.

FRED BOVE: We're making potentially a large radical step today, and I don't think it's inappropriate. The way I see this, there's two different things we're trying to deal with. One is non-specific symptoms after diving which you may or may not need to treat, because we don't know for sure whether it's related to bubble disease. I think we're trying to say that those kinds of patients can be managed without recompression. That's a fairly straightforward question, because if you're comfortable that a lot of these folks don't have bubbles, you're comfortable with not recompressing them, and you can go through secondary treatment.

The other category of patients are those who do have bubble disease, but have very mild, what I'll call Type I symptoms. I think we're trying to get to the point where we're willing to say some of those divers can be treated without recompression, which I don't disagree with. I think David's point is that if there's a lot of severe symptoms, you would go ahead and treat them, but there are some who you can get away with surface oxygen and other medical therapy, even though you do make the proper diagnosis of a bubble-related disease. I think that's the big step we're taking today, and I don't disagree with that. We all know many, many cases of people with mild joint pain or a skin rash or whatever who didn't go to treatment and did fine and had no long-term consequences. I don't think it's inappropriate to make the statement. I think the implication that all Type I doesn't require recompression is an inappropriate implication, and we have to be careful not to make that implication. But it's appropriate to say that we could select certain true Type I's and treat them without recompression. We could still do that, and we're trying to struggle with getting the words right for that.

DES GORMAN: Well, we've got a statement here which is becoming probably less contentious with each iteration, that now states that "some people with mild symptoms and signs after diving can be treated adequately without recompression." That's a very robust statement. It then goes one step further and says, "Recovery may be slow." That doesn't say it will be and it doesn't say it'll be incomplete. I think most of us would have seen sufficient pain relief in the context of some decompression illness immediately with treatment to say that's a reasonable statement. There are two reasonable statements there consecutively. We need to move on a bit, so does anyone have any strong feelings about the wordings that currently are before we get some sense whether you'll support them?

RICK LESSER: When you put in "people" instead of "patients", you've now eliminated any inference that there's been medical intervention, which is what you need first. However, as soon as you start putting in that recovery is going to be slower (by not recompressing), you're putting back in the cost-benefit analysis that I thought you wanted to take out.

DES GORMAN: No, Rick. Slower's not a cost-benefit analysis, that's a statement of observation. Anecdotally and empirically, people with pain in decompression illness get better quicker when you treat them.

RICK LESSER: That will not eliminate what I thought we wanted to do, which was to see whether or not you can get away with non-recompression treatment.

DES GORMAN: I don't think it's what people are going to get away with, Rick. This man here had severe pain, and there's a chamber there, and he thought it was due to bends, and he'd jump in and make his bends go away. I think that's an option that he would want to have access to, and that's all that's saying.

RICK LESSER: OK.

DES GORMAN: OK. Does anyone feel any need to comment further on this? OK. Simon, let's move on to Statement 5, shall we? Do you want to read the statement out, Simon, please?

SIMON MITCHELL: The workshop recognizes that there will be some groups of divers competent in the appropriate use of 100 percent oxygen in diving whose members are willing to accept the risk of in-water oxygen treatment for mild decompression illness.

FRED BOVE: I think we ought to take the word "mild" out, and this would be a very nice statement.

JORDI DESOLA: Different point of view. I wonder if we need to have the statement. It has been clear this morning that these groups have always done this and continue to do now with or without our consent. On the other hand, we know that these have produced bad results in many, many cases. If we make the statement, we are simply supporting this attitude. My suggestion is to erase, to eliminate completely, this statement.

PETAR DENOBLE: That was my suggestion. If we agree that mild DCI can resolve without recompression, why would be put people at risk because this treatment includes some risks that are not outweighed by benefits?

ALF BRUBAKK: I think if we remove "mild," this would make perfect sense, because we have said in mild decompression sickness, we don't need to recompress them, but here we're saying something about all decompressions. If we take out "mild," I think this is OK.

MICHAEL LANG: Yeah. I'd like to see if we couldn't get away from the word "treatment" here and term it something like "advanced first aid." Twenty years ago, there was no oxygen treatment for the layperson. We got around that. Prior to that, there was no cardiopulmonary resuscitation training and so on for the lay people. We've gotten around that. If it's possible to change this treatment to some term that's called "advanced first aid" or something, I think that would fly better.

CARL EDMONDS: I was just going to say that I think you've qualified it enough to remove the word "mild."

MARK BROWN: "Advanced first aid" is more the way I was looking at this – the acknowledgement of some pretreatment or advanced first aid before you get to chamber or recompression treatment. It didn't necessarily mean that you're then going to just leave the entire treatment to the tech divers, just that it's a first aid option.

MICHAEL LANG: Plus, if you think about it, this should really be taken out, because you qualified that all this is for recreational diving.

DES GORMAN: I'm not sure that's right, Michael.

SIMON MITCHELL: Well, it's recreational diving, but I think technical diving is a form of recreational diving.

ALF BRUBAKK: I will support Michael in using "advanced first aid" or something like that. I think the main reason for that is that it changes the perception because, if you call it treatment, this elevates it to the level of Table 6's or similar as definitive management. "Advanced first aid" would imply that it is not a final treatment. It may be, but it is not necessarily final. I think we have to avoid that implication.

JOAN TAYLORS: I object to the word "competent," in that is there some certifying agency? Is there some certification process? Is there some clear-cut pathway for the judgment that these individuals are capable of performing in-water recompression and treatment?

SIMON MITCHELL: It's actually not what the statement says. It says "competent in the appropriate use of 100 percent oxygen in diving," and there is all of those things (training and certifications) for that.

JOAN TAYLORS: But in this setting as an in-water treatment, it's implying, even though it is separate in the phraseology, that they're competent to use 100 percent oxygen in recompression.

SIMON MITCHELL: No, it's not saying that.

JOAN TAYLORS: Well, I think it implies that, and I think that there is no such process.

DES GORMAN: We can put that as a footnote.

JOAN TAYLORS: Please.

JOHN LIPPMAN: I think the statement's a "nothing." I thought we voted earlier that we believed it could be an effective first aid management tool in remote DCI. I think that necessarily says it. It says that people are competent in the use of 100 percent oxygen in diving; it doesn't say anything about management of DCI. It doesn't say anything to the effect that its use can be effective when necessary.

SIMON MITCHELL: It's a big jump from that though, John, to us actually recommending it on the end of the phone. That's the problem.

JOHN LIPPMAN: The reality is, it can be effective, and maybe we should acknowledge that. We know that.

FRANS CRONJE: Am I missing something? Why aren't we calling it in-water recompression and leaving it at that?

