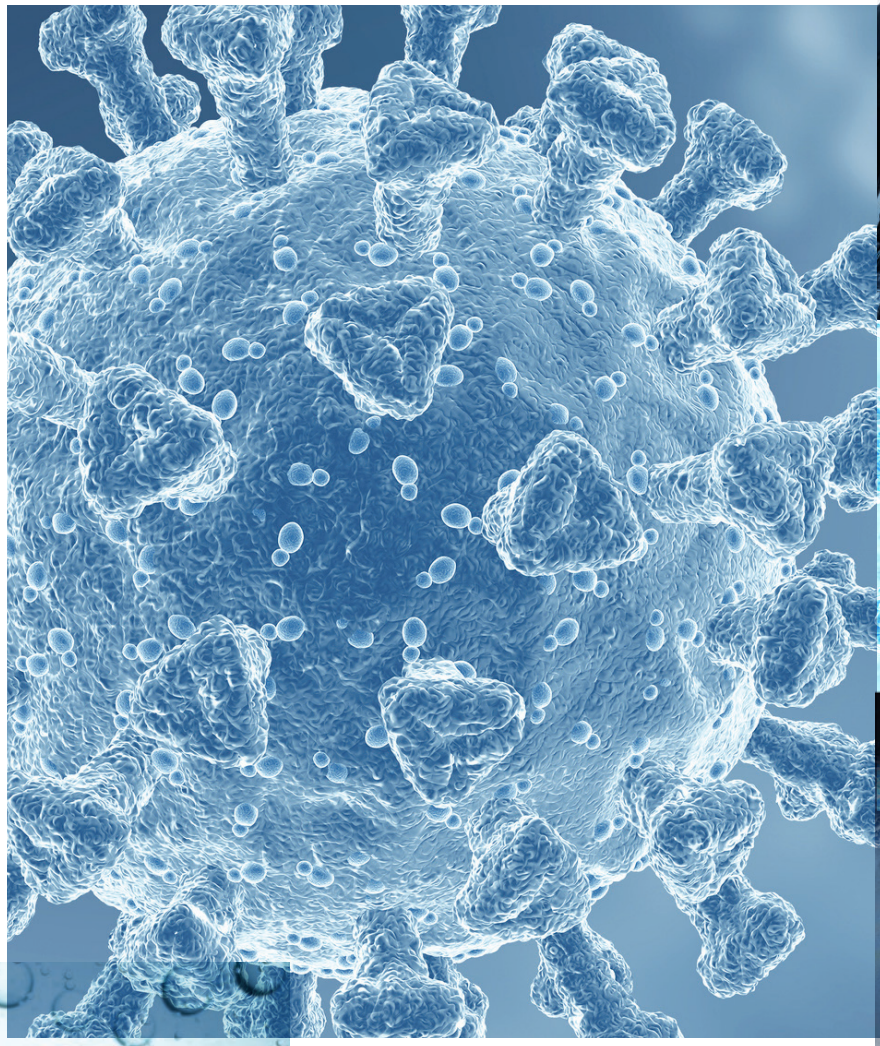
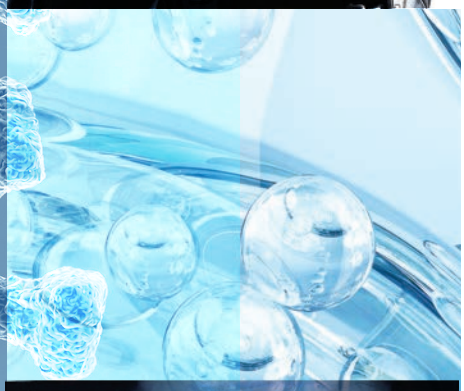
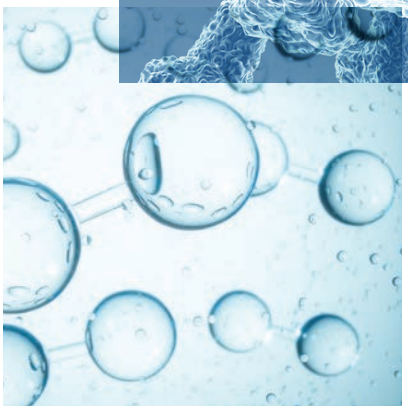
Cardiopulmonary Considerations for Divers Recovered From COVID-19 Infections







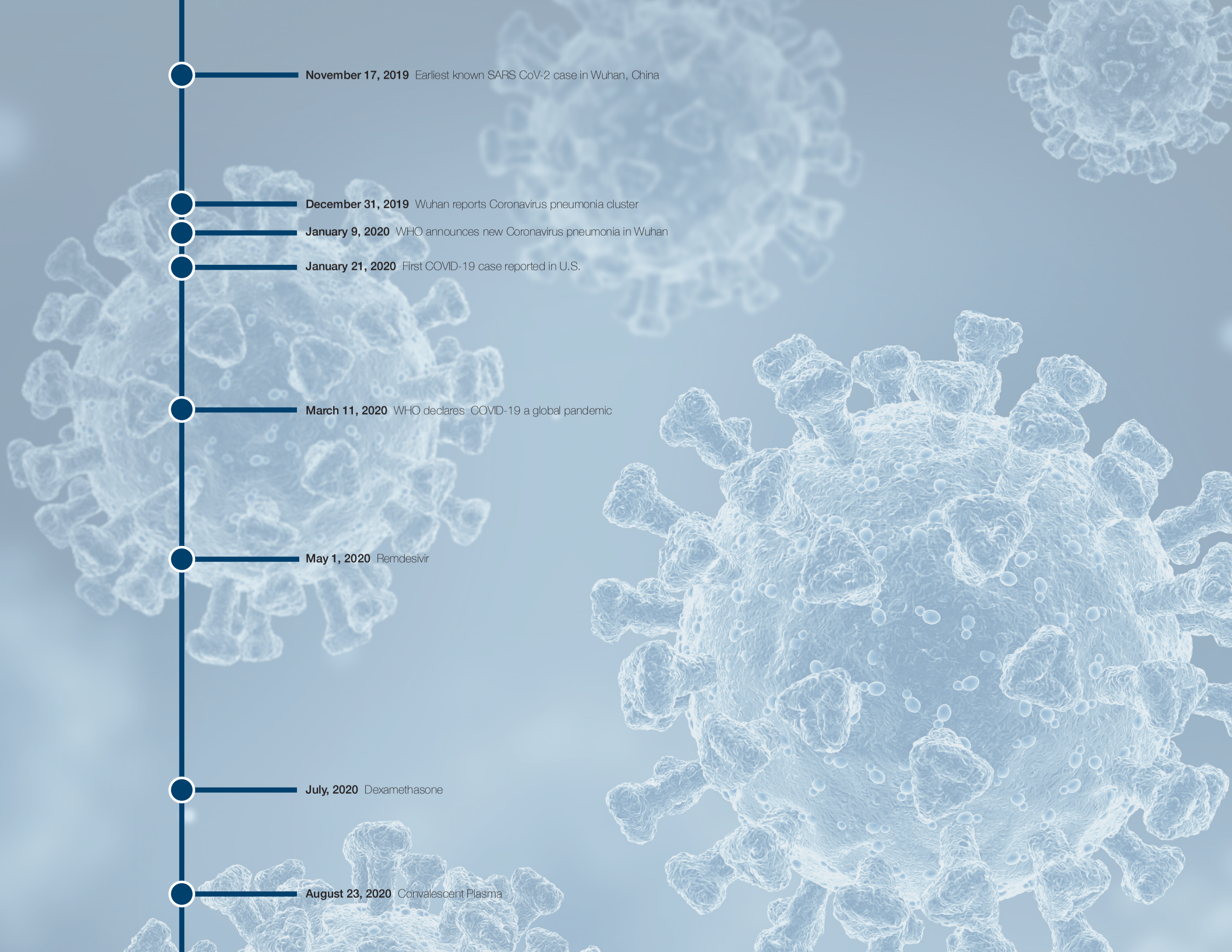
Workshop Proceedings

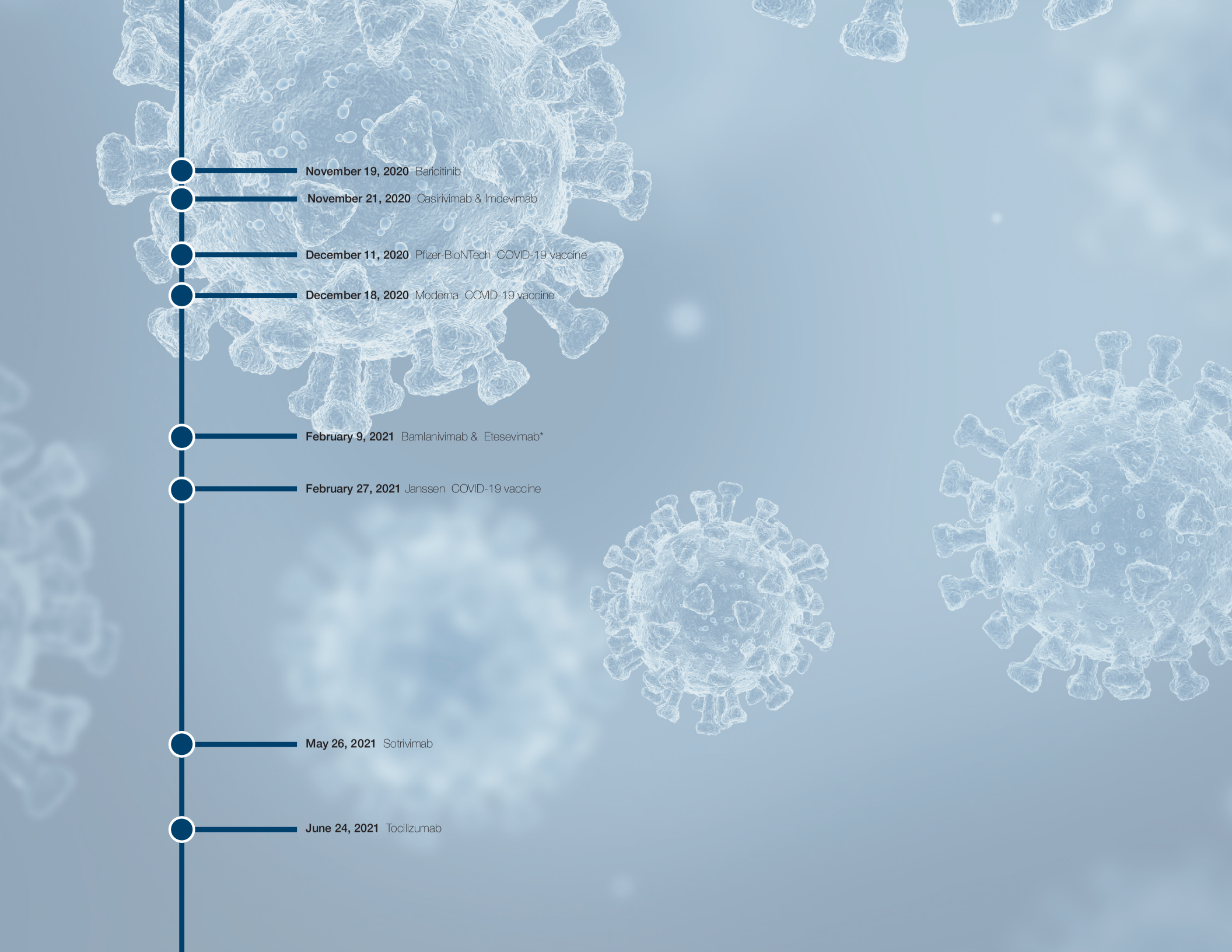
June 08, 2021

Editors:
James Chimiak, MD
Richard Moon, MD

UNDERSEA & HYPERBARIC MEDICAL SOCIETY

DAN
DIVERS ALERT NETWORK


November 17, 2019 Earliest known SARS CoV-2 case in Wuhan, China
December 31, 2019 Wuhan reports Coronavirus pneumonia cluster
January 9, 2020 WHO announces new Coronavirus pneumonia in Wuhan
January 21, 2020 First COVID-19 case reported in U.S.
March 11, 2020 WHO declares COVID-19 a global pandemic
May 1, 2020 Remdesivir
July, 2020 Dexamethasone
August 23, 2020 Convalescent Plasma


November 19, 2020 Baricitinib
November 21, 2020 Casirivimab & Imdevimab
December 11, 2020 Pfizer-BioNTech COVID-19 vaccine
December 18, 2020 Moderna COVID-19 vaccine
February 9, 2021 Bamlanivimab & Etesevimab*
February 27, 2021 Janssen COVID-19 vaccine
May 26, 2021 Sotrivimab
June 24, 2021 Tocilizumab

Cardiopulmonary Considerations for Divers Recovered From COVID-19 Infections

Workshop Proceedings

June 08, 2021

UHMS Symposium

Sponsored by

Divers Alert Network

Editors:

James Chimiak, MD

Richard Moon, MD

Chimiak J, Moon R (editors). Cardiopulmonary Considerations for Divers Recovered from COVID-19 Infections. Workshop Proceedings. UHMS Symposium. Durham, NC, Divers Alert Network, 2021, page 208.

ISBN 978-1-941027-82-0

This symposium and the publication of this document were sponsored by Divers Alert Network. Opinions and data presented at the symposium and in these proceedings are those of the contributors and do not necessarily reflect those of Divers Alert Network.

For information contact:

research@DAN.org

Divers Alert Network
6 W. Colony Place
Durham, NC 27705

Table of Contents

Pre-Course Schedule 8

Speaker Biographies 13

Introduction 17

Cardiopulmonary Considerations for Divers Recovered From Covid-19 Infection: Covid-19 Overview* 20
Bryan D. Kraft, MD

Imaging Consideration 37
Peter Lindholm, MD, PhD

Dyspnea After COVID-19 40
Michael Ott, MD, Lt Col, USAF

Pulmonary Implications of COVID-19 Infection for Divers 57
Richard E. Moon, MD

Neuropsychological Implications to Diving After COVID-19 65
Dr. Lindell Weaver, MD

Cardiopulmonary Considerations After COVID-19 Infections 77
Mathew W. Martinez, MD, FACC

COVID-19: Cardiac Implication for Divers 85
Douglas Ebersole, MD

Vascular Injury Implications for DECO and VGE 99
David M. Eckmann, PhD, MD

DRACO: Diver Return After COVID-19 109
Frauke Tillmans, PhD

Diving After COVID-19–UCSD Algorithm 115
Charlotte Sadler, MD

Concluding Remarks 125
Jim Chimiak

Addendum 147
Published algorithms from other sources

Pre-Course Schedule

Cardiopulmonary Considerations for Divers Recovered From COVID-19 Infections

Wednesday, June 8, 2021 0800-1630

Program Chairs: James Chimiak, MD and Richard Moon, MD

This workshop will present the relevant aspects of recovery after COVID-19 infection and discuss relevant aspects of the Post COVID-19 Syndrome (PCS), with particular attention to issues that can affect a diver's safety. Although issues involving a variety of organ systems, this workshop will primarily focus on cardiopulmonary concerns to include pulmonary fibrosis, pulmonary oxygen toxicity, gas exchange, shunting, cardiac dysrhythmia, myocarditis, cardiomyopathy, neuro-psych issues, and vascular injury.

The intended goal is to examine current algorithms and make modifications with the most recent scientific findings related to this significant health concern. Presentations will focus on the post infection sequalae with brief reference to prevention and acute management when needed for deeper understanding of PCS. The goal is to develop safe, cost effective recommendations for divers returning to diving after a COVID-19 infection that includes the extremes of age and severity of illness. The identification of available screening tools, readily available to the primary care physician is important given the large numbers of those infected worldwide and the need to wisely utilize finite diagnostic resources.

0800-0820	**Introduction/Goals**	Jim Chimiak, MD Richard Moon, MD
0820-0910	COVID 19 overview	Bryan Kraft, MD
0910-0940	Imaging considerations	Peter Lindholm, MD, PhD
0940-0950	**BREAK**	
	PULMONARY	
0950-1020	Dyspnea after COVID-19	Michael Ott, MD
1020-1110	Pulmonary Implication for Divers	Richard Moon, MD
1110-1140	Neuropsychological implications to diving After COVID-19	Lindell Weaver, MD
1140-1220	**LUNCH**	
	CARDIAC	
1220-1310	Cardiac concerns, return to play	Matthew Martinez, MD
1310-1400	COVID-19: Cardiac Implications for divers	Douglas Ebersole, MD
1400-1410	**BREAK**	
1410-1500	Vascular injury implications for deco and VGE	David Eckmann, MD, PhD
1500-1530	DRACO — DAN COVID-19 study update	Frauke Tillmans, PhD
1530-1600	Diving after COVID-19 UCSD algorithm	Charlotte Sadler, MD
1600-1630	**Summary/consensus**	**Jim Chimiak, MD** **Richard Moon, MD**

Continuing Education

Accreditation Statement: The Undersea and Hyperbaric Medical Society is accredited by the Accreditation Council for Continuing Medical Education (ACCME) to provide continuing medical education for physicians.

DESIGNATION STATEMENTS:

- **Physician CME:** The Undersea and Hyperbaric Medical Society designates this live activity for a maximum of 7.5 AMA PRA Category 1 Credit(s)™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.
- **Nursing CEU:** Approved license types: Advanced Registered Nurse Practitioner; Clinical Nurse Specialist; Licensed Practical Nurse; Registered Nurse; Certified Nursing Assistant; Respiratory Care Practitioner Critical Care; Respiratory Care Practitioner Non-Critical Care; Registered Respiratory Therapist; Certified Respiratory Therapist. This live activity is approved for a maximum of 7.5 contact hours by the Florida Board of Registered Nursing Provider #50-10881.
- **NBDHMT:** The NBDHMT does not recognize this educational program as meeting their requirements and scope for credit."

Full Disclosure Statement: All faculty members and planners participating in continuing medical education activities sponsored by Undersea and Hyperbaric Medical Society are expected to disclose to the participants any relevant financial relationships with commercial interests. Full disclosure of faculty and planner relevant financial relationships will be made at the activity.

Disclaimer: The information provided at this CME activity is for Continuing Medical Education purposes only. The lecture content, statements or opinions expressed however, do not necessarily represent those of the Undersea and Hyperbaric Medical Society.

Disclosures: The following individuals have disclosed a relevant financial relationship with ineligible companies. Financial relationships are relevant if the following three conditions are met for the individual who will control content of the education:

1. A financial relationship, in any amount, exists between the person in control of content and an ineligible company and;
2. The content of the education is related to the products of an ineligible company with whom the person has a financial relationship and;
3. The financial relationship existed during the past 24 months.

- Bryan Kraft, MD, faculty for this educational event, is a Consultant/Speaker: American College of Chest Physicians, Boehringer Ingelheim, Shionogi Inc., La Jolla Pharmaceutical Company; received Research Funding: Savara Pharmaceuticals, NIH/NHLBI, DoD and has a Patent pending: Co-inventor, U.S. Provisional Patent Application 63/017,290, "Compositions comprising mesenchymal stromal cells for the treatment of viral infections."

All of the relevant financial relationships listed for these individuals have been mitigated. Except for the above-named individuals, none of the other individuals in control of content (planners/faculty/reviewers/authors) for this educational activity have relevant financial relationship(s) to disclose with ineligible companies whose primary business is producing, marketing, selling, re-selling, or distributing healthcare products used by or on patients.

No commercial support was received for this activity.

Corporate sponsor: Divers Alert Network, Durham, NC.

Stacy Harmon

UHMS Activity Director/Coordinator

June 1, 2021

Speaker Biographies

JAMES CHIMIAK, MD

Dr. Chimiak is the Chief Medical Officer for DAN. He is triple-boarded in anesthesiology, pain management and hyperbaric medicine. Qualified as US Navy Special Operations, Flight Surgeon and Undersea/Saturation Diving Medical officers, he is co-chair of the dive committee for the UHMS.

RICHARD MOON, MD

Dr. Moon is currently the Professor of Anesthesiology Medical Director, Hyperbaric Center, Professor of Medicine. His research interests include the study of cardiorespiratory function in humans exposed to environmental conditions ranging from 200 feet of seawater depth to high altitude, gas exchange during diving, the pathophysiology of high-altitude pulmonary edema, the effect of anesthesia and postoperative analgesia on pulmonary function and monitoring of tissue oxygenation. Ongoing human studies include mechanisms of immersion pulmonary edema and the effect of chemosensitivity on postoperative ventilation and gas exchange.

BRYAN KRAFT, MD

Dr. Kraft completed an Internal Medicine residency, a Pulmonary, Allergy, and Critical Care Medicine fellowship, and an Undersea and Hyperbaric Medicine fellowship at Duke University Medical Center in Durham, NC. Dr. Kraft's research includes clinical and translational studies in sepsis, pneumonia, COVID-19, acute respiratory distress syndrome, hyperbaric oxygen therapy, and pulmonary alveolar proteinosis.

PETER LINDHOLM, MD, PHD

Dr. Lindholm is Professor in Residence, Gurnee Endowed Chair of Hyperbaric and Diving Medicine Research, Department of Emergency Medicine, University of California San Diego. He is a radiologist (licensed in Sweden), and associate professor in physiology and radiology from the Karolinska Institutet in Sweden. Together with colleagues at UCSD he developed the widespread guidelines for clinicians in evaluation of divers post-COVID-19: Sadler C, Alvarez Villela M, Van Hoesen K, Grover I, Lang M, Neuman T, Lindholm P. Diving after COVID-19: Fitness to dive assessment and medical guidance. Diving Hyperbaric Medicine 2020 2020 Sep 30;50(3):278-287. doi: 10.28920/dhm50.3.278-287. PMID: 32957131.

MICHAEL OTT, MD

Dr. Michael Ott is a Colorado native who received his undergraduate degree from Davidson College, followed by his medical degree from Wake Forest University. He then studied internal medicine/pulmonary medicine/critical care at Mayo Clinic. Ott has been an active dive instructor since 1994 and a Diving Medical Officer with NOAA since 1998, serving on the USS *Monitor* and Aquarius missions. He serves as the Chief of Pulmonary/CCM/UHM at Eglin AFB, and is a Lt Col/Flight Surgeon in the USAF working as the Chief of Aerospace Medicine in the 44th Fighter Group (F22/T38). He worked 365 consecutive days this past year in the ICU with COVID-19 patients and served as the SME/training director for the COVID-19 Joint Task Force alternate care facility in Miami, Florida.

LINDELL WEAVER, MD

Pulmonary, critical care trained, with clinical and research practice in hyperbaric medicine for decades, Dr. Weaver is former President UHMS, a former undersea and diving medical officer, and is based in Salt Lake City, Utah.

MATTHEW MARTINEZ, MD

Dr. Martinez is Associate Professor of Medicine. He serves as director of Sports Cardiology and Co-Director of Hypertrophic Cardiomyopathy program at Morristown Medical Center, Atlantic Health System in New Jersey. Dr. Martinez serves as a cardiology consultant for elite and professional athletes including acting as the League cardiologist for Major League Soccer, team cardiologist for the New York Jets and cardiac consultant for the NFL. He regularly presents on Sports Cardiology and Hypertrophic cardiomyopathy at national and international meetings and served as the American College of Cardiology's Chair of Sports and Exercise section until 2020. He has expertise in advanced cardiac imaging using echo, cardiac MRI and CT and has led many educational events nationally and internationally on these topics. He has also served as the educational program chairman for the international Athletic Heart Symposium on management of athletes with cardiovascular risk.

DOUGLAS EBERSOLE, MD

Dr. Ebersole is an interventional cardiologist at the Watson Clinic in Lakeland, Florida and is the Director of the Structural Heart Program at Lakeland Regional Health. He learned to scuba dive in 1974 and currently teaches diving from open-water to closed-circuit rebreathers with trimix and cave diving. An avid diver and instructor as well as a practicing cardiologist, Dr. Ebersole is also a cardiology consultant to Divers Alert Network.

DAVID ECKMANN MD, PHD

Dr. Eckmann is the Director of the Center for Medical and Engineering Innovation as well as Vice Chair for Academic Affairs in the Department of Anesthesiology at The Ohio State University. He received his BS in bioengineering from the University of California San Diego and his PhD in bioengineering and MD from Northwestern University. He joined the faculty at OSU in 2019 after 23 years at the University of Pennsylvania, where he held the Horatio C. Wood Endowed Chair as Tenured Professor of Anesthesiology and Critical Care and Professor of Bioengineering. He has more than 25 years of continuous federal funding, including grants from NIH, NSF, Department of Defense, NASA, the Office of Naval Research, as well as private foundations and industry. His research has focused on the interfacial biofluid dynamics of vascular gas embolism, targeted drug delivery, thin film surface grafting for biomaterial biocompatibility, drug elution and antimicrobial protection, and the interrelationship between cell mechanics and cellular bioenergetics and mitochondrial function. He has served as the principle investigator of an NIH T32 grant in perioperative medicine and is a member of the Foundation for Anesthesia Education and Research Academy of Research Mentors. He has directed undergraduate and graduate courses in bioengineering and holds patents in biotechnology. Dr. Eckmann is American Board of Anesthesiology-certified with expertise in cardiopulmonary physiology, anesthesia for bariatric surgery and airway management. He practices clinically at the Ohio State Wexner Medical Center.

FRAUKE TILLMANS, PHD

Dr. Tillmans is the Research Director at Divers Alert Network (DAN). She has a PhD in Human Biology and oversees DAN's in-house research initiatives in injury monitoring, diving physiology, and population health, as well as the DAN Research Grant Program. A current focus for DAN includes acute diving injuries as well as long-term health effects of diving and extreme exposures. An avid and well-traveled diver herself, she has become DAN's point of contact for national and global collaborations in diving-related research. Before joining DAN in 2019, Dr. Tillmans participated in projects covering a variety of medical and health aspects in recreational and military diving.

CHARLOTTE SADLER, MD

Dr. Sadler is currently an Associate Professor of Emergency Medicine at the University of California, San Diego. She is also the program director of the Undersea and Hyperbaric Medicine fellowship at UCSD. She graduated medical school in her home state of Iowa at the Carver College of Medicine, University of Iowa. She completed her residency in Emergency Medicine and fellowship in Hyperbaric Medicine at UCSD. She is a past member of the UHMS board of directors and is co-chair of the UHMS Diving Committee. Her research interests include diving fatalities, cardiovascular disease and diving, rebreathers, and COVID-19 in divers. She helps run the diving medicine clinic at UCSD and was lead author of the UCSD Guidelines for returning to dive after COVID -19.

Introduction

James Chimiak, MD

Welcome to the pre-course, Cardiopulmonary Considerations for Divers Recovered From COVID-19 Infections, sponsored by the UHMS and DAN. I am Dr. Jim Chimiak and will be co-chairing this pre-course with Dr. Richard Moon today. As we are all aware, COVID-19 has also affected many things including the way we travel and meet with one another. As a result, this may be the first virtual UHMS ASM pre-course conducted over the internet. Although it does make the productive, in-person discussions and debate more challenging, we have made every effort to enable your important interaction both by enabling both text and voice capabilities for each of you. CME credit will also be available. Each presenter will make an individual financial disclosure.

I have no relevant financial relationships to disclose but do have an ongoing close relationship to diving safety as does Dr. Moon that ranges from military to breath hold divers. We've all have seen the staggering statistics from the COVID-19 infections world-wide. This pre-course addresses the return to diving after full recovery after a COVID-19 infection. Full recovery for this pre-course will be considered as the patient who is no longer infectious, exceeded his baseline or organization's exercise capacity, and remains asymptomatic. It addresses the cardiopulmonary issues important for divers, hence the name of the pre-course, as well as vascular and neuro-psych aspects.

Figure 1.

The Johns Hopkins COVID-19 dashboard is continuously updated and displays the increasing numbers of cases and deaths in graphic detail.

The impact of effective vaccines and preventive measures are making significant impact and the dashboard reflects this positive development as these numbers begin to dip from their peak. In addition, better patient management and treatment protocols have been implemented based on a better evidence based clinical research. Fortunately, most of the infections have been mild to moderate. Also, as more clinical experience is acquired, many patients have been treated at home, not hospitalized, and kept off mechanical ventilation. This has resulted in more patients managed at home, entirely in virtual hospitals, thus freeing up hospital beds for the most severely ill.

Although there are signs of recovery from this pandemic there are some reasons to remain cautious. With this optimism, comes the possibility of a premature return to pre-pandemic routines that may increase the rate of infection. Also, there is evidence that many of those infected will suffer long term sequelae with symptoms such as fatigue and shortness of breath months after the acute phase and now being termed PASC (post-acute sequelae of Covid) or long COVID. And lastly, there is always the possibility of viral mutation.

COVID-19 is a severe acute respiratory disease. In addition, to the respiratory symptoms, the CDC has described the range of issues seen with COVID-19 infection consistent with a systemic infection affecting other organ systems.

During the initial declaration of the COVID pandemic and the panic that ensued, the question of what impact this would have on an infected diver arose but with little known information available. Panic, a 24-hour news cycle, and the internet created the perfect storm for rapid dissemination of any news, especially the sensational. Quality, authoritative guidance could not compete with the same day production of information released with the click of the send button. For instance, a small case series implied divers infected with COVID-19 would be permanently disqualified. Initially, the military officially stated that if you ever had COVID, you could not enlist in the service but later reversed that decision. Conversely, there were some that reported COVID-19 was simply another flu or bad cold, an incorrect position that negatively impacted containment efforts and may have influenced cases of those that dove with active infection. This information thirst for anything COVID drove some of the angst and chaos, with such reports rapidly going (COVID) viral. Responsible physicians attempted to beat back these early misconceptions while simultaneously working extra shifts in hospitals overwhelmed by the critically ill, but their message lacked the sensational Armageddon-like appeal that was craved in the early onset. Fortunately, these initial recommendations were reviewed and changed significantly.

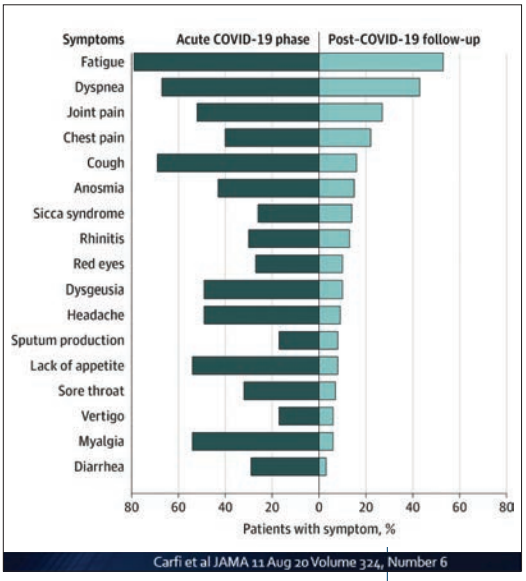


Figure 2.

The figure shows percentages of patients presenting with specific coronavirus disease 2019 (COVID-19)-related symptoms during the acute phase of the disease (left) and at the time of the follow-up visit (right).

Practicing diving medical physicians who have dealt with serious infections before and were now facing one that had become pandemic, a basic tenet remained unchanged: Do Not Dive if Unwell. This is applicable for any infection before returning to diving after the acute illness, subsequent recovery, and rehab. Our goal is to present the considerations for the baseline evaluation, consultations, and testing when your diver presents after full recovery and now asymptomatic.

For most infections, the general guidelines for returning to diving is making a full recovery without any lingering symptoms. The recovery period includes the period when the patient returned or exceeded pre-infection exercise baseline capacity without symptoms. Today we will better understand the COVID-19 infection and address issues that impact various organ systems in addition to its commonly known cardiopulmonary effects, hence the name of the workshop. Specifically, discussion concerning the vascular and the neuro/psych concerns will be conducted to understand the diving implications.

Early concerns arose over cardiac complications. Again, early reporting painted a dire picture. Fortunately, with the work of cardiologists that included Dr. Martinez and colleagues, the actual data showed a different situation. They systematically looked at the data for athletes returning to play after a recent COVID-19 infection. Their work was key to the ability of athletes to return to the field of play without the dire predictions of previous declarations. Their recommendations have been incorporated into the algorithms used for those returning to diving.

Critical assessment of the diagnostic recommendations is needed to ensure they yield accurate results and identify conditions that are a threat to a diver's well-being. Incidental findings of little consequence can lead to additional testing or even lead to unnecessary disqualification. The tests also need to be cost effective and available considering the large number of divers who have recovered uneventfully and may be subjected to a required panel of diagnostic testing despite no sequelae from their infection. The evaluation is important as the diver is released to full unrestricted rigorous exercise. Once at exercise baseline, the diving medical physician evaluates the diver. Assessing exercise baseline may be difficult to obtain for some. Previous recording of past exercise performance is helpful. Utilizing normative exercise data or the diver's own initial diver certification test scores can be the only option but a higher mark to achieve. Maintaining a period of rigorous exercise based on a percentage of age based maximal heart rate could be considered. Symptoms or a significant drop in oxygen saturation as well as any other symptoms while exercising should prompt appropriate physician consultation. The return to diving should begin with a relatively conservative series of dives. A refresher course could be considered. These initial dives should be monitored and event-free before returning to full unrestricted diving.

Fitness will be emphasized by our presenters. Exercise has a variety of known health benefits that include cardiovascular and neurocognitive gains including the reduction of blood pressure. Obesity is also reduced, a condition that has been linked linearly with the severity of the COVID-19 infection. Exercise is a proven benefit and everyone, especially divers, should engage in regular rigorous exercise. This is especially important during this pandemic with a special call now to run for your lives.

The UHMS Dive Committee met in May 2021 to review COVID-19 related issues that would have an impact on diving. In addition, the severity of illness, recovery period, exercise requirements, practical screening tests, impact of false positive test, incidental test findings, advanced age, medical conditions, type of diving were issues raised by the committee for discussion today. Special consideration for breath hold divers should be given as they rely on optimal respiratory gas exchange while apneic underwater to prevent loss of consciousness and drowning.

Diving organizations from commercial, military, scientific, academic, recreational to breath hold diving organizations have developed recommendations for return to diving evaluation. These recommendations share important commonality as they address the major issues that will be presented today. Special thanks to CAPTAIN Mike Tripp MC USN, head of US Navy's Undersea Medicine Program, who could not attend today but assisted in providing details of the US Navy's novel approach.

A presentation of DAN's DRACO study will be given and has just reached our goal of recruiting over 1000 divers returning to diving after a COVID-19 infection. The study will follow these divers for five years to evaluate if they return and any problems they encounter during this period.

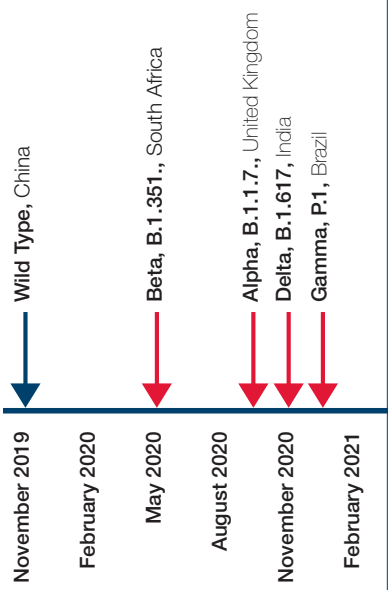
I would like to introduce Dr. Moon, co-chair. Dr. Richard Moon is a professor at Duke University, both a pulmonologist, anesthesiologist, and diving/hyperbaric medical specialist. He has been recently named the DAN/Rolex Diver of the Year for 2021. In addition to co-chairing, Dr. Moon will also be presenting pulmonary considerations, Dr. Moon.

Cardiopulmonary Considerations for Divers Recovered from COVID-19 Infection: COVID-19 Overview*

Bryan D. Kraft, MD

For perspective, I will start by showing a timeline of the COVID-19 pandemic. (Figure 1) The first cluster of coronavirus pneumonia cases was reported in Wuhan, China on New Year's Eve 2019. At least one case has since been documented retrospectively going back as early as November 17, 20191. By March 11, 2020, the World Health Organization announced that COVID-19 was officially a pandemic. Less than two months later, the first drug to treat COVID-19, Remdesvir, was authorized for emergency use by the Food and Drug Administration (FDA). Since then, a total of eight COVID-19 therapies and three vaccines have received emergency use authorization. This timescale represents a herculean effort by the medical community to advance the science and develop safe and effective treatments and vaccines for the virus.

Also shown are the current viral "variants of concern" as designated by the World Health Organization. The dates shown are the earliest known variant isolates. The Delta variant is currently the most prevalent variant. You can see that variants arise during times of intense viral replication, for instance, the late fall and winter months of 2019-2020 which correspond to surges. There are other "variants of interest" (Eta, Iota, Kappa, and Lambda) (not shown) that do not rise to the level of "concern" yet.



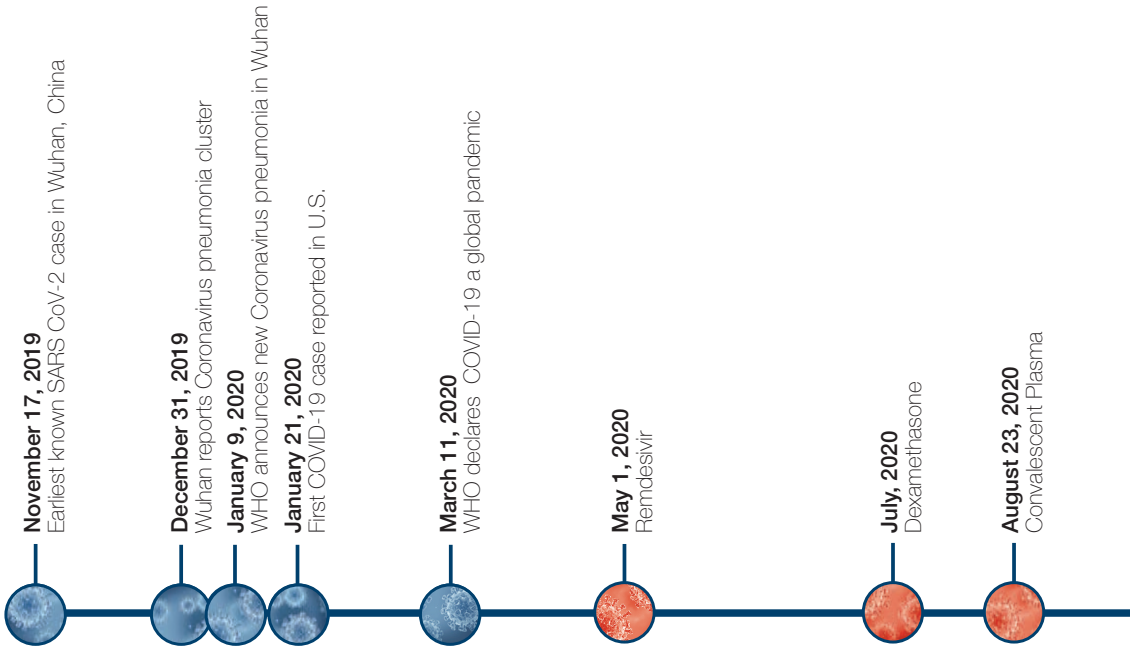
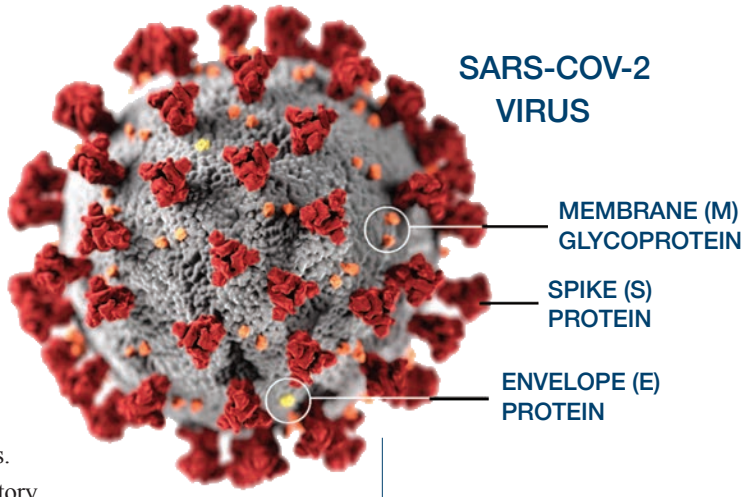


Figure 1.