PETAR DENOBLE: I'm confused. We were talking about management of mild or marginal decompression illness. We agreed that there is no need in situations that we exercised this morning here to treat people with recompression. Now we are coming with this, and we are not limiting ourselves to "mild." So I think this statement doesn't belong in this setting.

SIMON MITCHELL: It's possible that we can delete the whole thing.

DES GORMAN: My view, Simon, is that this doesn't sit well with the train of consensus statements we have made – sensible or not, as it may or may not be. I mean, what does this contribute to the evolution of thought? I wonder if this looks out of place here. Does anyone feel strongly that we should retain this sort of statement in this sort of series of consensus comments? To me, it looks out of joint. I'm not arguing about its merits, I'm just saying, is it out of joint?

BOB WONG: Delete it.

JAMES FRANCIS: The whole thing's about mild DCI. We've just agreed to get rid of the word "mild." We should get rid of the statement.

SIMON MITCHELL: Gone.

RICHARD SMERZ: I was just going to make the same statement that Frans did. When we start talking about trying to water down the statement so it's more accessible to everybody, I think we diminish the importance of the fact that in-water recompression therapy is in fact a recompression event and needs to be properly undertaken, properly effected. It's not just first aid. There is a huge process associated with that.

DES GORMAN: I'd agree with that. Although it was discussed here in the context of remote area treatments, this is not a workshop about the first aid or initial management of recompression. It's a specific workshop about how to manage mild disease in remote locations.

MICHAEL LANG: You might take a look at your decision tree, because under Statement 4, it specifically asks for recompression onsite of which in-water recompression is an element.

CHRIS WACHHOLZ: I think it should stay in, because we know it's being done with some success. Acknowledging that, there's a lot to be done to allow people on-call to rely on people doing it, and I think eliminating this statement or some statement about it will not encourage us to continue to look at this as an option.

DES GORMAN: We need to move on, because I'm cognizant of the time. What we'll do, Simon, is simply reflect that it was discussed, that there were people that felt strongly it shouldn't be included. We'll put it in the footnotes that this is something which people did discuss. We do need to move on now to look at these last two, because these last two have quite significant implications. I'm sorry, Rick. I think we'd better just kick along.

SIMON MITCHELL: We've provided two options for Statement 7.

The workshop consensus is that patients with stable or remitting mild decompression illness can be transported for recompression by commercial airliner after a surface interval of 24 hours or more.

Or:

The workshop acknowledges that transport of patients with stable or remitting mild decompression illness by commercial airliner after a surface interval of 24 hours or more is unlikely to be associated with worsening of outcome.

DES GORMAN: What I'd like you to do, please, is comment on the generic statement – which of these two you prefer. Don't worry about the words "mild DCI." We'll make the generic replacement as suggested before to "mild symptoms and signs after diving" so that we're not making any implicit value judgments.

MICHAEL BENNETT: I much prefer the second of the two. The first has some implication in that I can see someone hanging around for 24 hours in order to wait to fly back, and I'm not sure that's our intention. In other words, they might be treatable, but if we hold them for 24 hours and hope their symptoms don't get any worse, then that may legitimize commercial airliner transport. I'm not sure that's quite the sense I'd like to derive from it so I think I prefer the second for that reason.

DAVID ELLIOTT: I'm a little bit unhappy with only 24 hours before flying as the result of the one case which I presented of the slow progression of somebody who hadn't

been treated. I think the issue here is you're putting somebody into the sky who is dodgy. I'm not happy with either statement.

DES GORMAN: I know what you're unhappy with. I'd like to know what would make you happy, David?

DAVID ELLIOTT: As far as I'm concerned, if anybody still has symptoms and they're not flying off for treatment elsewhere, then why do they fly?

DES GORMAN: If you want to change the time, you're arguing about the time here, David? Or are you arguing about the concept at all?

DAVID ELLIOTT: I'm not going to force my view because I'm not in this field. I'm basically unhappy with somebody who has stable symptoms just 24 hours after a dive getting in a plane.

DAVID DOOLETTE: Our intention when we wrote this statement was that this was a means of getting people with DCI somewhere for treatment.

DAVID ELLIOTT: OK. Well, that needs to go in.

GEORGE MACRIS: I'm comfortable with the statement, except I think it's too open-ended, because you have to specify a flight duration. You can't just say "15 hours" or what have you. We have to put in whatever the data shows. I think DAN has some information. I know for us, 100 minutes is safe. But to go on and say that a diver has to wait 72 hours after treatment to fly contradicts this. We need to qualify this with a time. Yes, you can commercially evacuate people after 24 hours of remitting or stable symptoms, but it has to be for a flight of a certain duration. We may even put a certain altitude. Otherwise, I think it's dangerous.

FRANS CRONJE: There appears to be a slight non sequitur here. We've just said that mild symptoms don't need recompression, and now we're willing to fly them for recompression.

DES GORMAN: Frans, the earlier statement referred to "some people." We were quite qualified in that regard.

RICK LESSER: I think we've got that same problem with Statement 8 as well, and certainly with Statement 7A, because it says that if they've got stable or remitting mild symptoms and signs after diving, then we can fly them for recompression. It seems to imply that that's your only option. And when you look at the next one, Statement 8, after treatment do we have to say "recompression in hyperbaric oxygen" or "after treatment" period?

DES GORMAN: No, we'll come to that. Simon, let's go back to Statement 7. We put, "The workshop acknowledges that transport of patients for treatment." That implies exactly what you're talking about, David.

DAVID ELLIOTT: Yeah. This is why I tripped up, because your statement doesn't have full recompression. It's only the first statement that had full recompression. That's why I tripped up over that statement.

DAVID SMART: Semantics. Are we really going to recompress them using a commercial airliner, because that's the way it reads at the moment if we convert "transported by commercial airliner for recompression?"

SIMON MITCHELL: Which statement are we going to run with?

DES GORMAN: Simon, just get rid of the top one, because I've heard no one support that. In the interest of time, let's pretend it isn't there.

Editorial note: There was a short discussion to modify the statement to reflect Dr. Smart's semantic concerns.

PETAR DENOBLE: I suggest we should reconsider qualifying 24 hours post-dive that we used in previous statements, and we should use 24 hours after symptom onset. In many cases, people develop symptoms in 18 hours post-dive, and 24 hours post-dive you still cannot say that the symptoms are stable. Usually, these people are those who have worsening during the flight. If you have somebody under observation for 24 hours after he has developed symptoms, you could say that he's stable and is not likely to get worse.

JOHN ROSS: I would agree with that. You're talking about after symptom onset here and not surface interval, because you've already said earlier on in this symposium that we're going to accept symptom onset of up to 24 hours.

DAVID ELLIOTT: But that doesn't handle the problem of denial, which is one of the biggest problems one has in this game. It could be 48 hours after the dive instead of 24 hours after the reporting of the first symptom.