COVID-19 Timelines.

(Above) World Health Organization (WHO) variants of concern are shown in red. EUA, emergency use authorization.

(Right) Timeline of COVID-19 origin, spread, drug development, and vaccine development.



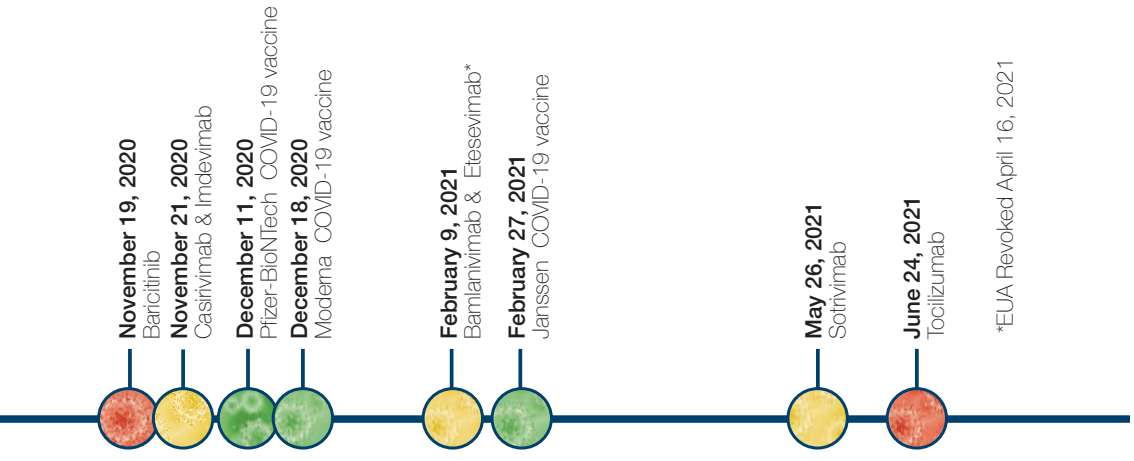
COVID-19 PATHOPHYSIOLOGY

The virus contains three major outer membrane proteins: the envelope (E) protein, the spike (S) protein, and the membrane (M) glycoprotein. (Figure 2) The spike protein is what binds to the host ACE2 receptor to facilitate viral entry via endocytosis and is the protein target of the current vaccines. ACE2 receptor is highly expressed in the human lower respiratory tract, which is believed to be a major reason for the virus' predilection to cause pneumonia. Electron micrographs taken of autopsy lung specimens show the virus infects both lung endothelial cells and alveolar type 2 pneumocytes2. As the epithelial stem cells of the alveolar region, the type 2 cells repopulate the damaged epithelial lining of the basement membrane, and their destruction may in part explain the severity of the acute lung injury seen from COVID-19 infection. Infection of the lung endothelial cells themselves is noteworthy, and has been posited to be the culprit lesion responsible for vascular and thrombotic complications of COVID-193.

Figure 2.
Illustration of SARS-CoV-2 virus when viewed by electron microscopy. Adapted from: Centers for Disease Control and Prevention Image Library.

COVID-19 CLINICAL MANIFESTATIONS

In addition to the respiratory tract, ACE2 receptor expression is found throughout the body, including the brain, the heart, the gastrointestinal tract, the liver, the kidneys, and the vasculature. This expression pattern mirrors the clinical manifestations observed in patients with COVID-19. COVID-19, or coronavirus disease 2019, is probably more accurately referred to as "coronavirus syndrome 2019," as not every patient displays the same manifestations. For instance, in addition to the lung involvement that can lead to acute respiratory failure and acute respiratory distress syndrome (ARDS), a minority of patients, perhaps 5-15%, will display cardiac involvement with



WHO COVID-19 ORDINAL SCALE

PATIENT STATE	DESCRIPTOR	SCORE
Uninfected	No	0
Ambulatory, mild	No limitation of activities	1
	Limitation of activities	2
Hospitalized, moderate	No oxygen	3
	Oxygen by mask or prongs	4
Hospitalized, severe	Non-invasive ventilation or high-flow oxygen	5
	Intubation and mechanical ventilation	6
	Ventilation + additional organ support: Pressors, RRT, ECMO	7
Dead	Death	8

Figure 3.
World Health Organization (WHO) Ordinal Scale for COVID-19 severity. RRT, renal replacement therapy (e.g. acute dialysis); ECMO, extracorporeal membrane oxygenation.

myocarditis, arrhythmias, heart failure, and/or myocardial infarction. Other patients will display overt evidence of vasculature involvement characterized by endothelial dysfunction, vasculitis, and thrombosis.

The clinical time course of SARS-CoV-2 infection is now known to consist of three major phases. The first phase is the pre-symptomatic phase, which probably accounts for the majority of the spread of the virus to others, and is apparent even a week before symptom onset. The second phase is the symptomatic phase, characterized by constitutional symptoms (fever, fatigue, malaise), myalgias, cough, gastrointestinal symptoms, headache, nasal congestion, rhinorrhea, and most classically dysgeusia and anosmia. The third phase is the pneumonic phase, which develops around 7-14 days after symptom onset, and is characterized by dyspnea, pulmonary infiltrates, and hypoxemia. Up to 40% of patients will develop dyspnea, whereas approximately 14% of patients require hospitalization and 5% require admission to the intensive care unit (ICU)[4]. As the U.S. has approximately 3 ICU beds per 10,000 people[5], a simple back-of-the-envelope calculation illustrates how a virus causing 5% critical illness will vastly outstrip hospital resources if proper mitigation strategies are not practiced.

The viral and antibody kinetics have been well characterized. Viral replication is evident up to a week before symptom onset and peaks around 2 weeks after symptoms appear. The virus is most commonly measured in the nasopharynx but can be detected in a number of tissue compartments including the lower respiratory tract secretions, peripheral blood, and stool. Viral shedding can persist many weeks after infection onset and even after clinical recovery. This is

not believed to represent live virus, but rather viral debris (remnants of viral RNA) that remain detectable by the highly sensitive PCR test. Antibodies are generally detectable starting the second week of infection, including both IgM and IgG classes, and peak at around four weeks after infection. Humoral response appears to correlate with infection severity, and high titers of neutralizing antibodies are found in patients admitted to the intensive care unit, suggesting deficient humoral immunity is not likely to be a therapeutic target at the later stage of illness in most immunocompetent patients. However, in patients lacking humoral responses, neutralizing antibody infusions appear to improve outcomes[6].

The World Health Organization has published an ordinal scale to classify COVID-19 clinical severity. (Figure 3) The scoring ranges from 0 or uninfected, 1-2 or mild infection, 3-4 or moderate infection, 5-7 or severe infection, to 8 or death from infection. Patients that are either asymptomatic or have mild infection that do not require hospitalization can be said to have mild disease. Patients that are hospitalized without requiring oxygen, which is less common, or that (more commonly) require low flow oxygen (oxygen delivered via conventional nasal cannula) can be said to have moderate disease. Patients that require either high flow nasal oxygen (delivered via specialized device such as an Optiflow or Vapotherm at flows of typically 30-60 liters/minute with titratable FiO2), non-invasive ventilation (e.g. continuous positive airway pressure or bilevel positive airway presssure), invasive mechanical ventilation, or additional organ support such as vasoactive drugs, renal replacement therapy, or extracorporeal membrane oxygenation, can be said to have severe disease.

CASE PRESENTATIONS

The following three case presentations, 1 mild infection and 2 severe infections, will be used to illustrate the currently available COVID-19 therapies approved for emergency use by the FDA.

CASE 1:

The first case is a 45-year-old female who presented with two days of cough, dyspnea, headache, anorexia, and anosmia. Her past medical history included hypertension, hypercholesterolemia, type 2 diabetes, and obesity (BMI 37). She reported a family member had been sick the week prior to presentation. She also reported high-risk work place exposures in her job as a nurse at local correctional facility. On physical exam, she was afebrile with a room air saturation of 97%. A chest radiograph was clear. A COVID-19 nasopharyngeal PCR test was positive. Due to underlying risk factors, she was considered high-risk for progression to severe COVID-19 and was given a dose of i.v. casirivimab/imdevimab.

USE OF MONOCLONAL ANTIBODIES TO REDUCE THE RISK OF SEVERE COVID-19

A number of patient-specific risk factors for progression to severe COVID-19 have been identified including advanced age (≥ 65 years), increased body mass index (BMI) (> 25 kg/m2), pregnancy, chronic heart, lung, or kidney disease, diabetes, immunosuppressed state, sickle cell disease, neurodevelopmental disorders, chronic use of medical devices such as tracheostomy or gastric feeding tube, or other conditions deemed by medical providers to be high risk. To date, three different monoclonal antibody products have been developed and authorized for emergency

use in patients who are at higher risk for progression to severe COVID-19: casirivimab/imdevimab, sotrovimab, and bamlanivimab/etesevimab, although the latter is no longer in use due to its lower efficacy against the Gamma (Brazilian) and Beta (South African) variants7. Casirivimab/imdevimab was studied in the REGEN-COV study that found a 71% relative reduction in hospitalization or death (3% absolute risk reduction) and a significant four-day reduction in the median symptom duration compared to placebo8. Sotrovimab was studied in the COMET-ICE trial (NCT04545060) which found an 85% relative reduction in hospitalization or death (6% absolute risk reduction) compared with placebo9,10. Casirivimab/imdevimab and Sotrovimab appear to retain neutralizing activity against the Delta variant11,12. On an individual level, these monoclonal antibodies should be considered for all high-risk patients meeting the defined inclusion criteria without contraindications to reduce the risk of severe COVID-19. To be maximally effective, they should be administered as soon as possible after confirming a COVID-19 diagnosis, and within 10 days of symptom onset. They are not appropriate for hospitalized patients or patients requiring oxygen due to COVID-19. At a population level, despite modest absolute reductions in disease attenuation, these therapies can mitigate strain on an already overburdened healthcare system by reducing hospitalizations.

Casirivimab/imdevimab has also been studied for post-exposure prophylaxis, and has received emergency use authorization for patients exposed to SARS-CoV-2 that are either not fully vaccinated, or are not expected to mount a complete immune response to vaccination (for instance, in immunosuppression). Recent data suggests they can also reduce or prevent infections in household contacts of infected persons 13.

Back to our patient from Case 1, she tolerated the casirivimab/imdevimab infusion well. Her symptoms peaked at nine days and slowly resolved thereafter, leading to a full recovery. Thankfully, she did not develop severe disease.

CASE 2:

The second case is a 53-year-old female with a complicated past medical history, including obesity (BMI 35), tobacco abuse, hypertension, hypercholesterolemia, diabetes, coronary disease, NSTEMI, and chronic thromboembolic pulmonary hypertension status post pulmonary artery endarterectomy. She is chronically anticoagulated. One week prior to hospital admission,

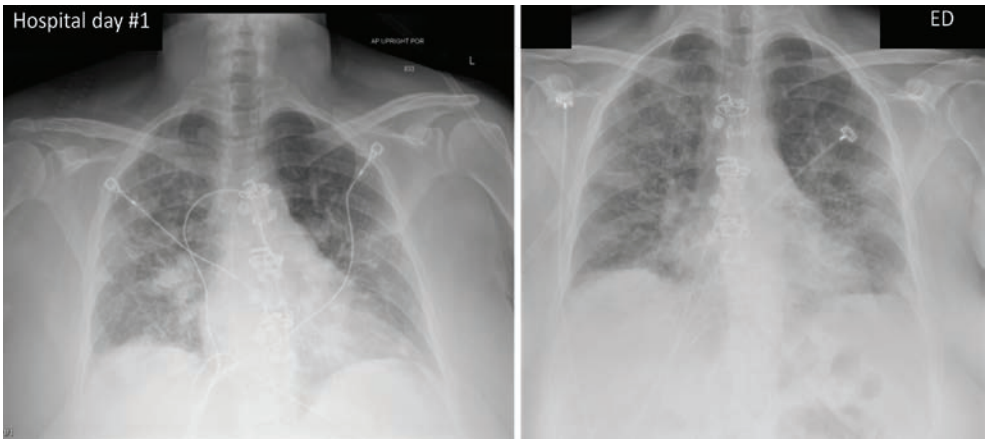


Figure 4. Serial chest radiographs in a patient with rapidly progressive COVID-19 pneumonia (Case 2). Chest radiographs at presentation to the Emergency department (ED) on the right and on hospital day #1 on the left.

she developed fatigue, dyspnea, dry cough, and poor appetite. The dyspnea became severe and she presented to the emergency department where she was found to be hypoxemic with an oxygen saturation of 92% on oxygen at six liters/minute by nasal cannula. She was SARS-CoV-2 PCR positive and she was admitted to general medicine. She began treatment with dexamethasone and remdesivir.

On hospital day one, her oxygen requirements escalated quickly, from 6 liters to 10 liters and then to high-flow nasal cannula at 45 liters per minute and 80% FiO2. Due to her rapid decline, she was transferred to the medical ICU. Her chest radiographs are shown in Figure 4 and show bilateral interstitial and alveolar opacities. There is progression of the alveolar opacities in the right hilar region on hospital day #1. Due to her rapid deterioration, she was given a single dose of intravenous tocilizumab, an anti-IL-6R monoclonal antibody, and performed self-proning, rotating back and forth from the prone, lateral, and supine positions every few hours. This combination of regimens and time allowed her to be weaned from her oxygen all the way down to room air before she was discharged to home on hospital day #10.

Treatment of severe COVID-19 pneumonia

I will present some of the data in support of those drugs. Remdesivir is a nucleoside (adenosine) analog that inhibits viral synthesis. The loading dose is 200 mg i.v. on day 1 followed by an additional 4-9 days of 100 mg i.v. daily doses for a total of 5-10 day course. It is generally well tolerated, but may cause nausea, vomiting, or transaminase elevation to name a few of the potential adverse effects. A landmark study published in 2020 in the *New England Journal of Medicine* found a significantly shorter median time to recovery in patients given remdesivir (10 days vs. 15 days, $P<0.001$) compared with placebo[14]. The effect was most pronounced in patients with moderate COVID-19 pneumonia requiring conventional supplemental oxygen, with less clear benefits in patients requiring more advanced support, such as high flow nasal oxygen, non-invasive positive pressure, or invasive mechanical ventilation. However, it is still quite reasonable to administer remdesivir to the more severe patients, as it appears to be a relatively safe drug, there are no alternative anti-viral agents at this time, and it may provide some benefit. It is also more beneficial in patients with symptom durations of 10 days or less, which is the time period where patients are believed to exhibit the most viral replication, but again should not automatically be withheld from patients with symptom durations of more than 10 days on this basis alone.

Dexamethasone is a glucocorticoid steroid and was shown in a landmark study to significantly reduce 28-day mortality in patients with moderate and severe COVID-19 pneumonia compared with placebo.[15] This study changed clinical practice almost overnight and has improved outcomes and saved the lives of countless patients. The dose studied was 6 mg once daily for 10 days. Patients with COVID-19 pneumonia that do not require supplemental oxygen do not appear to benefit from dexamethasone, and may in fact be harmed. The fact that corticosteroids are beneficial in COVID-19 pneumonia, a putative viral pneumonia, is most unusual and suggests that the host inflammatory response may be more relevant to pneumonia pathogenesis than the viral infection itself. More studies are needed to truly understand this process.

Tocilizumab is a monoclonal antibody targeting IL-6 receptors that inhibits downstream IL-6 activation and has been the focus of a number of studies, some positive and some negative.[16] The sweet spot for its use appears to be within 24-48 hours of admission to the ICU in patients already receiving dexamethasone that experience progressive hypoxemic respiratory failure and significantly elevated inflammatory markers (e.g., C-reactive protein ≥ 7.5 mg/dL). Administering it to patients with milder disease or with protracted severe disease appears to expose them to the risks of immunosuppression without apparent benefit. Tocilizumab received emergency use authorization from the FDA in June 2021.

While not given to this patient, baricitinib is another immune modulator (selective inhibitor of Janus kinase (JAK)-1 and -2) authorized for emergency use that inhibits downstream cytokine signaling and was shown to accelerate time to recovery in patients receiving remdesivir compared with placebo.[17] As a suitable alternative to tocilizumab (but not both together), baricitinib is an oral, once daily medication, and could be considered as add-on therapy to patients already receiving dexamethasone who display escalating oxygen requirements. The largest benefit was seen in patients that did not require mechanical ventilation or other organ support. At institutions where baricitinib or tocilizumab is not available, tofacitinib (an oral JAK-3 inhibitor) could be considered as another alternative.[18]

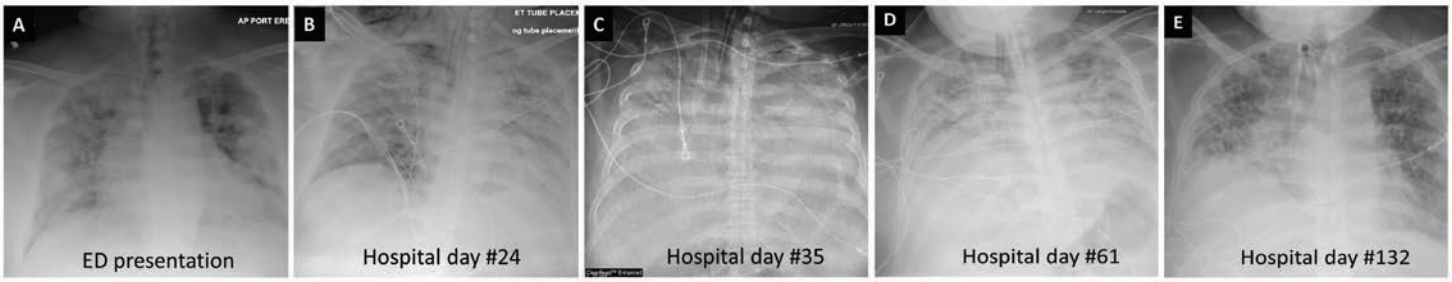


Figure 5.
Serial chest radiographs in a patient with severe COVID-19 pneumonia (Case 3).

A) **Emergency department (ED) presentation**.
B) **Hospital day #24**, immediately after intubation and prior to transfer.
C) **Hospital day #35**, after initiation of extracorporeal membrane oxygenation (ECMO).
D) **Hospital day #61**, still ventilator and ECMO dependent.
E) **Hospital day #132**, decannulated from ECMO and weaned from the ventilator, trach is capped.

CASE 3

The final case is a 42-year-old male with a past medical history notable for hypertension and obesity (BMI 46) who presented to an emergency department with a three-day history of significant dyspnea and hypoxemia and diagnosed with severe COVID-19 pneumonia. He was treated with remdesivir, methylprednisolone, and antibiotics for community-acquired bacterial pneumonia. He had profound hypoxemia and required 100% FiO_2 to maintain PaO_2 in 50-60 mmHg range. He self-proned and was treated with full face BiPAP for approximately three weeks. He was unable to tolerate removing the BiPAP mask to eat and so was given intravenous total parenteral nutrition. His presenting chest radiograph in the ED is shown in Figure 5A. It is an anterior-posterior film, but he probably has cardiomegaly, and also has bilateral alveolar opacities. Due to failure to improve, he was transferred to a tertiary care academic medical center for further management. Figure 5B shows the chest radiograph on the day of hospital transfer, now 24 days after presentation, that shows an endotracheal tube (he was intubated for transfer), more confluent alveolar opacities (left greater than right), and subcutaneous emphysema and possible right apical pneumothorax indicative of barotrauma. Figure 5C shows his chest radiograph now 35 days into his Covid illness. There is profound lung injury, with near complete opacification of both

lungs. There are air bronchograms bilaterally. There is very little remaining lung available for gas exchange, and as a result, he also required cannulation for venovenous extracorporeal membrane oxygenation (VV ECMO). You can see the right internal jugular and right femoral cannulas. Figure 5D shows the chest radiograph at hospital day 61, still on ECMO, with perhaps slightly improved pulmonary edema. Figure 5E shows a chest radiograph at hospital day #132 that shows resolution of the alveolar opacities but new courser, interstitial opacities consistent with fibrotic response. There is elevation of the right hemidiaphragm consistent with volume loss. By hospital day #140, the patient had been fully weaned from the ventilator, and was receiving oxygen by nasal cannula during the day and BiPAP via full facemask at night.

Use of invasive mechanical ventilation for severe COVID-19 pneumonia

What is remarkable about this case is the conscious and deliberate avoidance of intubation and mechanical ventilation for three weeks in favor of using continuous full face BiPAP with 100% FiO_2 and intravenous total parenteral nutrition. What is apparent is the secondary and significant worsening of the acute lung injury due to oxygen toxicity and probably patient self-inflicted lung injury.[19] This case is not unique, though, as many patients, family members, and healthcare providers recall the study published in JAMA by Richardson, et al. reporting an 88% mortality rate of intubated patients in the New York City area.[20] This statistic generated significant coverage in the mainstream media and led many patients, and even providers, to wonder if intubation did more harm than good. However, a correction was issued several days later that flew under the radar. Due to an errant denominator (failing to take into account the 72% of patients that remained alive on the ventilator), the 88% mortality rate of intubated patients was really closer to 24%. This correction did not get much media coverage though, and the 88% statistic stuck. Even many doctors continued to believe (falsely) that intubation was a guaranteed death sentence for patients with severe COVID-19 and should be avoided at all costs, thus leading to patients receiving Bipap for weeks at a time. A mortality rate closer to 24% approximates what is seen for ARDS in general, and should not dissuade providers from intubating patients for severe COVID-19 pneumonia that do not improve after a reasonable course of Bipap. It should also be expected that recovery may be prolonged, as the collective experience is that the lung injury from COVID-19 ARDS is worse than other forms, such as influenza, and can take longer to resolve.

COVID-19 lung histopathology

For the unfortunate patients that do not recover, they do not die from uncontrolled viral replication; they generally die from multi-organ failure and refractory ARDS. An autopsy series[21] found three major patterns of acute lung injury: an epithelial pattern, which is predominantly diffuse alveolar damage, the classical histopathological pattern for ARDS; a vascular pattern, characterized by microvascular damage and/or micro-thrombosis of the capillaries and small pulmonary arteries; and a fibrotic pattern, characterized by interstitial fibrosis, collagen deposition, and architectural distortion. Of course, there is significant overlap between the patterns, and patients can display one or more patterns at the same time, although the most common are the epithelial/vascular overlap pattern (41%) and the isolated epithelial pattern (35%). Fibrosis was seen in 22% of patient lung samples.

SARS-CoV-2 viral loads and viral neutralization

But much like every other infectious disease, viral load is important. And this is likely dependent of the size of the viral inoculum. A significant viral exposure is more likely to cause severe disease than a small viral exposure. The highest viral loads are seen in respiratory tract secretions, but viremia is seen in about one-quarter of hospitalized patients.[22] Not only is higher viremia seen in patients that do not survive, but it also associates with higher inflammatory markers (e.g. cytokines, C-reactive protein), and lower lymphocyte counts.[22]

It stands to reason, then, that antibody neutralization of the virus would be beneficial in patients hospitalized with COVID-19 pneumonia. The first studies to examine this used convalescent plasma (CP). Unfortunately these studies have shown mixed results, with some demonstrating a potential for improved survival,[23-25] and others showing no apparent benefit.[26,27] Taken together, the data suggests that CP is most beneficial when high-titer units are administered to

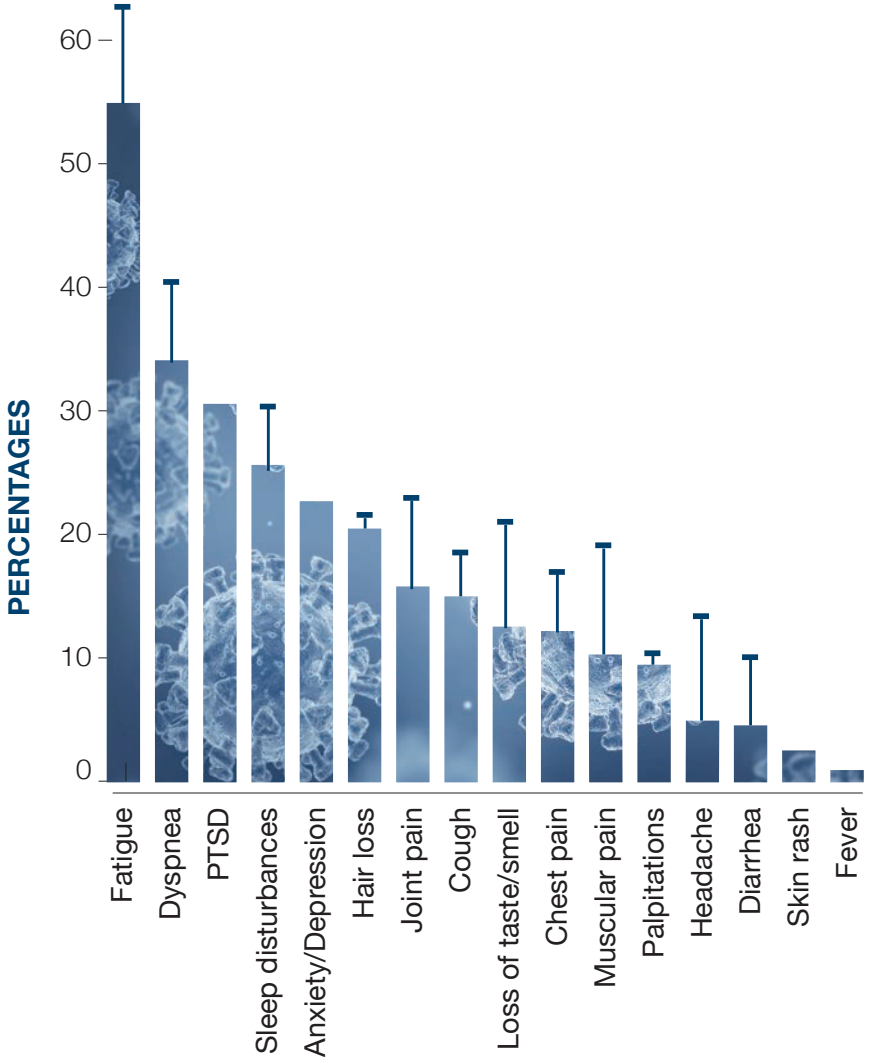


Figure 6.
Symptom prevalence in patients with post-acute sequelae of COVID-19 (PASC). Composite of nine PASC studies (total of n=3,128 patients) reporting prevalence of each symptom at 1-6 months after COVID-19 infection. Adapted from: Nalbandian A, et al. Post-acute COVID-19 Syndrome. Nature Medicine. 2021;27:601-615.

patients with COVID-19 pneumonia that do not require mechanical ventilation. A neutralizing monoclonal antibody was also studied in hospitalized patients with COVID-19 pneumonia without organ failure, but did not show any efficacy.[28] Other monoclonal antibodies tested by the ACTIV-3 trial network were also non-beneficial, but some are still under investigation. Another layer of complexity to this topic is the observation that neutralizing antibody levels appear to associate with COVID-19 severity, i.e. the sickest patients have the highest titers of neutralizing antibodies.[29] This suggests that humoral immunity is not the culprit lesion in severe COVID-19 pneumonia. The one caveat is that patients with poor humoral immune responses, such as those with immunodeficiencies, experience worse outcomes,[30] and might benefit the most from CP[31] or other neutralizing antibody therapies; this is an area of active study.

Extra-pulmonary manifestations of COVID-19

As already mentioned, COVID-19 can affect nearly every organ-system, either in isolation or in combination. For instance, involvement of the central and peripheral nervous systems can manifest as migraine, encephalopathy, myelitis, neuropathy, and even acute psychosis as the sole manifestation of COVID-19 infection.[32] The virus can infect the kidney[33] causing acute kidney injury, and possibly the liver as well causing acute hepatic injury.[34] As already discussed, the vasculature is involved with evidence of endothelial injury predisposing to thrombotic complications. Cardiac involvement has been well described, particularly myocarditis.[35,36] Even genitourinary involvement is reported.[37] Other organs, such as GI tract involvement, manifests clinically as nausea, vomiting, diarrhea, and stomachaches.

Questions specifically related to divers

Which information is most relevant to gauge whether it is safe for patients recovered from COVID-19 to return to diving? Should routine testing be performed after COVID-19 infection? When should it be performed? Should it vary by Covid severity, by past symptoms, by ongoing symptoms, or by something else? Should there be an automatic waiting period after COVID-19 illness before returning to diving? And how do the recommendations differ based on the type of diving being performed, e.g. commercial, recreational, scientific?

These questions have no immediate answers, but offer a nice segue into discussing Post-Acute Sequelae of COVID-19 (PASC), also known as post-Covid syndrome, Covid Long Hauler syndrome, or Long Haul Covid. This is a conditioned defined by the persistent or delayed long-term symptoms or complications four weeks after a Covid illness.[38] Increasingly more information is coming out about PASC, but there is a lot we do not know, such as what causes it and what the long-term effects might be. A number of pathophysiological mechanisms have been proposed, such as direct viral cytotoxicity; an inflammatory insult; endothelial or microvascular damage; thrombotic complications; or ACE-2 receptor pathway dysregulation.[38]

A review of nine studies of over 3000 patients with PASC was reported.[38] (Figure 6) These patients were typically middle-aged (40s-60s years old), 37–56% female, moderate to severe COVID-19 (53–78% required oxygen during their acute Covid illness), with 0-32% requiring ICU-level care. The most common symptom was fatigue, followed by dyspnea, PTSD, sleep disturbances, anxiety/depression, and others.

My colleagues and I have studied pulmonary function testing (PFT) in patients with PASC, and found significant impairments in forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), and diffusing capacity for carbon monoxide (DLCO) at nine weeks following Covid infection.[39] (Figure 7) These impairments associated with Covid severity, i.e. the more severe the COVID-19 infection was, the more severely impaired the lung function was. Most of the impairment was in a restrictive pattern, indicating a lung fibrotic response after COVID-19 pneumonia, although there were isolated cases of obstructive lung disease as well.

One are the most notable and surprising things we found was the lack of relationship between patient-reported subjective respiratory symptoms (dyspnea, fatigue, and cough) and the objective degree of lung function impairment as measured by PFT. (Figure 8) This means that patients with no respiratory symptoms at all could still have severely impaired lung function. There is really no way to distinguish between patients with normal lung function and reduced lung function based on symptoms alone.[39,40]

What about structural lung disease? Cystic lung changes have been described in patients who have recovered from COVID-19 pneumonia. In fact, the incidence of lung pseudocysts or pneumatoceles may be as high as 10% after Covid.[41] This was illustrated nicely in a case report from Japan where a patient with acute COVID-19 pneumonia was followed with serial CT scans of the chest on days 1, 9, and 16 of Covid illness.[42] The CT scans showed progression from ground-glass opacities, to consolidation, to a large cystic structure. These kinds of structural changes are relevant to diving due to the risk of air trapping and pulmonary barotrauma.

Certainly patients with PASC that are experiencing persistent dyspnea and reduced exertional tolerance could be unable to meet the high cardiopulmonary requirements of diving. It has also been proposed that the pulmonary microvascular damage may increase the risk of arterial gas emboli, possibly due to increased shunting or altered transpulmonary blood flow.

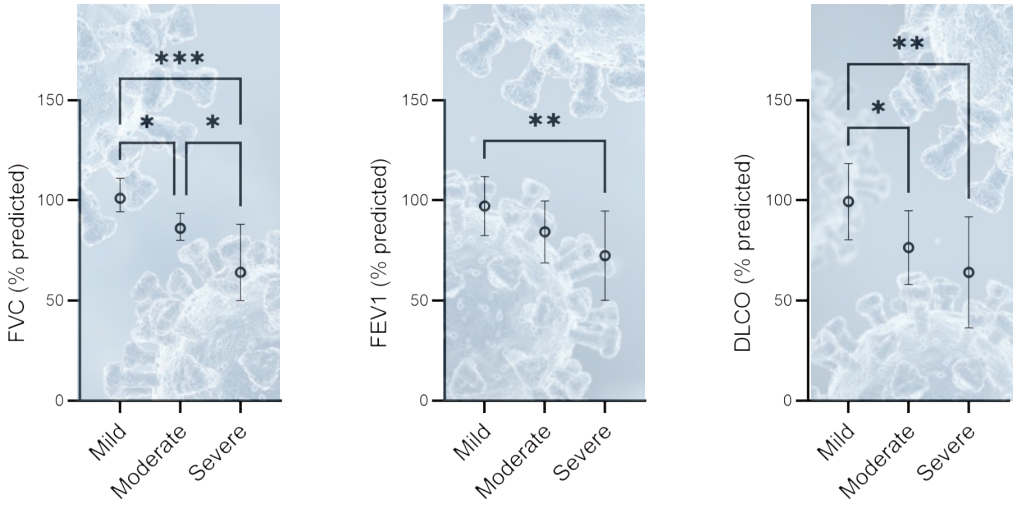


Figure 7.
Pulmonary function tests in patients at 9 weeks after COVID-19 infection. Percent predicted forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), and diffusing capacity for carbon monoxide (DLCO) are shown in patients that recovered from mild (n=9-12), moderate (n=24-27), or severe (n=17) COVID-19 infection. *P<0.05, **P<0.01, ***P<0.001 by Kruskal-Wall test with Benjamini-Hochberg post-hoc test. Adapted from: Chun H, et al. Immunofibrotic drivers of impaired lung function in postacute sequelae of SARS-CoV-2 infection. JCI Insight. 2021;6(14):e148476.

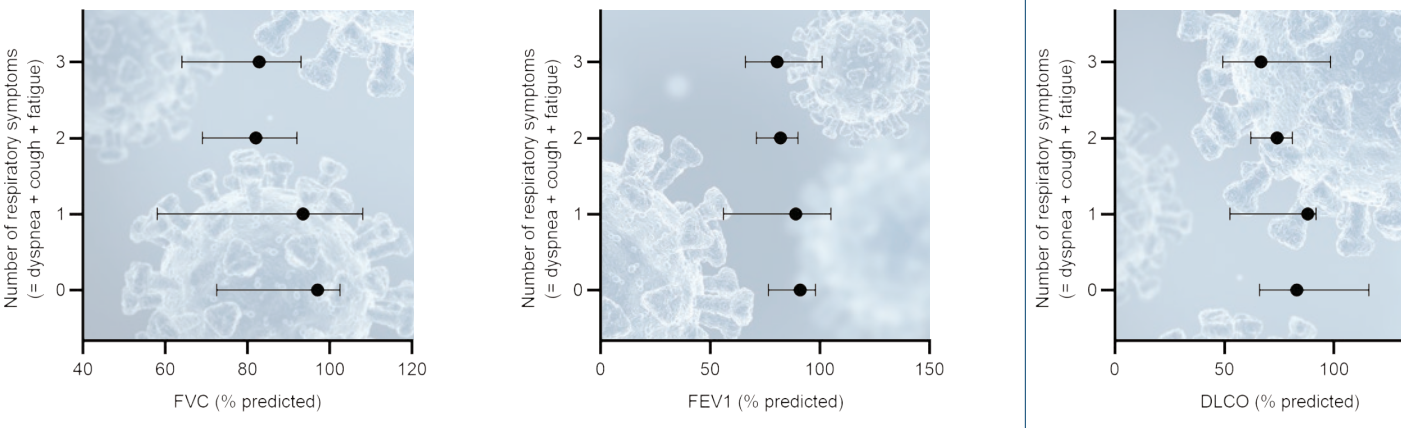
This is an interesting question that has not yet been definitively answered. And any cardiac involvement may predispose to new-onset arrhythmias, heart failure, or myocardial infarction when at pressure.[43]

Thoughts on the future of the COVID-19 pandemic

We have learned a lot about coronaviruses in the last year and a half. It is doubtful at this point that SARS-CoV-2 will vanish from the U.S., like polio has, for instance. But it is expected that immunity will gradually increase over time in adults and in children, as natural infections and vaccination efforts surge. Hopefully the latter will predominate over the former. We know that variants arise from significant viral replication, which is the hallmark of a surge, and it is likely that future variants will emerge from uncontrolled spread of the Delta variant. The fear of course is that a new variant could escape immunity from the vaccine, which would take us back to square one of combating the pandemic. Also the immunity that comes from a natural infection does not appear to be as robust or durable as that from a vaccine. But eventually we will, as a society, reach a level of herd immunity. Put differently, every single one of us at some point will be exposed to SARS-CoV-2, and the outcome of that exposure will depend on our preexisting immunity and vaccination status. The pandemic will eventually evolve into an endemic disease that causes a seasonal upper respiratory tract illness in children, similar to the other four seasonal coronaviruses that circulate in the U.S. As has already been seen, this will be mild in most children, but a not insignificant number could develop severe complications, and therefore vaccinations will likely start at 6 months of age similar to influenza. Based on research of other coronavirus pandemics, the transition from pandemic to endemic could take about two years. It is likely that a booster vaccine dose will be necessary, although whether it is given annually, or according to a different schedule is not yet clear. We are already seeing this done in other countries (e.g. Israel) and for select groups (immunocompromised) in the U.S. Perhaps the COVID-19 vaccination will be combined with the annual influenza vaccine in the future.

Figure 8.

No correlation between subjective symptoms and impaired lung function in patients at 9 weeks after COVID-19 infection. Percent predicted forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), and diffusing capacity for carbon monoxide (DLCO) are shown in patients at 9 weeks after COVID-19 infection with 0 (n=9), 1 (n=15), 2 (n=25), or 3 (n=7) lingering respiratory symptoms (1 point each for fatigue, dyspnea, and cough). There were no significant differences by lung function. Adapted from: Chun H, et al. Immunofibrotic drivers of impaired lung function in postacute sequelae of SARS-CoV-2 infection. JCI Insight. 2021;6(14):e148476.