JOHN ROSS: What this is saying is you need a stable time period before flying. That period of stability has got to be something like 24 hours.

GREG EMERSON: I presume that you're talking about flying without oxygen. I just wonder for clarity for people who aren't used to organizing transport. You need to clarify whether or not to utilize oxygen on the commercial plane.

DES GORMAN: I think we can put that as a footnote, Greg. There are a series of things that we think should accompany that sort of retrieval. In the interest of time, we'll fiddle with the English of this subsequently, but in terms of the general idea that if someone's had disease for more than 24 hours that's remained mild, then a commercial airliner remains a viable option. You made the point about short haul, and I think that's a point that you want to come back to obviously.

GEORGE MACRIS: If individuals who do not have overt DCS can develop symptoms of DCS on flights after they wait 24 hours, I think we need to qualify it with some duration whether it be maybe "short haul" or something similar.

FRANS CRONJE: Would it be helpful to change "transport" to "medical evacuation by commercial airliner," because that's really what we're doing here to get someone to treatment? It makes provision for all the oxygen issues, duration of flight, and everything else.

CHRIS WACHHOLZ: Yeah, I think one suggestion would be, instead of "24 hours or more," to make it "at least 24 hours." Emphasize that longer would be better. Certainly, in the cases that we talked about yesterday, most of them were well beyond 24 hours. The second point is maybe we should say "some patients," as we did in Statement 4, just to aid the ability of the physician to select which patients would be appropriate for this.

DES GORMAN: I'll take the liberty of ending this now so we can move on the last one. Simon, we'll take on board that this needs wordsmithing and then redistributing. I'll take George Macris' point about short haul. We just need to put a footnote there that the experience to date applies mainly to short-duration flights. For long haul flights, this statement's probably not robust. So let's move on to the final one then, Simon, Statement 8, please. This is not the same. This is now looking at successful treatment and the conundrum of how long after successful treatment must a diver wait before flying.

SIMON MITCHELL: Statement 8. The workshop endorses repatriation on commercial airliners after treatment – that is recompression and hyperbaric oxygen – and complete recovery for mild decompression illness after a post-treatment wait of three days minimum.

ALISON DREWRY: Again, this is semantics, but can we just take out "repatriation" and just make that "transport" or "travel" or something like that? It's not necessarily repatriation.

DAVID ELLIOTT: Just exactly as we said before, we need to relate this to the duration of the flight. Alf, correct me if I'm wrong, but I think we have said for intercontinental travel, a minimum of seven days. That's for the commercial divers. I think that a wait of three days' minimum is correct, but I do think we ought to say "in relation to the duration of subsequent flight" and add what John said earlier too, maybe as a footnote, "arrangements should be made for receiving unit to assess them on landing."

DES GORMAN: That's the sort of thing which I think will sit well on a footnote, David.

ALISON DREWRY: I thought that the data that we saw yesterday suggested that five days was probably a better point at which the relapse rate became kind of constant.

JAKE FREIBERGER: The data that I showed yesterday did indicate that in the symptom-free diver after treatment – the diver who has had good response to recompression treatment – that flying after three days is fine. Five days was when the relapse rate stabilized. It may be advisable to indicate that if there are still symptoms that that time may need to be longer.

DES GORMAN: It's probably easier to have an inclusive statement. There are two things. You can either have "after successful treatment" to make it three days, or you can make that five days as a generic. Probably the second covers the base better.

ALF BRUBAKK: We have to think about the fact that the data presented yesterday are based on treatment using pressure. We are now talking about treatment using oxygen, and we know nothing about what happens. How long will these bubbles survive if they're not treated by pressure? Maybe we need longer times because of that. I don't know the answer obviously, so three days? Let's leave that. But still we probably have to suspect there may be a different situation than we had from your data.

DES GORMAN: Thank you. That's a very valid point.

CARL EDMONDS: I'm glad you think that, because I think the statement's wrong anyway, so I can't see why we're putting it up. Secondly, I would be worried about doing anything that's going to limit the options of the supervising diving medical officer. I think if he believes that the guy can fly – with his knowledge of the dive profile and the treatment given and the post-treatment oxygen given – if he thinks the guy can fly two minutes after he makes his statement, then I think he should be allowed to do it. I don't think any of you have got the experience to be able to cover all the different diving accidents that are going to happen. I think the whole thing should go.

DES GORMAN: Simon, one of the things I heard in the point that Jake was making before is that this statement may look better if we say "the workshop recognizes the level C data to show that...," and just turn it into a statement of what was presented yesterday. That takes out the opinion element and simply states what was presented which was that there is – was it level C or level B?

FRED BOVE: I think it should be level C. I think level C is individual studies and consensus of expert opinion, whereas, level B is one or two randomized clinical trials. I think everything we're talking about today should be level C.

JOHN LIPPMAN: I think the way that's rewritten will cover my concern. My concern is that there needs to be a minimum, and I didn't agree with what Carl said that the physician necessarily could say 10 minutes or so. There's a huge range of knowledge with diving physicians in different parts of the world, and some of them aren't exposed to mainstream diving medicine, so I think you've got to have a minimum.

DES GORMAN: This is not the complete statement. We need a suffix for this to actually make sense. If we make it literal, I think that's the easy way for us to get out of here by 4:00. The literal data were that this was associated with a relapse rate of 10 percent.

Is that correct? Our experience in Australia is exactly that, by the way, that in a group we treated with a mean number of treatments of nine over a mean period of 10 days, the relapse rate going out over the Adelaide Hills by train was 10 percent. We had to fly 10 percent back. That's exactly what we found.

ALISON DREWRY: The data from yesterday showed that if you waited five days, it was 10 percent "forever."

JAKE FREIBERGER: I'm sorry. I'm not willing to put an absolute relapse rate on this data. I don't have that degree of confidence in it, and I don't think that anyone has good data on what the actual relapse rate is after complete treatment for DCI. I think it's almost impossible to say. Now, we can say that the data did seem to indicate that the divers that still had symptoms after being treated relapsed at a higher rate than those that did not have symptoms. That's all I'd be willing to say at this point. I'm not going to say that there's a specific number.

DES GORMAN: Any final comments before we wrap up this particular one?

SIMON MITCHELL: Well, I actually don't know what to put on the end of it yet. What are we saying?

DES GORMAN: Simon, you could change it to "recognizes on the basis of level C data that transport on commercial airliners after recompression and complete recovery can occur three days after treatment."

PHIL BRYSON: First of all, thank you, Jake, for accepting that some of your data really isn't that hard. We've worked with Dick on this, and he's accepted fully that that data is not hard. I would be very cautious of putting that in. Secondly, we have surveyed a huge number of chambers with Robin Barnes from New Zealand. We've got replies from quite a few of them, quite a high percentage of them, and none of them had any data to suggest what they were advising was based on any science whatsoever. Thirdly, probably the largest group said 72 hours post diving for intercontinental travel, so that was the Caribbean back to the U.K., back to Germany, back to Italy. They claimed they had no evidence of a high relapse rate. When asked whether they followed their divers up, almost none did. The SSS chambers are probably the only group that we know of that have tried to come to some sense on this by themselves by following up their patients, and maybe we could encourage them to take that a little further, if possible.

GEORGE MACRIS: If we don't eliminate the word "complete," we're going to have people trapped in places for a long time. Regarding the data, I think right now the DAN recommendation of three days seems to be appropriate. We haven't seen a problem in the long hauls at three days, but I would just eliminate "complete," because if you have a little "wooliness" or what have you, when can you legally move a person? If they do relapse, where are you going to stand?

DES GORMAN: I think we may put that as a footnote.

KATHY MEEHAN: What happens to those people that are not treated with recompression? Is there a Statement 9?

DES GORMAN: We're simply saying these are the data that exist which is a reflective statement rather than an opinion statement. What we're going to drop in there, Kathy, is a couple of footnotes about the data presented about people with persistent symptoms to show that they don't conform to that.

KATHY MEEHAN: No, the question I'm asking is, what's the recommendation for the divers that these symptoms have resolved with adjunctive therapy and how long before they can fly?

DES GORMAN: Well, that's the point. We're not making a recommendation because we have no data to make a recommendation on it.

KATHY MEEHAN: So what happens to them? Stay there forever?

JAKE FREIBERGER: I want to clarify the data. It did not say anything about three days. It simply said that those divers who flew within one day had a higher relapse rate than those who flew greater than one day. When Dick did the analysis that showed five days, that was really a little bit far out. We can't really accept that as strong data. I believe that three days is probably adequate. I don't think you need to have a statement about complete recovery because those divers that have not completely recovered after – just leave it "without complete recovery."

CARL EDMONDS: If you send a patient up in an airplane seven days after your treatment, you've got the person stable, you're finished your treatment. If you send someone up seven days later and they get a recurrence, then your treatment is wretched. If they get a recurrence three days after, your treatment needs to be revised, because you can do better. If you really treated someone correctly and fully, they can fly. They're the same as the rest of us.

FIONA SHARPE: In the context of remote locations, if the diver goes on their next leg of the journey in four days and they then get bent, will they come and see you for the cost of their ongoing holiday? This is something that Chris Acott brought up in the Phuket meeting. Are you determined that the person is safe after four days, and are you then going to cover their costs if they do have a relapse after flying on day four?

DES GORMAN: Well, if you read that, it's actually a remarkably heavily qualified statement. The more honest statement here, and one that I would rather it were, is that we have no idea when people can fly after treatment, because there's no consistent data. If that's what we want to say, then we can. How do people feel about this? We have two choices. We can go with a statement that simply says, "This is not our opinion. This is simply the data presented as it is." That's all it says, nothing more than "these are the data that were presented to us." Or do we simply shrug our shoulders

and say, "We actually don't know?" We've got two choices. They're both reasonably viable. This is one that simply says that these are the data that were presented, full stop.

FRANS CRONJE: How about saying, as it is, that there is level C data that indicates that "earlier transport by commercial airline is represented with a higher relapse rate than after three to five days" and leave it at that?

JAMES FRANCIS: Jake has just told us that the statement up there does not actually reflect his data. The data are of very poor quality anyway, and I don't know why we're saying this.

DES GORMAN: Anybody else? Does anyone feel the overwhelming need for this statement to be made, or are they happy with – which would be my preferred option – simply saying that we don't have the data to actually answer this question at the moment? What do people think?

FRED BOVE: It wouldn't hurt to take it out because I think the standard of practice, or at least around the Caribbean, is three days after treatment for any kind of treatment for DCI. But reflecting what was presented in the meeting as a simple statement of fact is reasonable, but it's getting hard to do. It seems to me that it wouldn't hurt to just take it out at this point.

JAKE FREIBERGER: This statement as presented is not correct.

DES GORMAN: Well, Simon, what we need to put there is that the issue was discussed, that we couldn't agree on how to describe the data, and that, in fact, we have no other basis to actually make an alternative statement. I think we should actually say that, and I think that's probably it.

Well, surprisingly, we are 11 minutes over time, but nevertheless, have you got anything else you'd want to do? I'd like, on behalf of us all, to thank Simon and David and Lynn for this session. I think what we have produced are a series of very sensible consensus statements which would at least help advance to some degree the management of people in remote locations, by identifying where there is uncertainty, where is some certainty, and where there's some statements which can be made with confidence. That's always a good thing. Thank you all for your participation this afternoon.

I think we've probably got it, Simon, pretty much to where you want it to be. Is that correct?

SIMON MITCHELL: Very good.

DES GORMAN: Thank you.

APPENDIX A

TREATMENT OF DCS CASES IN REMOTE LOCATIONS: A 1965-1990 SUBJECTIVE POSITION PAPER, ILLUSTRATING THE TRAPS, MISTAKES, AND LESSONS LEARNT

Carl Edmonds
Sydney, Australia

Overview

My experience extends from the mid-60s to the early 90s. It may not be appropriate to extrapolate to earlier or later times, but I have done so. Certainly, the scientific data on which to devise protocols for remote treatment of decompression sickness (DCS) were not available during those years, and most of the decisions and developments were based on observations and mistakes.

This is not so any longer, thus the appropriateness of this workshop. Statistical evidence will gradually overcome anecdotal clinical experience.

In the mid-60s, the only available and practical treatment chamber in the Australian area was based in Sydney. Treatment responsibility was taken by the Navy for the armed services, police, recreational, and most commercial divers. From 1967 onwards, it also covered most of the Indo-Pacific Islands.

Local recreational diving was booming, as was wreck diving, abalone and pearl diving, and tropical diving holidays. Innovative but inadequate decompression meters flooded the market, and the flotsam drifted into our chamber at about one per week.

At that time there were popular simplistic mantras that had gained the imprimatur of fact. These included:

- Any symptom developing after diving must be presumed to be DCS unless proven otherwise; and
- Response to recompression proves the diagnosis.

How any astute physician could have accepted such criteria is beyond comprehension, now. But then, it was the conventional teaching. No one would have suggested the analogies that every coal miner with a cough suffered from silicosis, or that relief after surgical excision of the Piriform sac was proof of its pathology.

In fairness, there was an explanation for the dogma at that time. Most of the divers in previous decades were young naval ratings, free of medical diseases or coincidental treatments, and physically very fit. Such young men rarely had other serious illnesses presenting during or after a dive, and most diving diseases were not well understood except for DCS and pulmonary barotrauma (PBt).