Sadly, this is unlikely to be the last respiratory virus pandemic. In the last twenty years alone we have seen four respiratory viruses cause pandemics or had pandemic-potential: the first SARS in 2003, H1N1 in 2009, MERS or Middle East Respiratory Virus in 2012, and then of course SARS-CoV-2 in 2019. There are other pre-pandemic coronaviruses in bats that are known, as well as avian influenza strains, all of which have pandemic potential. Frighteningly, the first human avian influenza cases in China and Russia, due to H5N8 and H10N3, were reported this year. But all is not lost. Colleagues at the Duke Human Vaccine Institute have developed a novel vaccine that not only targets SARS-CoV-2, but retains activity and protection against the tested COVID-19 variants, against the original SARS coronavirus, and was against a one of the pre-emergent coronavirus that has not yet jumped to humans[44].

The mRNA vaccine technology is particularly exciting and has already transformed vaccination research. For instance, the Moderna pipeline includes candidate vaccines for human metapneumovirus, Zika, influenza, HIV, and avian influenza. If there is a silver lining to this pandemic, it's the rapid yet robust advancement of the mRNA vaccine science. Amazingly, the mRNA vaccines were developed at record pace and are some of the safest and most efficacious vaccines ever created. And the technology allows for rapid modification of the mRNA message to address future viruses or escape variants. Thank you.

Discussion:

Richard Moon: Bryan, that was fantastic. Thank you for a great lecture. If you have any questions, please enter them into the chat. I would just like to comment on the slide that you showed, indicating that the presence or absence of pulmonary function test abnormalities was not predictable by symptoms. So in other words, totally asymptomatic people can have significant abnormalities in PFTs and I think this will cite further discussion later when we talk about who to test or when to test for divers.

Bryan Kraft: Thank you. Yes, this was one of our more surprising findings. One other study published in PLoS One last year also found a discordance between subjective and objective respiratory impairments. That paper is cited in our manuscript. It does give one pause to use subjective symptoms alone as a marker for clearance to dive, and just like you said, it's deserving of further discussion.

Speaker 3: Bryan, as a follow up to that question, do you think that cardiopulmonary exercise testing as screening may uncover those patients that do ultimately have altered PFTs?

Bryan Kraft: Yes, I do. Exercise testing would be a great way to evaluate a patient's level of underlying cardiopulmonary reserve and should uncover those limitations if present.

Speaker 3: Another question, Bryan, and this is something that I guess we will discuss throughout the day is the thromboembolic events that were discussed and its particularly someone who proceeds to dive fairly close to his infection. Are there measures that one can take, such as getting up frequently during prolonged air travel or transportation in a motor vehicle or attention to hydration, that could be done to reduce thromboembolic risks? Is there anything else that you

might recommend that a diver could consider? And this is something I guess we'll discuss later on in the afternoon. Could a diver take an aspirin if they had concern about having a thromboembolic phenomenon, such as PE or DVT.

Bryan Kraft: That's a great question. And this is a topic of ongoing research. The data we have from the ACTIV-4 studies to date do not support the routine use of anticoagulants or aspirin to reduce thrombotic complications in ambulatory patients with mild COVID-19. I am not aware of this being studied in the PASC population though. This probably requires further study. I did not go into the inpatient use of anti-coagulants, but a recent ACTIV-4 study found that patients with moderate disease given full dose anticoagulation had a reduced risk of progression to severe disease[45]. This is certainly consistent with our understanding of the COVID-19-associated vascular injury and complications thereof, and should be used in patients with moderate disease without contraindications. I expect you will start to see guidelines updated to reflect this study. Interestingly, the same benefit was not seen in patients with severe disease[46], and may suggest the thrombotic complications have already occurred in this population. Another trial is now studying whether adding anti-platelet drugs to anti-coagulants is helpful. But this is for the inpatient side. For patients that are recovered from COVID-19 who may or may not have PASC, there is not enough known either way regarding whether adding aspirin, for instance, is beneficial.

Richard Moon: There's a question in the chat. Are you aware of any case reports of the effect of hyperbaric oxygen on Long Hauler COVID-19 syndrome?

Bryan Kraft: Interesting question. No, I'm not aware of any. I know that hyperbaric oxygen has been studied in the acute COVID-19 pneumonia setting, which I didn't go into, but I'm not aware of anything in the Long Hauler setting.

Richard Moon: Is there any evidence that repeat doses of anti-inflammatory drugs, such as steroids may affect Long Hauler COVID-19?

Bryan Kraft: Another great question. We've used steroids in pulmonary clinic in patients with PASC that have evidence of persistent airways inflammation, such as wheezing, reactive airways disease, or persistent bronchitis. But for non-specific symptoms, like myositis or fatigue, there's nothing to support the use of it in that setting.

REFERENCES

1. Ma J. Coronavirus: China's first confirmed COVID-19 case traced back to November 17. *South China Morning Post.* March 13, 2020, 2020.
2. Dittmayer C, Meinhardt J, Radbruch H, et al. Why misinterpretation of electron micrographs in SARS-CoV-2-infected tissue goes viral. *Lancet.* 2020;396(10260):e64-e65.
3. Ackermann M, Verleden SE, Kuehnel M, et al. Pulmonary Vascular Endothelialitis, Thrombosis, and Angiogenesis in COVID-19. *The New England journal of medicine.* 2020.
4. Berlin DA, Gulick RM, Martinez FJ. Severe COVID-19. *The New England journal of medicine.* 2020;383(25):2451-2460.
5. Carr BG, Addyson DK, Kahn JM. Variation in critical care beds per capita in the United States: implications for pandemic and disaster planning. *JAMA : the journal of the American Medical Association.* 2010;303(14):1371-1372.
6. PRNewsire. REGEN-COV™ (casirivimab and imdevimab) Phase 3 RECOVERY Trial Meets Primary Outcome, Improving Survival in Hospitalized COVID-19 Patients Lacking an Immune Response to SARS-CoV-2. https://www.prnewswire.com/news-releases/regen-cov-casirivimab-and-imdevimab-phase-3-recovery-trial-meets-primary-outcome-improving-survival-in-hospitalized-COVID-19-patients-lacking-an-immune-response-to-sars-cov-2-301313292.html. Published 2021. Updated June 16, 2021. Accessed August 4, 2021.
7. Hoffmann M, Arora P, Gross R, et al. SARS-CoV-2 variants B.1.351 and P.1 escape from neutralizing antibodies. *Cell.* 2021;184(9):2384-2393 e2312.
8. Philley JV. Antibody treatment for COVID-19: a combination is successful. Paper presented at: American Thoracic Society Annual Conference2021; Virtual.
9. An EUA for sotrovimab for treatment of COVID-19. *Med Lett Drugs Ther.* 2021;63(1627):97-xx98.
10. Gupta A, Gonzalez-Rojas Y, Juarez E, et al. Early COVID-19 Treatment With SARS-CoV-2 Neutralizing Antibody Sotrovimab. *medRxiv.* 2021:2021.2005.2027.21257096.
11. Planas D, Veyer D, Baidaliuk A, et al. Reduced sensitivity of SARS-CoV-2 variant Delta to antibody neutralization. *Nature.* 2021.
12. Chen RE, Winkler ES, Case JB, et al. In vivo monoclonal antibody efficacy against SARS-CoV-2 variant strains. *Nature.* 2021;596(7870):103-108.
13. O'Brien MP, Forleo-Neto E, Musser BJ, et al. Subcutaneous REGEN-COV Antibody Combination to Prevent COVID-19. *The New England journal of medicine.* 2021.
14. Beigel JH, Tomashek KM, Dodd LE, et al. Remdesivir for the Treatment of COVID-19–Final Report. *The New England journal of medicine.* 2020;383(19):1813-1826.
15. Group RC, Horby P, Lim WS, et al. Dexamethasone in Hospitalized Patients with COVID-19. *The New England journal of medicine.* 2021;384(8):693-704.
16. Angriman F, Ferreyro BL, Burry L, et al. Interleukin-6 receptor blockade in patients with COVID-19: placing clinical trials into context. *Lancet Respir Med.* 2021;9(6):655-664.
17. Kalil AC, Patterson TF, Mehta AK, et al. Baricitinib plus Remdesivir for Hospitalized Adults with COVID-19. *The New England journal of medicine.* 2021;384(9):795-807.
18. Guimaraes PO, Quirk D, Furtado RH, et al. Tofacitinib in Patients Hospitalized with COVID-19 Pneumonia. *The New England journal of medicine.* 2021;385(5):406-415.

19. Grieco DL, Maggiore SM, Roca O, et al. Non-invasive ventilatory support and high-flow nasal oxygen as first-line treatment of acute hypoxemic respiratory failure and ARDS. *Intensive care medicine.* 2021;47(8):851-866.

20. Richardson S, Hirsch JS, Narasimhan M, et al. Presenting Characteristics, Comorbidities, and Outcomes Among 5700 Patients Hospitalized With COVID-19 in the New York City Area. *JAMA : the journal of the American Medical Association.* 2020;323(20):2052-2059.

21. Polak SB, Van Gool IC, Cohen D, von der Thusen JH, van Paassen J. A systematic review of pathological findings in COVID-19: a pathophysiological timeline and possible mechanisms of disease progression. *Mod Pathol.* 2020;33(11):2128-2138.

22. Fajnzylber J, Regan J, Coxen K, et al. SARS-CoV-2 viral load is associated with increased disease severity and mortality. *Nat Commun.* 2020;11(1):5493.

23. O'Donnell MR, Grinsztejn B, Cummings MJ, et al. A randomized double-blind controlled trial of convalescent plasma in adults with severe COVID-19. *The Journal of clinical investigation.* 2021;131(13).

24. Klassen SA, Senefeld JW, Johnson PW, et al. The Effect of Convalescent Plasma Therapy on Mortality Among Patients With COVID-19: Systematic Review and Meta-analysis. *Mayo Clin Proc.* 2021;96(5):1262-1275.

25. Joyner MJ, Carter RE, Senefeld JW, et al. Convalescent Plasma Antibody Levels and the Risk of Death from COVID-19. *The New England journal of medicine.* 2021;384(11):1015-1027.

26. Group RC. Convalescent plasma in patients admitted to hospital with COVID-19 (RECOVERY): a randomised controlled, open-label, platform trial. *Lancet.* 2021;397(10289):2049-2059.

27. Simonovich VA, Burgos Pratx LD, Scibona P, et al. A Randomized Trial of Convalescent Plasma in COVID-19 Severe Pneumonia. *The New England journal of medicine.* 2021;384(7):619-629.

28. Group A-TL-CS, Lundgren JD, Grund B, et al. A Neutralizing Monoclonal Antibody for Hospitalized Patients with COVID-19. *The New England journal of medicine.* 2021;384(10):905-914.

29. Garcia-Beltran WF, Lam EC, Astudillo MG, et al. COVID-19-neutralizing antibodies predict disease severity and survival. *Cell.* 2021;184(2):476-488 e411.

30. Dispinseri S, Secchi M, Pirillo MF, et al. Neutralizing antibody responses to SARS-CoV-2 in symptomatic COVID-19 is persistent and critical for survival. *Nat Commun.* 2021;12(1):2670.

31. Senefeld JW, Klassen SA, Ford SK, et al. Use of convalescent plasma in COVID-19 patients with immunosuppression. *Transfusion.* 2021;61(8):2503-2511.

32. Lanier CG, Lewis SA, Patel PD, Ahmed AM, Lewis PO. An Unusual Case of COVID-19 Presenting as Acute Psychosis. *J Pharm Pract.* 2020:897190020977721.

33. Braun F, Lutgehetmann M, Pfefferle S, et al. SARS-CoV-2 renal tropism associates with acute kidney injury. *Lancet.* 2020;396(10251):597-598.

34. Wang Y, Liu S, Liu H, et al. SARS-CoV-2 infection of the liver directly contributes to hepatic impairment in patients with COVID-19. *J Hepatol.* 2020;73(4):807-816.

35. Inciardi RM, Lupi L, Zaccone G, et al. Cardiac Involvement in a Patient With Coronavirus Disease 2019 (COVID-19). *JAMA Cardiol.* 2020;5(7):819-824.

36. Grimaud M, Starck J, Levy M, et al. Acute myocarditis and multisystem inflammatory emerging disease following SARS-CoV-2 infection in critically ill children. *Ann Intensive Care.* 2020;10(1):69.

37. Grimberg DC, Tejwani R, Allkanjari A, Forrester MT, Kraft BD, Kaye DR. Ischemic priapism due to coagulopathy of severe COVID-19 infection. *Journal of Clinical Urology.*0(0):20514158211025914.

38. Nalbandian A, Sehgal K, Gupta A, et al. Post-acute COVID-19 syndrome. *Nature medicine.* 2021;27(4):601-615.

39. Chun HJ, Coutavas E, Pine AB, et al. Immunofibrotic drivers of impaired lung function in postacute sequelae of SARS-CoV-2 infection. *JCI Insight.* 2021;6(14).

40. Townsend L, Dyer AH, Jones K, et al. Persistent fatigue following SARS-CoV-2 infection is common and independent of severity of initial infection. *PloS one.* 2020;15(11):e0240784.

41. Shi H, Han X, Jiang N, et al. Radiological findings from 81 patients with COVID-19 pneumonia in Wuhan, China: a descriptive study. *The Lancet infectious diseases.* 2020;20(4):425-434.

42. Sugimoto H, Era Y, Sugimoto K. Pneumatocele after recovering from COVID-19. *BMJ Case Rep.* 2021;14(4).

43. Sadler C, Alvarez Villela M, Van Hoesen K, et al. Diving after SARS-CoV-2 (COVID-19) infection: Fitness to dive assessment and medical guidance. *Diving Hyperb Med.* 2020;50(3):278-287.

44. Saunders KO, Lee E, Parks R, et al. Neutralizing antibody vaccine for pandemic and pre-emergent coronaviruses. *Nature.* 2021;594(7864):553-559.

45. Investigators A, Investigators AC-a, Investigators R-C, et al. Therapeutic Anticoagulation with Heparin in Noncritically Ill Patients with COVID-19. *The New England journal of medicine.* 2021.

46. Investigators R-C, Investigators AC-a, Investigators A, et al. Therapeutic Anticoagulation with Heparin in Critically Ill Patients with COVID-19. *The New England journal of medicine.* 2021.

Imaging Consideration

Peter Lindholm, MD, PhD

Diving can pose risk of barotrauma during ascent from depth, and unhealthy lungs can be considered to increase this risk of overexpansion injuries during decompression (Boyle's law: volume is inversely proportional to pressure P1 x V1 = P2 x V2). The result could be pneumomediastinum, pneumothoraces, and arterial gas emboli.[1,2] COVID-19 often include severe pulmonary disease, and often even mild cases of non-hospitalized patients have shown pathology on pulmonary imaging.

Localized trapping of air cannot be excluded by spirometry: general obstructive disease can be monitored by non-invasive pulmonary function testing, while local air trapping phenomena, emphyeamtous bullae etc. will require imaging for their detection. Likewise localized smaller areas of fibrosis may not show on pulmonary function tests.

- Air trapping in chest imaging refers to retention of excess gas ('air') in all or part of the lung, especially during expiration, either as a result of complete or partial airway obstruction, or as a result of local abnormalities in pulmonary compliance. It may also sometimes be observed in normal individuals.
- Air trapping is common, occurring in ~50% of CT thorax examinations. Mild (<25% parenchyma) air trapping may be commonly symptomatic or clinically insignificant
- Pulmonary blebs are small subpleural thin-walled air-containing spaces, not larger than 1 or 2 cm in diameter (with the precise limit varying by source). Their walls are less than 1 mm thick. If they rupture, they allow air to escape into the pleural space resulting in a spontaneous pneumothorax (from radiopaedia.org).
- Bulla: thin wall (<1 mm), usually considered larger than blebs (>1 or 2 cm)
- Pneumatocele: deeper within the lung
- Pulmonary cyst: wall thickness 1–3 mm
- Emphysema: lucencies without a wall and with a central vessel

BULLAE AND BLEBS

Traditionally, the presence of bullae and blebs have been contraindications for Scuba diving due to increased risk of overexpansion injury.[3,4] Their presence is a disqualifying condition for military, commercial, and scientific divers. Based on case reports, it has been shown that individuals who have suffered barotrauma have had large (>20 mm) pulmonary bullae, and patients with large bullae and blebs should probably be excluded from diving. In a case series of autopsies performed on otherwise healthy individuals without lung disease, the incidence was approximately 33%.[5]

Some describe the presence of bullae and blebs as so frequent a finding that "radiologists in my institution do not routinely report on small blebs on CT scans as they are so common as to be considered normal findings in the patient population seen by a major hospital radiology department."[6]

Winglaar[7] studied 94 asymptomatic military divers with high resolution computer tomography (HRCT) whom were without findings on chest x-ray CXR (Netherlands), age 18–53. HRCT determined that seven had blebs, and five of those were excluded from further diving. Another 13 was also excluded due to physiological air trapping and bronchiectasis.

Pulmonary fibrosis is a serious condition, which makes the lungs stiffer and so reduces lung compliance and also impairs gas transfer. Diving is generally considered contraindicated in subjects who have fibrotic lung disease. The British Thoracic Society Fitness to Dive Group based their recommendations on evidence from expert committee reports or opinions and/or clinical experience of respected authorities. There are no directly applicable studies of good quality.

It is worth noting that some post-covid changes in the lungs look like fibrosis but may not be the classical chronic scarring. Some radiologist use "fibrous-like changes" as a new intermediate terminology.

Various imaging techniques that could be considered for use were reviewed briefly in the lecture with images etc. These will not be described in these proceedings, refer to radiology literature for standard procedures etc.