Under these conditions, most cases not due to PBt were diagnosed as DCS, and if that was the correct diagnosis, then response to recompression gave some diagnostic validity. Neurotic responses and positive placebo reactions were not characteristic of this unexcitable, water-skilled population.

During the 70s, two separate therapeutic worlds developed. The working divers' successful underwater treatments of DCS were considered routine by their fellow divers – but not promulgated by the media or prestigious journals.

Concurrently in large cities, universities, and major hospitals, hyperbaric facilities developed. Academics and medical professionals, whose voices carry further than those of divers, became more influential, and they often decried the activities of the lay divers. Research grants and superegos both played a role, and diving medical experts flourished. They advocated one option – medevac retrieval of DCS injured divers, back to their own sophisticated facilities.

Unfortunately, to an enthusiast with a hammer, everything looks like a nail. The hammer and nail analogy applies to compression chambers and DCS.

Many mistakes were made in both diagnoses and medevac protocols, with divers arriving at the hyperbaric destination either

- with an obviously different disease,
- totally cured without treatment, or
- sometimes, in a much worse clinical state

Clearly other options needed to be considered and the indications for medevac clarified.

A Task List for these indications includes

1. Diagnosis
2. Severity of DCS
3. Options for DCS Rx
4. Medevac
5. Medevac Problems

This list, although reflecting the chronological presentation, is also in order of importance. Most misadventures stemmed from inadequate attention to the first two.

Diagnosis

Appropriate treatments rely on accurate diagnoses. Before arranging a medevac for DCS, one should ensure that it exists.

Fortunately the diagnoses of DCS and PBt, with its complications, were (and still are, by me) considered separate entities. The hotchpotch "acute DCI" had not come into

vogue, and the provisional diagnosis was made by clinicians able to differentiate between the two. This would not have been the case if inexperienced personnel took the medevac request.

In the 1970s and beyond, more specific diving diseases were defined. Normal people of advancing age and with many general medical disorders and on drug treatments were enticed into the field. Many were not physically fit and often not at ease in the aquatic environment. Marketing skills, more sophisticated equipment and better facilities extended the diving exposures.

Instead of a self-selected population with aquatic skills and extraordinarily low trait anxiety (Eysenck neuroticism scores of <3), diving was being attempted by all and sundry. This new population was not dissimilar to that attending a General Practitioners consulting room – with over half the complaints being psychosomatic, neurotic, or stress based.

Thus, as well as DCS, a plethora of diagnostic possibilities emerged. These needed to be differentiated before the aviation cavalry was summoned.

On receipt of a request for DCS medevac, other possibilities needed to be excluded. These ranged from

- Pre-existing disorders
- Drug effects
- Other diving disorders
- Diseases associated with diving environments
- New psychoneurotic problems

Some of the cases that have presented as requiring medevacs, but which we managed to abort, included the following:

Pre-existing Disorders

- Migraine, multiple sclerosis and other neurological diseases
- Musculoskeletal and arthritic disorders
- Anxiety states (especially the hyperventilation syndrome), psychosomatic and somatoform disorders, including the Baron von Munchausen syndrome

Drug Effects

There are so many drugs with so many different adverse effects that these can only be assessed on an individual basis and compared with the presenting symptoms. The adverse side effects can be toxic (dose response), or an individual response (allergies, disease aggravation). The drug reactions mimicking DCS may be predictable or unpredictable.

Some drugs have predictable side effects, such as the production of paraesthesia by carbonic anhydrase inhibitors (hypotensive treatment, or glaucoma ocular drops) – provoked by long-term immersion and diving. Beta-blockers may also fall into this category.

Occasional, unpredictable side effects can occur from any drug, but some are more likely than others. Anti-cholinergics and antihistamines, often used as anti-seasick medications and decongestants, are provokers of urinary retention in males with prostatic hypertrophy, and acute glaucoma in the aged. Both have presented for DCS medevacs. Anti-malarials, especially mefloquine, have side effects which mimic vestibular and neurological DCS.

Other Diving Disorders

These are frequent and often aggravated by aviation exposure. They are the reason why medevac decisions should be made by clinicians with a comprehensive knowledge of diving medicine, and not merely an on-call resident. The diving diseases include:

- Sinus barotraumas (esp. sphenoidal)
- Ear barotraumas (esp. inner ear)
- Complications of URT barotraumas, e.g., cranial nerve damage
- Aspiration syndromes
- Cardiac disorders
- Pulmonary oedema
- Gas toxicities from O₂ and CO₂, mainly with technical diving
- Gas contaminants, e.g., CO, nitric oxides
- Headaches. DCS is one of 13 causes listed in one text (1)
- Vertigo. DCS is one of 18 causes listed in one text (1)

Diseases Associated with Diving Environments

- Malaria
- Cardiovascular accidents
- Cerebrovascular accidents
- Meralgia paraesthetica
- Lateral epicondylitis (tennis elbow)
- Other musculoskeletal stresses and disorders
- Skin reactions from equipment and environment
- Marine envenomations (Irukandji, blue ringed octopus)
- Scromboid poisoning

This is not a complete list of possibilities. I am still waiting to be caught out with cone shell envenomation and the other fish poisonings.

New Psychoneurotic Problems

Because the diving environment can be more stressful than those previously encountered by the aquatically unskilled novice, these psychiatric stress disorders may present without a previous history, especially in the young.

To exclude all these differential diagnoses, it is necessary for the diving medevac consultant to interrogate the patient, the dive instructor / leader, and a physician / health care worker or Good Samaritan on site. Communication intermediaries, be they well-

meaning paramedics or on-call anaesthetic registrars, are inadequate decision makers. They are, however, extremely useful in an organisational role.

Interrogation of the patient clarifies the clinical features and their sequence. Thus symptoms commencing pre-dive or at maximal depth can indicate non-DCS causes. It is also necessary to exclude existing diseases and recent drug intake. Previous diving problems may be relevant, as may recent diving exposures.

The dive instructor / leader clarifies the dive profiles (verifying the maximum possible depth and dive durations), environmental conditions, first aid and follow-up treatments, and problems with other divers. Others may become affected (e.g., with DCS, gas toxicities, etc.), and thus the dive leader should be instructed to follow up these other divers.

The health care worker cannot only perform basic neurological status exams, but may also be able to inspect areas of symptomatology (vision, hearing, weakness, ataxia, etc.) under instruction, and quantify the severity.

In some ways consultants, nowadays, have it easier. We had to rely on a description of the type of skin lesion given by the worker, but with digital cameras and internet access, a digital photo may be sent immediately and direct to the consultant as a JPEG file by email! Even a video of ataxia can be forwarded.

Mistakes that I have made include medevacs for paraesthesia (hyperventilation syndrome made worse by aviation exposure), and lateral epicondylitis (induced by carrying scuba cylinders). I have made this latter mistake twice, but only medevaced one.

A checklist covering the above disorders and many others is of value. It is inadequate in itself. It is not an alternative to expert clinical judgment. If the diver presents with a painful right elbow, interrogation will focus on activities involving that joint. Extensive interrogation on middle ear equalization techniques is not needed. It is needed, and must be very penetrative, if the presentation is dizziness. Each case requires clinical expertise and flexibility.

DCS Severity

If the provisional diagnosis is DCS, an assessment of severity is mandatory.

The vast majority of DCS cases do not result in death or permanent disability. As a corollary, they do not require costly and potentially dangerous medevacs. The latter should be limited to the severe DCS cases.

Opinions were expressed that unless one transports and treats mild DCS cases with recompression therapy, the patient was at risk of dysbaric osteonecrosis. This was a disingenuous argument, as the complication is very rare and there was no evidence that late treatment associated with medevac (many hours after the injury) had any influence on the development of this disorder. On the contrary, the argument is more an indication for immediate underwater oxygen treatment.

In the pre-90s, there was little scientific data which could be used to predict severity, but there was a lot of basic decompression physiology known and a plethora of clinical experience from cases (diving, caisson and aviation).

If one correctly diagnoses DCS, then removes the "severe" cases, we are left with the mild cases – the alleged focus of this workshop. The predicted "severe" cases comprised those with:

- DCS developing during ascent or decompression staging
- DCS soon after ascent (within an hour or so)
- Objective central neurological impairment
- Cardiopulmonary symptoms
- Progressing symptomatology
- Other evidence of serious DCS, e.g., cutis marmorata, girdle pain, etc.

The longer the delay in oxygen and hyperbaric treatment of serious cases the more ominous the prognosis. Thus, the importance of this distinction.

The cases classified as minor include those that have not the above manifestations and that have been surfaced for some hours. The specific period will depend on the dive profile and the symptomatology / pathology.

Minor symptoms are those that will not cause death or permanent damage. They do not necessarily equate with the degree of discomfort.

The clinical experience accumulated over these decades should not have been necessary. The above guidelines could have been deduced from an appreciation of the differences between fast-tissue DCS and slower-tissue DCS, and a knowledge of the pressure gradients between tissues and bubbles. Rapid outgassing of inert gas from tissues, as opposed to the slower outgassing from bubbles, ensures that there will be little inert gas inflow, expanding the bubbles of DCS, after a few hours. The exact time will depend on the dive profile, but would rarely exceed five to six hours for recreational dives. (The background for this conclusion is the many outgassing experiments from Behnke onwards, up to the PADI wheel development.)

Of course, one could expand the bubbles and aggravate the disease by further diving or aviation exposures, so advice was given to avoid these provocations.

Options for DCS Rx

Over those decades we were subjected to a host of alleged therapies for use in the absence of recompression facilities. They were all clinically unimpressive, although this does not denigrate some reports illustrating a statistically significant effect. They included:

- Acupuncture
- Alcohol
- Anti-inflammatory drugs

- Aspirin and other anti-platelet drugs
- Heparin and other anticoagulants
- Hypothermia
- Lignocaine
- Steroids
- Vasodilators

Some are still employed and may be indicated for specific symptomatic benefit (NSAIDS, Lignocaine, etc.) but have little general application.

Hydration has always been advocated, but the intensity of debate over the appropriateness of different types of intravenous fluids has been excessive. In practice, one not only avoids glucose containing fluids, but all other intravenous infusions in preference to a variety of light oral fluids, including water – and leaving electrolyte and colloid fine tuning to the kidneys. This is certainly so with the "mild" cases.

Symptomatic treatment is axiomatic. Obstructed bladders need catheterization and epileptic convulsions need diazepam or its cohorts. These cases do not fall into the "mild" category.

Positioning may be of import, and we usually advised the patient to lie quietly, supine, at least for the first hour or so. Avoidance of activity seems reasonable, to reduce the bubbling effect on the gas load and to deflect any existing intravascular bubbles away from the brain.

Oxygen has been used effectively to prevent the development or worsening of DCS since Paul Bert in the 19th century. He preceded both our introduction of this treatment, and similar French proposals, by almost 100 years. It works, both as a preventative and a treatment.

The amount and availability of oxygen, together with its method of delivery, should be clarified at the outset. Supplementation may be necessary, independent of any medevac, as the latter can be sometimes unavoidably delayed. Sources include diving operations, ships, neighbouring islands or towns, hospitals, garages and other industrial sites. Industrial oxygen is acceptable.

The use of various other treatments in the absence of the gold standard, recompression therapy, has been discussed, but why? The hyperbaric facility is at the end of the wharf, or off the dive boat. It is even more effective than oxygen alone for a plethora of reasons (1). It also usually changes a developing severe case into a mild or cured case. Our abalone and pearl divers commandeered this in the 1980s and now have it down to a fine art, as have some technical divers in the 1990s. It even squeezed its way into the U.S. Navy diving manual in 1985.

One regimen that has not been exploited is the use of oxygen post treatment to prevent recurrences and to remove tissue nitrogen pressures and bubbles prior to aviation exposure.

Another regimen still not adequately explored is the use of surface and underwater heliox as a treatment gas. This begs further experimentation.

Medevac

Delayed cases, even serious ones, may respond as well to surface oxygen as to recompression therapy, they just take a little longer. I would question the value of most emergency medevacs undertaken 24 hours after the commencement of symptoms. Surface oxygen and an elective medevac may be adequate and safer.

The options within medevac are many. They include transferring medical staff to the site or patients from the site, chambers inwards or chambers outwards, fixed wing or helicopters, pressurized cabins or non-pressurized cabins, surface or air transport, emergency or elective medevac, government or commercial organizations.

Originally, I preferred to transport portable chambers to the site if others could not be acquired nearby. In either case, I and my team would travel to the area to use them. This was often very successful, but logically, it had problems.

Use of Air Force medevac, with well-trained staff to administer first aid in a 1 ATA pressurised cabin, also had some successes, but delay in treatment was frequent.

The importance of early treatment (at least with serious cases) had been observed by all and verified by Rivera in 1964. He illustrated the dramatic reduction in success and the increase in residual symptoms as the treatment delay extended from half to six hours. Others showed that increased treatment depths were required if treatment was delayed.

Surface and underwater oxygen treatment was introduced by us around 1970, especially for mild cases but because of its success, it rapidly extended to encompass serious cases. The advantages and disadvantages are described elsewhere.

With serious cases, we then used underwater oxygen treatment during the pre-arrival time of the medevac aircraft, to reduce pathology, followed by surface oxygen. This was so successful that we rarely needed the transport.