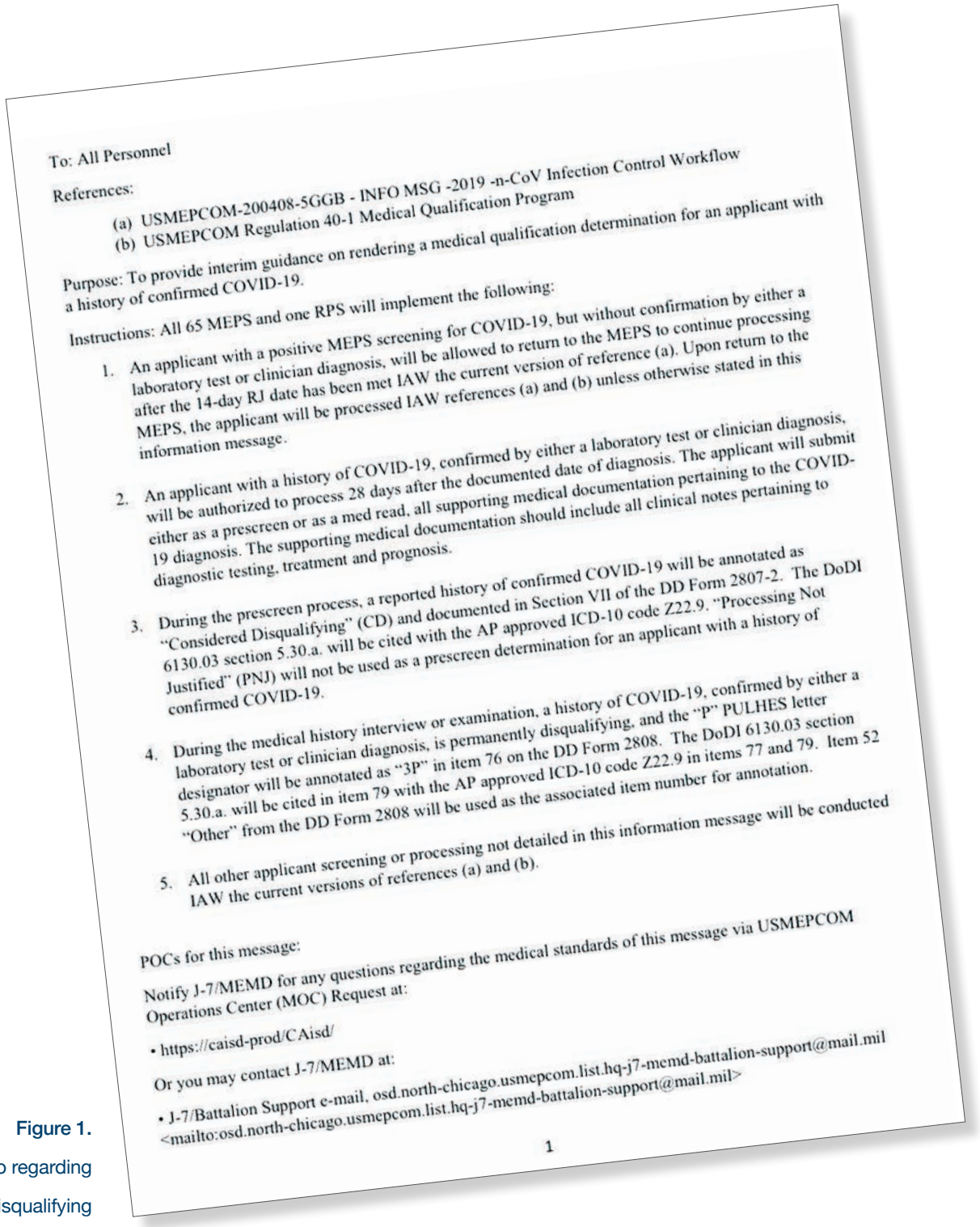
- Chest X-ray
- Computer tomography
- Computer tomography with intravenous contrast injection
- High resolution CT (HRCT) (today all CT are thin sliced…)
- Low dose (can produce fairly good images with lower radiation)
- CT inspired/expired scans
- Dual Energy Computer Tomography (DECT)
- Magnetic resonance imaging with perfusion, hyperpolarized Xenon
- V/Q scans low resolution

SOME SUGGESTIONS:

- If a diver has lingering symptoms, then consider that perfusion defects in the lung that affect exercise capacity may not show on regular imaging such as CT or X-Ray (but may show on DECT or perfusion MRI).
- Do not consider fibrosis on a standard radiology report in an otherwise healthy diver as a permanent condition. It could be worth seeking a second opinion or ask the radiologist whether it is covid-related fibrous-like changes or traditional fibrosis. Consider repeating the test, so not to disqualifying career divers for life.
- Not all radiologists describe findings with the same terminology; even if most terms are standardized, there are lots of variations with the evolving knowledge of COVID-19.
- We currently don't see the need to image asymptomatic non-hospitalized divers who have returned to normal exercise capacity,[9] just because they have had COVID-19. For those with symptoms, they should be treated on a case by case basis.

REFERENCES

1. Wingelaar T, van Ooij PJ, Koch D. AGE during controlled ascent training in a Navy Diver trainee: a case report with video. UHMS Annual meeting 2018. DOI:10.13140/RG.2.2.27791.28325.
2. Goffinet CM, Simpson G. Cerebral arterial gas embolism in a scuba diver with a primary lung bulla. Diving Hyperb Med. 2019 Jun 30;49(2):141-144. doi: 10.28920/dhm49.2.141-144. PMID: 31177521; PMCID: PMC6704005.
3. Reuter M, Tetzlaff K, Warninghoff V, Steffens JC, Bettinghausen E, Heller M. Computed tomography of the chest in diving-related pulmonary barotrauma. Br J Radiol. 1997 May;70(833):440–445. PMID: 9227223
4. Germonpré P, Balestra C, Pieters T. Influence of scuba diving on asymptomatic isolated pulmonary bullae. Diving Hyperb Med. 2008 Dec;38(4):206–211. PMID: 22692754
5. de Bakker HM, Tijsterman M, de Bakker-Teunissen OJG, Soerdjbalie-Maikoe V, van Hulst RA, de Bakker BS. Prevalence of Pulmonary Bullae and Blebs in Postmortem CT Imaging With Potential Implications for Diving Medicine. Chest. 2020 Apr;157(4):916–923. PMID: 31759963
6. Millar IL. Should computed tomography of the chest be recommended in the medical certification of professional divers? Br J Sports Med. 2004 Feb;38(1):2–3. PMCID: PMC1724731)
7. Wingelaar TT, Bakker L, Nap FJ, van Ooij PAM, Endert EL, van Hulst RA. Routine Chest X-Rays Are Inaccurate in Detecting Relevant Intrapulmonary Anomalies During Medical Assessments of Fitness to Dive. Front Physiol. 2021 Jan 6;11:613398. doi: 10.3389/fphys.2020.613398. PMID: 33488401; PMCID: PMC7816860.
8. British Thoracic Society Fitness to Dive Group, Subgroup of the British Thoracic Society Standards of Care Committee. British Thoracic Society guidelines on respiratory aspects of fitness for diving. Thorax. 2003 Jan;58(1):3–13. PMCID: PMC1746450
9. Sadler C, Alvarez Villela M, Van Hoesen K, Grover I, Lang M, Neuman T, Lindholm P. Diving after SARS-CoV-2 (COVID-19) infection: Fitness to dive assessment and medical guidance. Diving Hyperb Med. 2020 Sep 30;50(3):278-287. doi: 10.28920/dhm50.3.278-287. PMID: 32957131; PMCID: PMC7755459.



To: All Personnel

References:

(a) USMEPCOM-200408-5GGB - INFO MSG -2019 -n-CoV Infection Control Workflow
(b) USMEPCOM Regulation 40-1 Medical Qualification Program

Purpose: To provide interim guidance on rendering a medical qualification determination for an applicant with a history of confirmed COVID-19.

Instructions: All 65 MEPS and one RPS will implement the following:

1. An applicant with a positive MEPS screening for COVID-19, but without confirmation by either a laboratory test or clinician diagnosis, will be allowed to return to the MEPS to continue processing after the 14-day RJ date has been met IAW the current version of reference (a). Upon return to the MEPS, the applicant will be processed IAW references (a) and (b) unless otherwise stated in this information message.

2. An applicant with a history of COVID-19, confirmed by either a laboratory test or clinician diagnosis, will be authorized to process 28 days after the documented date of diagnosis. The applicant will submit either as a prescreen or as a med read, all supporting medical documentation pertaining to the COVID-19 diagnosis. The supporting medical documentation should include all clinical notes pertaining to diagnostic testing, treatment and prognosis.

3. During the prescreen process, a reported history of confirmed COVID-19 will be annotated as "Considered Disqualifying" (CD) and documented in Section VII of the DD Form 2807-2. The DoDI 6130.03 section 5.30.a. will be cited with the AP approved ICD-10 code Z22.9. "Processing Not Justified" (PNJ) will not be used as a prescreen determination for an applicant with a history of confirmed COVID-19.

4. During the medical history interview or examination, a history of COVID-19, confirmed by either a laboratory test or clinician diagnosis, is permanently disqualifying, and the "P" PULHES letter designator will be annotated as "3P" in item 76 on the DD Form 2808. The DoDI 6130.03 section 5.30.a. will be cited in item 79 with the AP approved ICD-10 code Z22.9 in items 77 and 79. Item 52 "Other" from the DD Form 2808 will be used as the associated item number for annotation.

5. All other applicant screening or processing not detailed in this information message will be conducted IAW the current versions of references (a) and (b).

POCs for this message:

Notify J-7/MEMD for any questions regarding the medical standards of this message via USMEPCOM Operations Center (MOC) Request at:

• https://caisd-prod/CAisd/

Or you may contact J-7/MEMD at:

• J-7/Battalion Support e-mail, osd.north-chicago.usmepcom.list.hq-j7-memd-battalion-support@mail.mil <mailto:osd.north-chicago.usmepcom.list.hq-j7-memd-battalion-support@mail.mil>

1

Figure 1.
DOD memo regarding COVID-19 as a disqualifying condition for military duty

Dyspnea After COVID-19

Michael Ott, MD, Lt Col, USAF

I'm really pleased to provide the perspective of someone in the trenches.

Disclosures: First and foremost, since we're discussing military information, everything presented today is unclassified. We've gone to great lengths to make sure that everything in this presentation is suitable for sharing. The protocols we're going to discuss from the military were designed for a military population, presumably a younger and healthier population. With that caveat, they weren't designed for a general population although we will discuss them as examples. The views expressed in this presentation do not represent the Defense Health Administration, the DOD, the Air Force, or any of my superiors, and we're not going to discuss any products or drugs.

This is where we started, which was in sheer panic. As Doctor Chimiak mentioned, in this Department of Defense (DOD) document number four, describes COVID-19 history as being permanently disqualifying from military duty. (Figure 1) We've moved through the year with different waves of panic and respite. In March of this year, the CDC described our impending doom.

Then in May, we had a dramatic change of guidance for relaxing masks and getting back out and traveling. So it really has been a chaotic, tumultuous year for all of us. This is where I've spent most of my year.

In February of last year, when they asked me to serve as the only Critical Care doctor at Eglin Air Force Base for the COVID-19 pandemic; I of course said, yes. We began to explore our resources which in the military include the war reserve material warehouses.

We began plans to expand our small military hospital into a huge facility with ventilators in the lobbies and all the other non-typical patient care areas. Thankfully that wasn't needed, and we were able to manage within our walls. But just as we were getting comfortable with our process at the hospital, the military decided to open additional facilities including field hospitals and hospitals of opportunity. Being a pulmonologist has very popular during this pandemic and I was tasked to go to Miami as the training director and SME for one of those hospitals in the Miami Convention Center.

We had seven facilities in total in Miami. They ranged from very austere on the right with just partitions in an open convention center to a full-blown ICU on the left which was hard plumbed, had negative pressure rooms with ventilation and UV lights.

It was a large facility scalable to 2000 patients. It was certainly an interesting experience with truckloads of materials including ventilators and personnel from all different parts of the country showing up daily. This was the initial setup team in the first week.

> "And this is how we felt as we tried to put this ship together. This is absolutely building the plane as we fly it."

> In talking with colleagues over the ensuing months, I've repeatedly detected a kind of '*Bayesian fatigue:*' a stress-induced dysphoria that is experienced when the corpus of knowledge that one has acquired over years to decades and that is the foundation of one's work becomes less important than information that's being gathered from disparate sources in real time.

J. Niels Rosenquist, M.D., PhD
January 7, 2021
N Engl J Med 2021;
384:7–9

Figure 3.

Bayesian Fatigue

We were able to quickly get a workable hospital together. When the DOD shifted their efforts to vaccination clinics, I was able to come back to Eglin and get back to work in the hospital. And then we really, I think, collectively experienced what the New England Journal beautifully described as Bayesian Fatigue. This was my favorite New England Journal article during the entire pandemic. (Figure 3.)

And this is how we felt as we tried to put this ship together. This is absolutely building the plane as we fly it.

At some point we have to make some decisions. Now we've dealt with this pandemic for a year, and we've decided that this is no longer disqualifying from military service, perhaps impending doom isn't on the way, but certainly we're not through this issue either and it was time to put some pencil to paper. This is DOD's current guidance for just returning to fitness/returning to normal duty.

What I like about this is approach is that in the top two rows it takes a large group of people off the table from having to be under serious consideration. In the military, we have hundreds of thousands of young, healthy people that were going to go through this pandemic with minimal issues and we certainly don't have the medical support to screen every single person in the military with complicated test for returning to their basic job duties. It would really present a readiness issue. So on the top row of the asymptomatic folks, after they've gone through their normal isolation guidance, they have a quick clinical exam to confirm absence of symptoms. An EKG, troponin, or echo are not indicated for asymptomatic or mildly symptomatic patients, thankfully. They may get an exercise prescription, but pretty rapidly, they're back to duty. If they're mildly symptomatic in that second row, again, normal isolation criteria, clinical exam, and then they would get an exercise prescription to their return to duty in a more measured fashion. The moderately and severely symptomatic, which are hopefully going to be a much smaller number now for our population starts to get gradually increasing evaluations prior to returning to duty such as an EKG, a troponin and an echo.

And then, if there's evidence of injury on the initial screening tests, they're going to get a more extensive evaluation. I know we're going to hear from cardiology folks later in the day so I don't want to belabor the cardiology testing required, but essentially, the first two groups are pretty rapidly back to duty with minimal evaluation and then there are graded evaluations for folks with more severe disease. Just for reference, this is an example of the exercise prescription that we would use with gradual stages of increased activity back up to normal training. (Figure 4.)

And lastly, a chart showing the different stages of activity (Figure 5) and the timeframes (Figure 6) that we would recommend proceeding through those stages based on the severity of disease on the left hand column.

So the problem with every guideline or every push is there's going to be a counter push. This is what we hear.

We know that people are scared that they will be kicked out of the military. We know that folks are prone to trying to get around the guidelines to get where they want to be. And we are certainly concerned that people will either not be tested or may do a home test, which is anonymous.

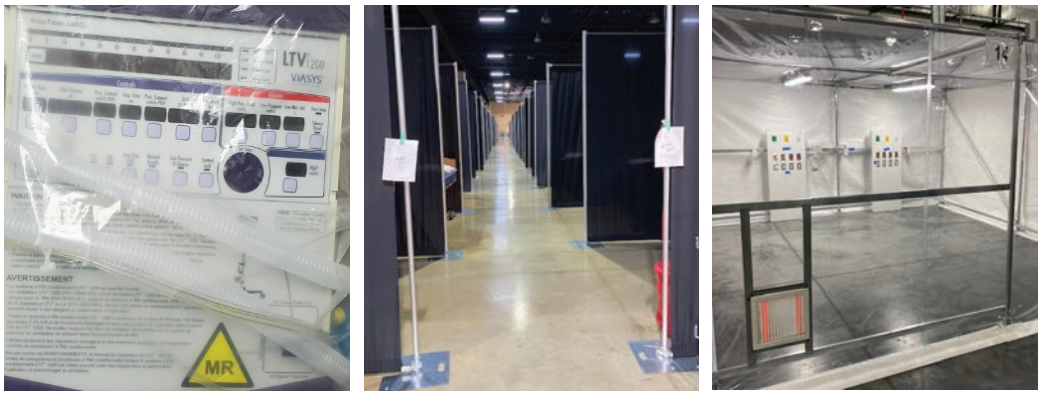


Figure 2.

Field hospital

COVID-19 POSITIVE

Asymptomatic → Isolation per CDC or local command isolation guidance with no exercise for minimum 10 days from positive test result → Clinical exam to confirm absence of symptoms. → **May receive** → **exercise*** prescription to gradually return to activity but not required

12 Lead ECG, TnI or TTE are not indicated for asymptomatic or mildly symptomatic infection

Mildly Symptomatic

Nausea, vomiting, diarrhea, anosmia, ageusia, nasal congestion, self limiting fatigue → Isolation per CDC or local command isolation guidance for minimum 10 days from symptom onset. → Clinical exam to confirm resolution of symptoms. → Exercise prescription to gradually return to activity **required**

Moderately Symptomatic

Persistent fever >100.4, persistent severe myalgias, persistent severe fatigue, hypoxia or pneumonia AND/OR cardiopulmonary symptoms defined as chest pain not associated with cough, activity limiting dyspnea, orthopnea, palpitations, syncope.

Persistent = at least 7 days in duration

→ Isolation per CDC or local command isolation guidance with minimum 10 days of activity restriction **including a minimum of 7 days after moderate or cardiopulmonary symptoms resolution**.

Evaluation for consideration to return to duty/ exercise:

12 lead ECG + TnI or HsTn + TTE

Low Risk Findings → Exercise prescription to gradually return to activity **required**

Isolation per CDC or local command isolation guidance with minimum 10 days of activity restriction **including a minimum of 7 days after moderate or cardiopulmonary symptoms resolution**

Evidence of myocardial Injury [b,c,d]

Severely Symptomatic

Persistent fever >100.4, myalgias, severe fatigue, hypoxia or pneumonia AND/OR cardiopulmonary symptoms defined as chest pain not associated with cough, activity limiting dyspnea, orthopnea, palpitations syncope.

Persistent = at least 7 days in duration

Requiring hospitalization for medical treatment and respiratory support (supplemental oxygen or above)

Myocardial Injury [b,c,d] at presentation

N → Consider further cardiac testing (**repeat ECG, TTE, TnI or HsTn**) if new onset of *chest pain not associated with cough, activity limiting dyspnea, orthopnea, palpitations or syncope.* → Myocardial Injury [b,c,d] at discharge

N → .

Y → **Cardiology evaluation**

- verification of myocardial injury.
- *Cardiac MRI with T1, T2 mapping and Late Gadolinium Enhancement by cardiologist based on clinical assessment.*
- **3 to 6 months of activity restriction if myocarditis/myopericarditis diagnosed**

Low Risk Findings → Exercise prescription to gradually return to activity **required**

Y → After completion of activity restriction:

- 12 lead ECG
- TnI or HsTn
- BNP or NT-pro-BNP
- TTE
- 2 weeks Cardiac event monitor
- Graded Exercise Treadmill Test

Figure 4

Stages of Activity

Figure 5.

Exercise prescription

	STAGE 1	STAGE 2	STAGE 3A	STAGE 3B	STAGE 4	STAGE 5
Activity Description	Minimum rest period	Light Activity	Light moderate	Moderate activity	Prolonged moderate activity	Normal training
Exercise Allowed	Walking and activities of daily living	Walking, light jogging (15 min/mile) for 0.5–0.75 mile	Jogging (12–15 min/mile) for 1 mile	Slow run 10–15 min/mile for 1.5 miles	Run 10–12 min/mile for 1.5–2.5 miles	Normal training exercise activities
		Stationary bike (60rpm, 0–25 Watts)	Stationary bike (60rpm, 25–50 Watts)	Stationary bike (60rpm, 50–125 Watts)	Stationary bike (60rpm, 150+ Watts)	
		No resistance training	Low resistance training	Moderate resistance training	Moderate to high resistance training	
% Heart Rate MAX (220–age)	N/A	<70%	<80%	<80%	<80%	Normal training
Duration	N/A	<15 min	<30 min	<45 min	<60 min	Normal training duration
Objective	Allow time for recovery. Protect cardiorespiratory system.	Gradual increase in HR	Increase load gradually. Manage post viral fatigue syndrome.	Exercise coordination and skills	Restore confidence and assess functional skills	Resume standard fitness routine
Monitoring	Persistence of symptoms	New onset or recurrence of moderate or cardiopulminary symptoms during return to exercise prescription require cessation of activity and further cardiac evaluation.				

Gradual Return to Exercise and Physical Avtivity Prescription: Recommended exercise prescription following COVID-19 resolution of symptoms. Stages indicate the objectives within each. The duration of each recovery stage is determined by the severity of experienced symptoms and listed as a separate table.

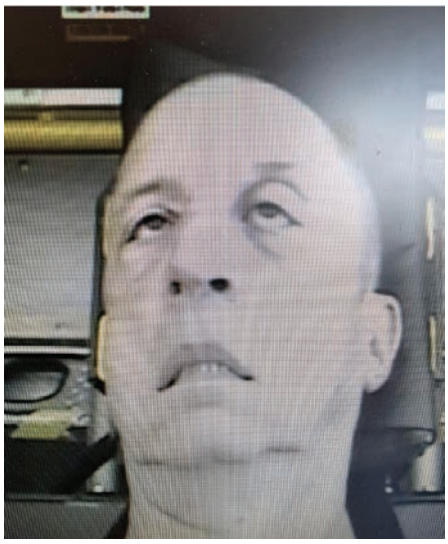
Figure 6 .