The Defence Forces then relinquished monopoly and control of Australian medevacs to a variety of enthusiastic hyperbaric units. The newcomers seemed to revert to the "all cases, big and small, must come to Mecca" protocol, possibly because of inexperience.

Cases with an isolated complaint of paraesthesia, or a patch of hypoesthesia, were designated as "neurological" and treated as genuine emergencies. The former often had other aetiologies, and I have never heard of anyone dying from a patch of numb skin.

Medevac Problems

Some of the main medevac problems were:

- Functional aircraft are not always available
- Delay. Not only due to distance, but also to over-optimistic ETAs, mechanical problems, inclement weather, etc.
- Excessive movement of patient
- Vibration effects
- Logistic difficulties and inadequacies with transport of treatment equipment, e.g., recompression chambers, compressors and gas cylinders
- Logistic problems supplying oxygen at airports and on commercial aircraft
- Interference with specialist communications en route
- Loss of continuity of treatment
- Cabin pressurisation not as promised
- Psychological stress disorders
- Adverse effect of altitude exposure on DCS pathophysiology
- Costs, both for individuals and on insurance premiums
- Management of cabin atmosphere (high oxygen concentrations from patient and chamber) may pose added dangers of fire and explosion
- Aviation dangers to crew, therapists and patients. The flights were not routine. Aircraft preparation had to be expedited. Maintenance and support staff were recalled but, like crew selection, availability took precedence over capability. Flights and landings were navigated into areas not well known, often at night.

The decision to medevac is a serious one, sometimes abrogating the Oslerian principle of *primum non nocere*.

Determining when a less serious post-DCS patient can fly on commercial aircraft, is less contentious. The problems are twofold.

1. The effect on bubbles and tissue inert gas. If there is any persistence of DCS bubbles, the altitude exposure could aggravate the pathology both from the effects of Boyle's and Henry's Laws. The relative hypoxia may also not be acceptable.

If the patient has spent more than 24 hours on the surface after the dive, the tissue inert gases will be normal. Bubbles may persist for an indefinite number of days but will not expand without diving or aviation exposure.

If the patient has been given some hours (say 4-6) of 100 percent oxygen inhalation following relief of symptoms, it is difficult to believe that any gas bubbles will remain, and tissue inert gas will be negligible. Aviation exposure is safe, but if further assurance is required, oxygen could be breathed en route.

2. A lesser problem is the recurrence of minor neurological symptoms, usually paraesthesia, in a post-DCS patient when exposed to aviation exposure – long after all bubbles have disappeared. This would not create any difficulty except when some enthusi-

ast then subjects the patient to more recompression therapy. A recurrence of symptoms does not necessarily require a recurrence of recompression. Reassurance is all that is needed. If the therapist is insecure in this approach, and feels the need to act, then 100 percent oxygen is more than adequate.

It is likely that sub-clinical neurological damage undergoes excitation from alkalotic / hypocapnoeic influences from the rarefied altitude exposure in commercial aircraft and from the common aviation anxiety accentuated by the correct belief that aviation can induce DCS. It is also possible that the mildly hypoxic environment aggravates this.

Discussion

Medevac problems of the 1960s involved otherwise healthy, non-neurotic divers developing DCS. With the adaptation of the conventional treatment techniques (hyperbaria and oxygen) so that they were available in most remote areas, these problems were mainly addressed and solved.

Medevac problems in the 1990s were the product of less healthy and less robust divers, complicated differential diagnoses, and less experienced but enthusiastic hyperbaricists who followed rigid protocols instead of clinical judgment. The fear of medical litigation and the active marketing of dive insurance programs may also have played a role.

Litigation should not be a major problem if the hyperbaric community acknowledges the range of options available and accepts that clinical judgment based on experience is a valid alternative to a one-line dictum. I would back any such clinical decision in any court or tribunal. Treatment should be directed to the patient, not the lawyer.

My experience over recent times is that the cases that proceed to litigation are as likely to be due to alleged PTSD and somatoform disorders, attributable more to basic personality traits, extended treatments and the associated attention, as they are to genuine DCS sequelae.

Different diving groups have their own types of DCS, as well as their own different personality types. I think it was Prof. David Elliott who coined the term The DCS Syndromes. Different diving produces different DCSs. One treatment option will not fit all.

The principles that I have outlined here, covering the mid-60s to the early 90s, really evolved in the first few years of that period. Most of the cases referred to me from 1970 onwards, were not medevaced. Indeed, certain diving groups would not contact the diving emergency services because they knew what the recommendation would be – and they saw it as excessive for the cases they were experiencing. So did I in many instances.

During that period cases referred to most agencies were medevaced. Now it appears as if the "consensus" may be swinging back the other way – probably for the same reasons that we deviated from the earlier treatment dogmas. This is not meant as an "I told you so" accusation. The lesson is far more important than that. Namely, do not

exclude, by recommendation or "consensus," alternative views. Leave open the possibility of other treatment options. All cases are different. If a cookbook diagram indicates that medevac is unnecessary, and you are not comfortable with that decision, medevac! And vice versa.

My only qualification is that it should be a diving physician, genuinely and widely experienced in that field, who undertakes the consultations with the people in the field, and makes the treatment decisions. Otherwise, one can call them all "DCI" and medevac – but this is not good medicine and is not always the "safe" option.

This is a position paper, circa 1965-90. In the supervening years, there have been many valuable contributions documenting the characteristics of DCS and its sequelae, the influences of various treatments, the effects of delay and the analysis of results. Although there may be some qualifications regarding the general conclusions (especially with retrospective analyses and specific population selection), there is still a great deal to be learnt from each of these different diving populations.

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1. Edmonds C, Lowry C, Pennefather J, Walker R. Diving and Subaquatic Medicine 4th ed. London: Arnolds; 2002. 719p.