Timeframe

	STAGE 1	STAGE 2	STAGE 3A	STAGE 3B	STAGE 4	STAGE 5
Asymptomatic	10 days from (+) test *exercise prescription may be considered but it is not required*	1 day minimum	1 day minimum	1 day minimum	N/A	Earliest Day 13
Mild Severity Symptoms nausea, vomiting. diarrhea, anosmia or aguesia, nasal congestion, self-limiting fatigue	10 days minimum of activity restriction including a minimum of 7 days **after** symptom resolution	1 day minimum	1 day minimum	1 day minimum	1 day minimum	Earliest Day 14
Moderate Severity Symptoms Persistent fever >100.4, persistent myalgias, severe fatigue, hypoxia or pneumonia, And/or chest pain not associated with cough, activity limiting dyspnea, orthopnea, palpitations, syncope **Persistent is defined as at least 7 days of symptoms duration**	10 days minimum of activity restriction including a minimum of 7 days **after** symptom resolution *Symptomatic patients with myocardial injury require strict 3–6 months of any activity restriction and must remain on stage 1*	2 days minimum	2 days minimum	2 days minimum)	2 days minimum	Earliest Day 18
High Severity Symptoms Requiring hospitalization for medical treatment and respirator support (supplemental oxygen or above) Persistent fever >100.4, persistent a myalgias, severe fatigue, hypoxia or pneumonia, And/or chest pain not associated with cough, activity limiting dyspnea, orthopnea, palpitations, syncope **Persistent is defined as at least 7 days of symptons duration**	10 days minimum of activity restriction including a minimum of 7 days **after** symptom resolution *Symptomatic patients with myocardial injury require strict 3–6 months of any activity restriction and must remain on stage 1*	5 days minimum	5 days minimum	5 days minimum	5 days minimum	Earliest Day 30

Adapted from Elliott N, et al. Br J Sprts Med 2020

Presence of new onset or recurrence of moderate or cardiopulmonary symptoms during return to exercise prescription reqire cessation of activity and further cardiac evaluation (ECG + Troponin I or HsTn + TTE if not previously performed or cardiology evaluation of ECG, Troponin I HsTn and TTE were previously performed.)



WHY WE CARE ABOUT FLYING FITNESS

So why do we care? This is a picture of preparing for a flight, and this is a picture at nine Gs in a centrifuge. (Figure 7)

So if you ever wanted to know what you will look like at 100 years old, just hop in the centrifuge and you'll find out quickly. We know that in the military and in many of the activities that all of us engage in that we experience significant stressors physiologically and we want to make sure that we're up to that challenge. This is the initial/current guidance from the DOD, on the Air Force side for returning to flight and special operator duty.

On the left it's graded and the vast majority of folks will fall under the asymptomatic and mild categories and be screened fairly quickly. The columns represent different categories of duty. We can use this as a reference for debating our guidance moving forward. The first column is the air traffic controllers and the ground-based operators; people who aren't in the airplane. The next column is the flying class two and three fliers that are less engaged with the mechanics of flight. And then lastly, the folks that we're most concerned about, the high-performance aircraft folks and anyone using an aviator mask.

For the asymptomatic infection or mild infection, they're going to get a clinical evaluation confirming lack of symptoms, physical examination, and then we're going to do an exertional pulse oximetry. If they had cardiopulmonary symptoms, then we're going to get an EKG, perhaps a troponin, and a spirometry. If they required hospitalization, they're going to get all the above plus EKG, troponin and echocardiogram, or potentially an MRI. They're going to have complete PFTs. And then we're going to make sure that any labs that were abnormal during their presentation have returned to normal. And then the last category is the myocarditis, which certainly is going to bear more significant evaluation and restrictions. The right of the slide for reference looking at what EKG abnormalities we're looking for, how to do the pulse oximetry, et cetera, and references for future use.

CATEGORY	ATC/GBO	FC/II/III/SWA	HIGH PERFORMANCE AIRCRAFT & AIRCREW REQUIRING ROUTINE USE OF AVIATOR MASK
SARS-CoV-2 Positive Not Requiring Hospitalization **(Asymptomatic infection and mild COVID-19)>94%**	The following criteria suggest return to full duty is reasonable: ■ CDC Guidelines for Discontiuation of Isolation **PLUS:** **Clinical evaluation** ■ Confirming no cardiac or respiratory symptoms or limitations (e.g., chest pain, palpitations, shortness of breath, exercise intolerance, etc.)[2] **Physical exam** ■ Normal respiratory, cardiac, neurologic and ENT exam ■ Normal vitals BP, HR, Sp02>94% ■ Normal exertional pulse oximetry[3]	The following criteria suggest return to full duty is reasonable: ■ CDC Guidelines for Discontiuation of Isolation **PLUS:** **Clinical evaluation** ■ Confirming no cardiac or respiratory symptoms or limitations (e.g., chest pain, palpitations, shortness of breath, exercise intolerance, etc.)[2] **Physical exam** ■ Normal respiratory, cardiac, neurologic and ENT exam ■ Normal vitals BP, HR, Sp02>94% ■ Normal exertional pulse oximetry[3] **PLUS:** ■ Normal/normal-variant ECG4 (add troponin if CP symptoms were experienced[5])	The following criteria suggest return to full duty is reasonable: ■ CDC Guidelines for Discontiuation of Isolation **PLUS:** **Clinical evaluation** ■ Confirming no cardiac or respiratory symptoms or limitations (e.g., chest pain, palpitations, shortness of breath, exercise intolerance, etc.)[2] **Physical exam** ■ Normal respiratory, cardiac, neurologic and ENT exam ■ Normal vitals BP, HR, Sp02>94% ■ Normal exertional pulse oximetry[3] **PLUS:** ■ Normal/normal-variant ECG4 (add troponin if CP symptoms were experienced[5]) ■ Normal pre-/post-8D spirometry[6] if CP symptoms were experienced
COVID-19 Requiring Hospitalization **(Moderate or severe COVID-19)**	The following criteria suggest return to full duty is reasonable: All clinical and physical exam criteria above.	The following criteria suggest return to full duty is reasonable: All clinical and physical exam criteria above. **PLUS:** ■ Normal ECG4, troponin and echocardiogram or cardiac MRI[7] ■ Normal full PFTs with DECO [6, 8] ■ No disqualifying abnormalities on CBC & CMP if abnormal during hospitalization[9]	The following criteria suggest return to full duty is reasonable: All clinical and physical exam criteria above. **PLUS:** ■ Normal ECG4, troponin and echocardiogram or cardiac MRI[7] ■ Normal full PFTs with DECO [6, 8] ■ No disqualifying abnormalities on CBC & CMP if abnormal during hospitalization[9]
COVID-19 complicated by myocarditis or SARS CoV-2 Critical Illness (Respiratory failure, septic shock, and.or multiple organ dysfunction)	Some significant complications of COVID-19 such as myocardistis, deep venous thromboembolism, stroke, and myocardial infarction are independently disqualifying and require aeromedical waiver. See relevant waiver guides.	Some significant complications of COVID-19 such as myocardistis, deep venous thromboembolism, stroke, and myocardial infarction are independently disqualifying and require aeromedical waiver. See relevant waiver guides.	Some significant complications of COVID-19 such as myocardistis, deep venous thromboembolism, stroke, and myocardial infarction are independently disqualifying and require aeromedical waiver. See relevant waiver guides.

Figure 8

Return to Flight and Special Operator Duty Guidance Post SARS-VoV-2 Infection

* Reference DoD Covid-19 Practice Management Guide for fitness profile guidance.

1. IAW CDC return-to-work guidance for non-hospitalized patients (https://www.cdc.gov/coronavirus/2019-ncov/hcp/disposition-in-home-patients.html) or hospitalized patients (https://www.cdc.gov/coronavirus/2019-ncov/hcp/disposition-hospitalized-patients.html).

2. Recommend review for other non-respiratory COVID-19 symptoms of aeromedical significance, such as anosmia, fatigue, anorexia, headaches, weakness and myalgia.

3. Exertional pulse oximetry is recommended to evaluate for persistent pulmonary dysfunction following resolution of SARS-CoV-2 infection. Multiple exertional tests are utilized in community practice to monitor exercise capacity (e.g., 1-min sit-to-stand test, 6-minute walk test, 40-step test, etc.) in chronic lung disease. These tests are now being utilized to assess for the presence of pulmonary dysfunction in individuals with SARS-CoV-2 infection even if clinical symptoms are absent. Abnormal exertional pulse oximetry (i.e. fall of 3% or more in pulse oximetry reading on exercise) should result in continued DNIF/DNIC until resolution of the exertional pulse oximetry dyscrasia. Further evaluation is recommended to ensure resolution of acute illness and exclude underlying pulmonary dysfunction that may be disqualifying. (See comments under Section 6 and 8) https://www.cebm.net/covid-19/what-is-the-efficacy-and-safety-of-rapid-exercise-tests-for-exertional-desaturation-in-covid-19/

4. ECG is indicated to screen for cardiac abnormalities, which have been documented clinically in up to 20% of all cases and objectively (via cardiac MRI) in up to 80% of symptomatic COVID-19 cases. Abnormal ECG should prompt further evaluation with troponin and echocardiogram or cardiac MRI. Additional work-up may be warranted for specific abnormalities identified on ECG. ECGs and any other cardiac studies should be forwarded to the Aeromedical Consultation Service ECG Library for review and image storage per AFI 48-123. See "ECG Findings Disposition" at https://kx.health.mil/kj/kx5/AeromedicalConsultationSvc/Pages/home.aspx

5. Individuals who experienced cardiac symptoms (e.g. dyspnea, exercise intolerance, chest pain, palpitations, syncope, etc.) during acute illness may be at higher risk for underlying cardiac dysfunction and warrant further evaluation.

6. Spirometry testing is recommended to evaluate for pulmonary dysfunction (i.e., obstruction or restriction), which has been noted to persist even after cardiopulmonary symptoms (dyspnea, cough, exercise intolerance, chest pain, etc.) resolve following SARS-CoV-2 infection. Abnormal spirometry should prompt continued DNIF and further evaluation with full PFTs to include lung volumes and DLCO. (See comments under Section 8.)

7. SARS-CoV-2 infection is associated with direct and indirect cardiotoxicity. Transthoracic echocardiogram (TTE) and/or cardiac MRI are used to evaluate the degree of cardiac involvement in symptomatic or hospitalized individuals and to further evaluate individuals with an abnormal ECG and/or troponin elevation.

8. Pulmonary dysfunction has been documented beyond resolution of COVID-19 symptoms. Individuals who were hospitalized are at higher risk for more significant lung damage, predisposing to hypoxia at altitude. Restriction and/or low DLCO on PFTs may indicate the presence of parenchymal lung damage (pulmonary fibrosis, ground glass opacities, etc.). Persistent pulmonary abnormalities may be disqualifying IAW MSD, 13 MAY 2020, G28 and warrant further evaluation (e.g., imaging, pulmonology consultation).

9. If abnormal laboratory testing or organ dysfunction were present during hospitalization (anemia, renal injury, liver injury, etc.), repeat laboratory studies should be obtained to ensure resolution. Persistent abnormalities identified on CBC or CMP warrant further evaluation and may be disqualifying. See "Aerospace Medicine Waiver Guide" at https://kx.health.mil/kj/kx7/WaiverGuide/Pages/home.aspx.

We do have to remind our pilots and our divers and all the patients we take care of that we may be willing to undertake significant risks for themselves, that "It's not all about you."

For our pilot, we have to remind him that they may be flying a $170 million aircraft that the taxpayers purchased and the risks of an accident go far beyond the risks to that individual pilot. And similarly as divers, that we are going to expose ourselves to significant changes in physiology. Accidents that occur underwater also don't just involve ourselves, they involve our dive buddies, the boat operators, the emergency folks that are going to respond. So we just have to remind folks that it's not just about an individual risk assessment, it's our collective risk assessment.

We have lots of specific conditions that we're concerned about. The military PT test is starting back up in July. We have folks that are either in special operations or trying out for special operations with dramatic stressors to their system and innumerable other potential significant circumstances we may have to consider.

Figure 9.

(Opposite) Return to Flight and Special Operator Duty Guidance Post SARS-VoV-2 Infection

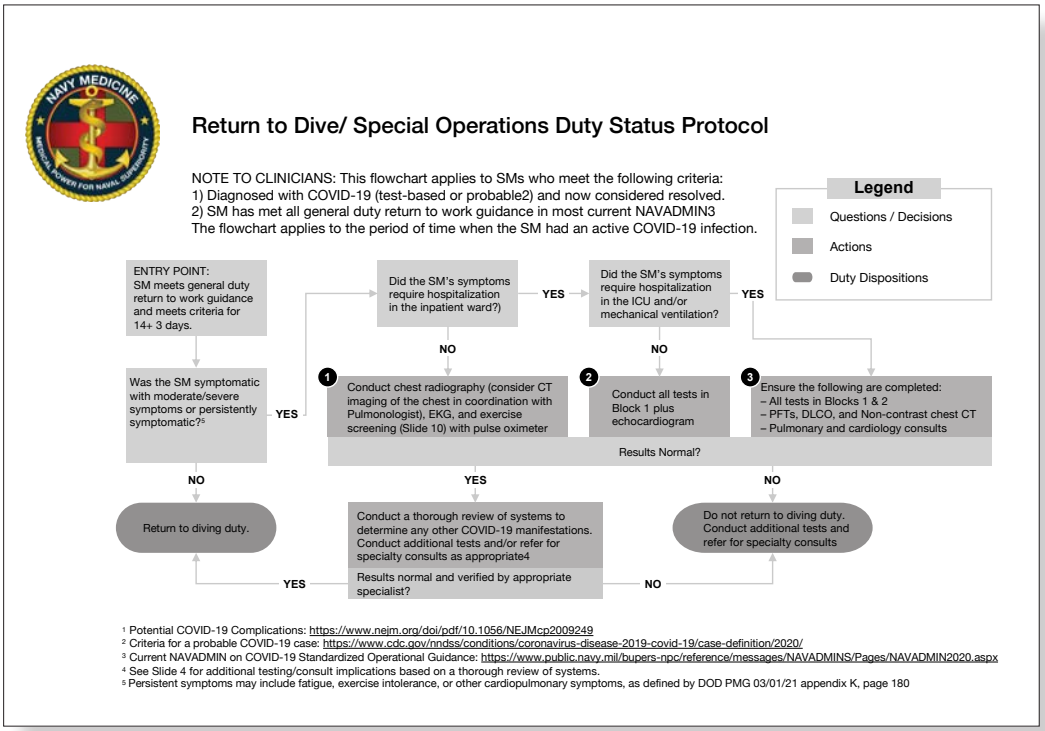
In the Air Force, we lean heavily on the Navy for guidance for diving guidance. For any joint operations, they're the boss. This is the latest guidance from Captain Tripp that he was kind enough to share with us from May 19th concerning their take on returning to diving or special operator duty status as well after COVID-19.

I like that it's simple. I think that it is going to be important for our collective audiences to find something that's not too complicated to use. After meeting general return to duty guidance and time criteria, her first question is, were they symptomatic with moderate or severe symptoms? Or are they persistently symptomatic? If the answer is no, then straight back to diving. So the vast majority of our folks won't have to undergo a significant evaluation. If they were moderately to severely symptomatic or still have symptoms, you go to the middle column. Were they hospitalized? If the answer's no, then they're going to get a chest x-ray with caveats for some lack of clarity as to the right radiographic followup. They're going to get an EKG and they're going to get an exercise pulse oximetry. So fairly similar to the Air Force guidance. If the results are normal, then they're going to get a quick clinical review to make sure they don't have additional symptoms that we weren't catching and if they don't get any further evaluation, then they're back to diving. If they did require hospitalization, but not in the Intensive Care Unit and not on a ventilator, then they're going to get all the above testing plus an echocardiogram. If they did require ICU admission or mechanical ventilation, then they're going to get all the above plus a complete PFT, CT chest, and then they're going to have to see cardiology and pulmonary before they're allowed to return to diving. Within our system, this is problematic, and I'm sure it is on the civilian side as well. There are only approximately 13 pulmonologists in the Air Force worldwide at this time, so we're really trying to keep this box with mandatory consults down to a manageable level. I know our private practice colleagues in this area are booked out about six months for a routine consultation.

We are going to have to be careful to make sure that we don't legislate ourselves out of the ability to get folks back into diving based on overly restrictive consultation requirements. The rest of this document is largely just for reference. It describes suggested tests that you might obtain before you obtain consultation to make that a more efficient process. The rest of this document is for reference. One of these is the case definitions for COVID-19. The next is descriptions of mild,

Figure 10.

Return to Dive/ Special Operations Duty Status Protocol



moderate, and severe disease, some laboratory guidance on COVID-19 diagnosis, the evaluation components and EKG components. There is also some information they included on screening strategies for athletes. Lastly, some reference on PFT guidance and exercise screening tests and how to perform the exercise screening test.

So we breathe a collective sigh of relief. We thought, okay, we've gotten through the worst of our hospital issues and our field hospitals and our vaccination efforts and our testing efforts. We've gotten some guidance, and so now it's back to the office trying to catch up on being largely out of the office for a year. But then comes what we have called the third wave of COVID-19, which is the office full of post-patients who are still symptomatic.

And as we were discussing and we'll discuss throughout the day, the broad causes for dyspnea are really overwhelming at times. A lot of folks just developed what we call the COVID-19, where they gained weight during the pandemic. We certainly had a lot of people that decided that sitting on the couch was a great way to spend the year, so we've had a lot of deconditioning. In the military, we've backed way off on our group conditioning exercises and we haven't had a PT test now for quite some time. From the military side, there's some anxiety because that PT test, again, resumes in July. There's such a wide variety of tests that we could perform and there's variable guidance for which tests we should be performing.

We also know that we shouldn't rush to over study patients when a lot of them are going to get better with time. I participated in a teleconference this week that described the more than 50% of patients sent to a pulmonologist at six weeks that were no longer symptomatic at three months. So certainly a tincture of time may be an appropriate prescription for a lot of folks, but we are not wanting to miss people who have significant disease. Below are a few snippets from up to date.

There are certainly concerning statistics about the persistent persistence of physical symptoms following COVID-19 and how common they are. And from a pulmonary perspective, the concern that those prolonged symptoms have a lot of our names: Shortness of breath, chest pain, tightness, cough. We are starting to recognize that we are going to be dealing with this for a long time.

This is a series of brief descriptions of patients that have been through the cardiology and pulmonary clinics here. This one was particularly concerning. A 60 year old gentlemen marathon runner, phenomenal shape, not overweight, retired Air Force without any significant past medical history. He had symptomatic COVID-19 infection in December of 2020. In January of 2021 he had COVID-19 related myocarditis with an elevated troponin. Palpitations, shortness of breath, changes on EKG. On a post COVID-19 treadmill, he had some rhythm changes. He had fixed defect on a profusion study. An event monitor showed symptomatic rhythm issues. He couldn't adequately perform a coronary score, and on cath, he was found to have no significant obstructive disease.

Beta blockers had little effect. A cardiac MRI was ordered and was pending for prognostic reasons. He had a second opinion at Mayo Clinic pending. He was on exercise restrictions, and unfortunately he was found dead in bed in May. Autopsy was requested but couldn't be performed for a variety of reasons. This is certainly the patient that we want to find early. We don't want to give this patient the tincture of time, and this is, I'm sure, the type of patient we're going to be discussing throughout the day.

> "Every good military story starts out with 'so there I was...'"