APPENDIX B. PRESENTERS, DISCUSSANTS, AND ATTENDEES

Presenters

Fred Bove	Philadelphia, Pa., USA
Michael Bennett	Sydney, Australia
David Doolittle	Adelaide, Australia
Alison Drewry	Auckland, New Zealand
David Elliott	Haslemere, UK
James Francis	Tintagel, U.K.
Jake Freiberger	Durham, N.C., USA
Des Gorman	Auckland, New Zealand
David Griffiths	Townsville, Australia
Rick Lesser	Los Angeles, Calif., USA
Simon Mitchell	Auckland, New Zealand
Richard Moon	Durham, N.C., USA
Christopher (Chris) Wachholz	Durham, N.C., USA

Non-Presenting Discussants

Alf Brubakk	Trondheim, Norway
Frans Cronje	Lyttleton, South Africa
Petar Denoble	Durham, N.C., USA
Jordi Desola	Barcelona, Spain
Carl Edmonds	Sydney, Australia
Caroline Fife	Houston, Texas, USA
Ed Kay	Seattle, Wash., USA
John Lippmann	Melbourne, Australia
Edwin Low	Singapore
George Macris	Guam
John Ross	Aberdeen, Scotland
Cuauhtemoc Sanchez	Mexico
Bret Stolp	Durham, N.C., USA
Klaus Torp	Bethesda, Md., USA
Robert Wong	Perth, Australia

Attendees

Husnoor Ali	Suva, Fiji
Caroline Bain	Calgary, Canada
Robyn Barnes	Arrowtown, New Zealand
Geoff Bayliss	Goulburn, New South Wales
Paul Bell	Darwin, Australia
Peter Benton	Groton, Conn., USA
Eyke Betinghausen	Kiel, Germany
Karen Bradler	Wilmington, N.C., USA
Mark Brown	Brisbane, Australia
Phil Bryson	Plymouth, UK
Francois Burman	South Africa
Roger Callaghan	Unknown

Chin Wei Ch'ng	Melbourne, Australia
Kevin Chan	Australia
Don Chandler	Kensington, Md., USA
Jerry Chia	Tech diver, unspecified location
Dick Clarke	Columbia, S.C., USA
Christine Cridge	Portsmouth, UK
Jamal Darandari	Saudi Arabia
David Davies	Perth, Australia
Michael Davis	Christchurch, New Zealand
David Dodson	Sydney, Australia
Susan Dukar	Unknown
Richard Dunford	Seattle, Wash., USA
Greg Emerson	Brisbane, Australia
Bobby Forbes	Orkney, Scotland
Micah Friend	Sydney, Australia
Mikael Gennser	Sweden
Mike Gernhardt	Houston, Texas, USA
Andrew Gray	Unknown
Bill Hamilton	Tarrytown, NY, USA
Neil Hampson	Seattle, Wash., USA
Matt Harrington	Seattle, Wash., USA
Richard Harris	Vila, Vanuatu
Glenn Hawkins	Sydney, Australia
Eric Hessel	Santa Barbara, Calif., USA
James Holm	Carpinteria, Calif., USA
Michael Holman	Sydney, Australia
Carl Huggins	Santa Catalina, Calif., USA
Gabriel Idrovo	Unknown
Tomosumi Ikeda	Japan
Ed Kelly	Unknown
David Kenyon	Morristown, NJ, USA
David King	Brisbane, Australia
Kiyotaka Kohshi	Japan
Michael Lang	Washington, D.C., USA
Chin Thang Lee	Malaysia
Charles Lehner	Madison, Wis., USA
Peter Lindholm	Stockholm, Sweden
David Little	Sydney, Australia
Robert Long	Brisbane, Australia
Pasquale Longobardi	Italy
Matthew MacLean	Brisbane, Australia
Mick Mair	Australia
David McIlwain	Unknown
Cathy Meehan	Cairns, Australia
Ian Millar	Melbourne, Australia
Mauricio Maureno	Unknown
Peter Mueller	Germany
Luci New	USA

Henrik Nimb	Sydney, Australia
Dale O'Halloran	Brisbane, Australia
Matthew O'Shea	Unknown
Hiromichi Oiwa	Japan
Kevin Okeby	Sydney, Australia
Dan Orr	Durham, NC, USA
Willma Padilla	Cozumel, Mexico
Debbie Pastell	Toronto, Canada
Neil Pollock	Durham, N.C., USA
Ralph Potkin	Los Angeles, Calif., USA
Stefan Pomply	Quebec City, Canada
Bob Ramsey	Melbourne, Australia
Piers Robertson	Adelaide, Australia
Stewart Robertson	Australia
Rowan Sanderson	Phuket, Thailand
Nathan Saunders	Sydney, Australia
Martin Sayer	Dunstaffnage, Scotland
Robert Schwartz	Sydney, Australia
Heather Selway	Sydney, Australia
Sarah Sharkey	Sydney, Australia
Fiona Sharpe	UK
David Smart	Hobart, Australia
Richard Smerz	Honolulu, Hawaii, USA
Jeremy Stevens	Blenheim, New Zealand
Anne Sydes	Brisbane, Australia
Lynn Taylor	Auckland, New Zealand
Maida Taylor	San Francisco, Calif., USA
Bruce Thompson	Unknown
Seiichiro Togawa	Japan
Jasmine Toh	Unknown
Stephane Tremblay	France
Barbara Trytko	Sydney, Australia
Tony Turner	Brisbane, Australia
Linas Vaicekavicius	Madison, Wis., USA
Gerhard Van Neikerk	South Africa
David Vote	Melbourne, Australia
Robyn Walker	Sydney, Australia
John Wassel	Concord, N.C., USA
Roland Watzl	Australia
Bob Webb	Townsville, Australia
Chow Weien	Singapore
Caroline White	Sydney, Australia
David Wilkinson	Adelaide, Australia
Colin Wilson	Dunstaffnage, Scotland

APPENDIX C. AGENDA

May 24, 2004		
Time	Topic	Presenter
08:40 – 09:00	Introduction to management of remote decompression illness (DCI)	Dr. Simon Mitchell
09:00 – 09:45	Diagnosing DCI in remote locations	Dr. Richard Moon
10:00 – 11:00	Review of the natural history of untreated cases of mild DCI	Prof. David Elliott
11:00 – 11:45	Cost/benefit in treatment of mild DCI, and the patient as informed risk acceptor	Dr. Alison Drewry
13:00 – 13:50	Benefit of surface oxygen, fluids and drugs as an alternative to recompression for treatment of mild DCI	Dr. Fred Bove
13:50 – 14:50	Influence of delay to recompression on the outcome of mild DCI	Dr. Jake Freiberger
14:50 – 15:25	Can divers with symptoms of mild DCI fly on commercial airliners?	Mr. Chris Wachholz
15:45 – 16:10	Ground transportation of divers with mild DCI	Dr. David Griffiths
16:10 – 17:05	Treatment in remote location hyperbaric chambers and in-water recompression	Dr. James Francis
17:05 – 17:35	Overview of accidents in aero-medical evacuations	Dr. Mike Bennett
17:35 – 18:15	Flying home after recompression treatment in a remote location	Dr. Jake Freiberger

May 25, 2004		
Time	Topic	Presenter
08:30 – 09:30	Hypothetical evolving case history of a serious remote DCI	Chairmen: Drs. Doolette, Mitchell
09:30 – 10:30	Hypothetical evolving case history of a mild remote DCI	Chairman: Drs. Mitchell, Doolette
11:00 – 12:00	The lawyers view on remote management of mild DCI	Mr. Richard Lesser
13:30 – 17:00	Consensus statement on the management of remote mild DCI	Chairman: Dr. Des Gorman

NOTES

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