1 So, there I was…

- 60 yo male, marathon runner, 69," 157#, retired USAF, no significant PMH
- December 2021 symptomatic COVID-19 infection
- Jan 2021 COVID-19 related myocarditis with elevated troponin of 1.3
- Palpitations, DOE, new RBBB on EKG, echo–normal EF
- CXR–NAD
- Post COVID-19 treadmill–NSVT in recovery
- Myocardial Perfusion Rest and Stress–fixed defect inf wall
- Event monitor–symptomatic PACs and PVCs with symptomatic PSVT
- Coronary CTA–Ca score 666–could not perform
- Cath–no obstructive disease, max stenosis 20%

Figure 11.
Case study with fatal resulty

The next patient is well known to me, a 62 year old lifelong diver with thousands of dives under his belt. Never a smoker. He had very mild COVID-19 infection in December of 2020. He had no imaging, was not hospitalized, and had gotten through his illness without issue, full recovery, no pulmonary symptoms whatsoever. (Figure 12)

He had a pre-operative chest x-ray for unrelated issues in February and was found to have a asymptomatic pneumothorax. CT confirmed a moderate pneumothorax with some scattered ground glass opacities. He was treated conservatively and all issues resolved on follow up imaging, but being a lifelong diver, he looked at me and asked, "Doc, is this a spontaneous pneumothorax?" knowing that that's usually the first on our list of absolute contraindications to future diving. This is certainly something our community is going to be debating. We've seen quite a few of these.

2 Pneumothorax

- 62 yo male, lifelong diver, never smoker
- Mild COVID-19 infection December 2020. No imaging. Not hospitalized.
- Full recovery–no Pulmonary symptoms
- Pre-op CXR for unrelated issue February 2021: PTX
- CT–moderate PTX with scattered GGO
- Treated conservatively
- All resolved on follow up imaging
- Back to diving??

Figure 12.
Pneumothorax

This is a 31 year old active duty Air Force patient with no significant history. He had COVID-19 in March of last year, not hospitalized, but had persistent dyspnea. PFTs showed a moderate obstructive defect with significant bronchodilator response. His FEV1 was only 59% predicted with a significant response following bronchodilator. He was treated with standard asthma therapies and his PFTs normalized. Meds were tapered over after time. No new symptoms, PFTs are now normal, and now off all medication. We are seeing some patients with asthma that seems persistent and other patients that seem to have what we're hopeful is really that more temporary form of RADS.

3 Asthma/RADS

- 31 yo Active Duty USAF
- No pertinent PMH
- March 2020 COVID-19–not hospitalized
- Persistent symptoms of DOE
- August 2020 PFTs–moderate obstructive defect with BD response
- FEV1 1.43L/59%, 14% improvement with BD
- ICS/LABA
- FEV1 2.85L/118%
- Meds tapered off over time. Now no symptoms, normal PFTs, and off all meds (as of Jan 2021)

Figure 13.
Asthma/RADS

Another patient. Female with COVID-19 pneumonia that was severe. She was treated with high flow and CPAP. She was not intubated. She was in the ICU for five days. Her mother died in a shared room beside her. Prolonged recovery, residual symptoms, inappropriate tachycardia, extensive evaluation, ultimately diagnosed with POTS, which our cardiologists are seeing quite a lot of post COVID-19. With routine treatment, her symptoms were managed and follow up was planned. We've seen a series of these cases that have been concerning.

4 Tachycardia

- 41 yo female dependent
- Severe COVID-19 pneumonia December 2020
- Hi-flow, CPAP, not intubated
- ICU 5 days
- Mother died in bed beside her
- Prolonged recovering
- Residual DOE, inappropriate tachycardia
- Extensive evaluation

Figure 14.

Tachycardia

Next is a 34 year old patient with mild COVID-19. A few weeks later, he thought he was back to normal and tried to run some sprints. He had dramatic shortness of breath and stridor. Recurred the next day just while talking on the phone. His PFT showed a flattened inspiratory flow volume loop, consistent with a variable, extra thoracic airway obstruction, something. He was given Heliox in the PFT lab and immediately felt better. His CTs were clear. He was seen by our speech therapist and found to have severe paradoxical coordinate motion at rest with near complete closure during inspiratory attempts.

There have been numerous reports of direct tracheal injury from COVID-19 and also neuropathy related presentations. He was ultimately seen by the laryngologist at UAB and had a vagal nerve branch block unilateral, followed by a contralateral block three weeks later and now he's back to moderate cardio and gradually improving.

5 SOB/Stridor

- 34 yo active duty, military intelligence
- No pertinent PMH
- March 2021 mild COVID-19
- Few weeks later–tried to run sprints
- DOE/stridor
- Recurred next day while talking on the phone
- PFTs–flat inspiratory flow volume loop
- Symptoms much better with Heliox
- CT chest/neck clear

Figure 15.

SOB/Stridor

6 DVT/PE

- 63 yo retired male without pertinent PMH
- Hospitalized with COVID-19 pneumonia July 2020
- ICU 2 weeks, not intubated
- Discharged and making a steady recovery for 6 weeks
- Recurrent DOE–CT showed bilateral PE, u/s showed DVT
- GGO gradually not resolved, but improving
- Placed on A/C for 6 months
- Echo–no pulmonary HTN
- CT 3 months later–slowly improving interstitial pneumonitis, PE resolved
- Ongoing follow up planned

Figure 16.
DVT/PE

Next is a patient who was hospitalized with COVID-19, recovered, discharged, and then had recurrent significant shortness of breath. CT showed PE and ultrasound showed DVT. He had residual ground-glass opacification. We've had patients with GGO ultimately resolve after 10 to 12 months of follow up and other patients who are continuing to improve at that point, but still not resolved.

And then lastly, the oddballs, the bronchiolitis cases, the bronchiectasis, and then folks that have unexplained symptoms despite extensive workups.

I think the answer ultimately is, we need an algorithm that's clean and easy. I think that the Navy algorithm is pretty straightforward such that it's easy to navigate for non-diving folks in particular. And with limited time that we'll get the vast majority of folks back to activity without having to see specialist. When you are persistently symptomatic, you're going to need to see a doctor. And this is still just a short list of the reasons that we're seeing for persistent dyspnea after COVID-19.

Pulmonary Implications of Covid Infection for Divers

Richard E. Moon, MD

EFFECTS OF DIVING ON RESPIRATION

Mechanical Load: First, there are changes in ventilation and both resistive and elastic loads. The increased resistive load is related to higher gas density: airways resistance increases approximately in proportion to $\sqrt{gas\ density}$, which increases in direct proportion to depth. For example, during a dive to 100 fsw (4 atmospheres absolute, ATA) breathing air, density is increased fourfold, causing a doubling of airways resistance. Changes in elastic load are largely related to redistribution of blood into the thorax, causing an increase in lung elastance. There are effects on gas exchange, with an increase in physiological dead space while breathing enriched oxygen mixtures.

Ventilatory Control: There are also effects on ventilatory control, which is governed by chemosensors. There are two sets of these in our bodies. One is the carotid body, which senses PO_2, pH and PCO_2; sensors in the brainstem react to PCO_2 and pH. These sensors provide feedback to the respiratory centers in the brainstem as part of a process that maintains arterial pH: a rise in PCO_2 causes a decrease in arterial pH, which then triggers an increase in ventilation. This then lowers PCO_2 and returns pH toward normal. The other function is transduction of hypoxemia by the carotid body, which signals the ventilatory control centers in the brainstem to increase ventilation. Hyperoxemia on the other hand tends to inhibit ventilation. While most divers in the water are hyperoxic due to increased breathing gas PO_2, divers underwater tend to be at least mildly hypercapnic,[1] and under some circumstances such as increased breathing rig resistance, PCO_2 can be exceptionally high.[2] This is due to a combination of the increased mechanical breathing load and hyperoxia.

The rise in ventilation in response to an increase in PCO2 is linear. The slope of this relationship, the hypercapnic ventilatory response (HCVR, with units $L.min^{-1}.mmHg$), can be measured in the lab and varies considerably among individuals. As predicted, there is an inverse relationship between HCVR and arterial PCO_2 during exercise at depth.[3] During a dive, individuals with a low HCVR tend to have a higher PCO_2, and vice-versa.

Pulmonary Barotrauma (PBT): PBT during ascent from a dive can be caused by breath holding or focal gas trapping. The latter can predispose to hyperexpansion of gas exchange units distal to the obstruction, causing gas to enter the interstitial space, the pleural cavity or pulmonary capillary blood. There has been an association, at least in anecdotal reports, between large bullae and arterial gas embolism, both from diving and altitude exposure.[4] Whether this reflects a major risk factor for all people with pulmonary bullae is unknown, as analysis of published case reports can be severely influenced by selection bias. While many undersea medicine practitioners have seen cases where PBT appears to be linked to interstitial lung disease, that conclusion is less supported

by published data. Other possible predisposing factors could include diffuse airways obstruction such as asthma[5] and prior spontaneous pneumothorax.[6] ($\dot{V}O_3$)

Ventilatory Limitation: Classic exercise physiology indicates a linear relationship between oxygen consumption ($\dot{V}O_2$) and work rate up to a maximum $\dot{V}O_2$ ($\dot{V}O_2max$). CO_2 elimination rate ($\dot{V}CO_2$) initially increases linearly with work rate. This occurs up to a work rate where there are disproportionate increases in $\dot{V}O_2$ and ventilation ($\dot{V}_E$), correlated with a rise in blood lactic acid. In addition to metabolically produced CO_2 buffering of excess acid is buffered by bicarbonate to produce CO_2,[7] which further stimulates ventilation. This was formerly called the anaerobic threshold because it was believed that the excess lactic acid production was due to anaerobic metabolism, an outdated concept.[8] Nevertheless, under normal circumstances at sea level, maximum breathing capacity (MBC), exceeds the maximum rate of ventilation required during exercise. In individuals who are physically fit, ventilation during heavy exercise normally approaches only 50–60% of MBC. In Olympic class athletes, exercise ventilation may approach 90% of MBC. However, during a dive, because of the increase in elastic and resistive loads, MBC decreases, and there may be a point at which point $\dot{V}_E$ approaches MBC. Indeed, the ventilation required to maintain normal PCO_2 and pH may actually exceed MBC, at which point arterial PCO_2 will disproportionately increase. Therefore, if lung function (MBC) is abnormal at baseline, for example post-COVID, during a dive hypercapnia may be severe.

Table 1: Abnormal Pulmonary Function Tests at 1 and 3 Months Follow-Up in 81 Patients Following COVID-19 Infection[13]

TIME	MILD	PNEUMONIA	SEVERE PNEUMONIA	CRITICAL
1 Month	1/4	5/44	1/13	0/1
3 Months	0/4	3/40	1/16	1/1

Muscle Oxygen Uptake Exercise Capacity: It may have been assumed that decreased exercise capacity after COVID infection is due to impaired pulmonary or cardiac function. However, a recent study demonstrated that compared to a control group, peak oxygen consumption in these patient recovering from COVID may also occur due to impaired oxygen uptake by tissues despite similar maximum heart rates.[9] Exaggerated hyperventilation was also observed in the post-COVID group. Implications for diving could include increased ventilatory limitation.

POSSIBLE LONG-TERM EFFECTS OF COVID ON DIVERS

Divers recovering from COVID may have long-term lung injury, which could impair ventilation as measured by standard spirometric measures such as forced vital capacity (FVC), forced expired volume in one second (FEV_1) and MBC. Focal lung injury also might predispose to pulmonary barotrauma. ARDS survivors may have long-term impairment of exercise capacity[10] as well as hypercapnia.[11] It is feasible that in the same way that COVID infection can induce loss of smell and taste (anosmia and dysgeusia)[12] ventilatory control might also be affected. Published data suggest that response to hypercapnia is attenuated in hospitalized patients with COVID-19 infection.[13] An open question is therefore whether COVID-19 could temporarily or permanently attenuate HCVR, leading to exaggerated hypercapnia in survivors who dive.

LUNG FUNCTION POST-COVID

A recently published study classified 81 COVID-19 patients into ***mild*** (mild symptoms, normal chest radiographs), ***pneumonia*** (symptoms, abnormal radiographs, no supplemental O_2 requirement), ***severe pneumonia*** (respiratory rate >30 breaths/min, severe respiratory distress, or room air SpO2 ≤93%) or ***critical illness*** (mechanical ventilation, shock, other organ failure or ICU admission).[14] The prevalence of abnormal pulmonary function tests is shown in Table 1. Abnormal CT findings were present in 73% of patients at 1 month and 54% at 3 months.

Abnormal lung CT findings can persist for weeks after recovery from even moderate disease.[15] In a study of 124 patients assessed three months after recovery residual pulmonary parenchymal abnormalities were present in 91% of discharged patients.[16] Interestingly, radiographic severity correlated with reduced lung diffusion capacity (carbon monoxide transfer factor, DLCO), suggesting that perhaps DLCO is a relatively inexpensive test to screen for lung abnormalities after COVID infection, a finding confirmed by several other studies.[17,18]

Regarding mild disease, in a group of 18 professional soccer players with positive COVID tests, 12 had mild illness and the remainder had no symptoms. Two weeks after resolution none had CT abnormalities.[19]

THE BOTTOM LINE

For mild cases with no post-COVID symptoms and normal exercise tolerance, lung injury is unlikely. If there is clinical uncertainty, pulmonary function testing with DLCO is reasonable. For moderate to severe cases there is a risk of ventilatory impairment and potential for gas trapping and pulmonary barotrauma during ascent due to structural lung abnormalities. For such individuals who wish to return to diving a chest CT should be part of the workup. Regarding impairment of ventilatory control/respiratory drive, there is no information at present.

DISCUSSION

Jim Chimiak: Bob Saunders asks, "I have seen significant PFT abnormalities: 50%, 29% mid flow decrements in asymptomatic divers with mild illness, allergy like symptoms, conjunctivitis. I am very concerned about this and agree with getting PFTs for everyone. In light of your lecture, and when we asked Dr. Kraft, if we added the exercise tolerance, does that maybe decrease that need to get PFTs for the mild cases?"

Richard Moon: Published studies have followed up for only 3–4 months. There are as yet no long-term studies. Some information will be obtained from reporting of complications or lack of complications in individuals who decide to dive without medical assessment.

Jim Chimiak: Along that same line that you gave for the loss of smell and taste. Would you add postural orthostatic tachycardia syndrome (POTS) to that same suspicion that there's an alteration in autonomic function?

Richard Moon: POTS occurring after COVID would be an indication that the virus is affecting the autonomic nervous system. With POTS, getting out of the water after immersion diuresis and

climbing up a ladder onto the deck of the boat could cause severe hypotension. Whether there is a correlation with hypercapnia is an open question at this point.

Jim Chimiak: Regarding the breath-hold diver, should PO_2 and PCO_2 be put included on a higher level of investigation? Let's say the discussion here today goes toward minimal testing for the mild asymptomatic fully recovered diver, should arterial blood gases for breath-hold divers after COVID be conducted?

Richard Moon: Jim, that's a very good question because we thought we understood breath hold diving pretty well, until a couple of years ago. The conventional wisdom is that during a breath-hold dive PO_2 increases in direct proportion to the ambient pressure, thus hypoxia is not initially an issue. PCO_2 increases as well, but PCO_2 is somewhat buffered by the blood and the interstitial fluids. At maximum depth PO_2 is also maximum. During decompression, PO_2 slowly decreases. However, studies by Dino Bosco in Padua have changed our thinking about it.[20] In his study of six breath-hold divers in whom blood gases were measured at 40 msw depth, PO_2 increased as predicted in four. In two individuals, it was relatively low, yet those individuals reached the surface without any significant hypoxemia. I think the most likely explanation for relative hypoxemia at depth is compression of lung volume leading to atelectasis at maximum depth, thereby inducing a right to left shunts and secondary hypoxemia. With parenchymal lung disease due to prior COVID infection, there may be a greater likelihood of compression atelectasis, and therefore potentially a much lower PO_2 at maximum depth, which could engender hypoxia-induced loss of consciousness. For breath-hold divers seeking medical evaluation after COVID, I would recommend a very low threshold for obtaining a CT scan.

Jim Chimiak: Another question was submitted: "Do the PFT studies you reviewed comment on changes in residual volume? RV/TLC might be another way to assess for significant gas trapping without CT scanning."

Richard Moon: There haven't been that many reports looking at subdivisions of lung volumes, so I am not sure I can answer the question. It should be pointed out that gas trapping that occurs during exhalation, and which can be observed on CT (occurring at low lung volume), is not the same as gas trapping during decompression from a dive (high lung volume). During testing for "gas trapping" in the lab (closing volume) or the radiology department, there is maximal exhalation, whereas gas trapping for an ascending diver occurs when lung volume and airways diameter are increasing. Thus, I'm not sure there is a very good correlation between the two.

Jim Chimiak: Dr Kraft discussed pneumatosis and the 10% incidence of that finding. A question submitted asks, "Do we go back to the routine ordering of chest x-ray, and is there evidence that it is relatively common?"

Richard Moon: Published data include severely abnormal CT scans including pneumatosis, particularly after severe infection. In the mild group, at least in the Gervasi study, with relatively small numbers of individuals, they didn't see any, although others have observed rare instances of pneumatosis. In patients who had moderate symptoms, significant numbers within the three-to-four-month window, have abnormalities that should preclude diving. Peter Lindholm pointed out that these may recover over the course of months, or a year, but we will have to await further data.

REFERENCES

1. Dunworth SA, Natoli MJ, Cooter M, Cherry AD, Peacher DF, Potter JF, Wester TE, Freiberger JJ, Moon RE. Hypercapnia in diving: a review of CO2 retention in submersed exercise at depth. Undersea Hyperb Med. 2017;44(3):191-209.
2. Warkander DE, Norfleet WT, Nagasawa GK, Lundgren CE. CO2 retention with minimal symptoms but severe dysfunction during wet simulated dives to 6.8 atm abs. Undersea Biomed Res. 1990;17:515-23.
3. Cherry AD, Forkner IF, Frederick HJ, Natoli MJ, Schinazi EA, Longphre JP, Conard JL, White WD, Freiberger JJ, Stolp BW, Pollock NW, Doar PO, Boso AE, Alford EL, Walker AJ, Ma AC, Rhodes MA, Moon RE. Predictors of increased PaCO2 during immersed prone exercise at 4.7 ATA. J Appl Physiol (1985). 2009;106(1):316-25.
4. Goffinet CM, Simpson G. Cerebral arterial gas embolism in a scuba diver with a primary lung bulla. Diving Hyperb Med. 2019;49(2):141-4.
5. Elliott DH, editor. Are Asthmatics Fit to Dive? Kensington, MD: Undersea and Hyperbaric Medical Society; 1996.
6. Villela MA, Dunworth S, Harlan NP, Moon RE. Can my patient dive after a first episode of primary spontaneous pneumothorax? A systematic review of the literature. Undersea Hyperb Med. 2018;45(2):199-208.
7. Wasserman K, Whipp BJ. Exercise physiology in health and disease. Am Rev Respir Dis. 1975;112(2):219-49.
8. Brooks GA. The science and translation of lactate shuttle theory. Cell Metab. 2018;27(4):757-85.
9. Singh I, Joseph P, Heerdt PM, Cullinan M, Lutchmansingh DD, Gulati M, Possick JD, Systrom DM, Waxman AB. Persistent exertional intolerance after COVID-19: insights from invasive cardiopulmonary exercise testing. Chest. 2022;161(1):54-63.
10. Pfoh ER, Wozniak AW, Colantuoni E, Dinglas VD, Mendez-Tellez PA, Shanholtz C, Ciesla ND, Pronovost PJ, Needham DM. Physical declines occurring after hospital discharge in ARDS survivors: a 5-year longitudinal study. Intensive Care Med. 2016;42(10):1557-66.
11. Neff TA, Stocker R, Frey HR, Stein S, Russi EW. Long-term assessment of lung function in survivors of severe ARDS. Chest. 2003;123(3):845-53.
12. Lechien JR, Chiesa-Estomba CM, Beckers E, Mustin V, Ducarme M, Journe F, Marchant A, Jouffe L, Barillari MR, Cammaroto G, Circiu MP, Hans S, Saussez S. Prevalence and 6-month recovery of olfactory dysfunction: a multicentre study of 1363 COVID-19 patients. J Intern Med. 2021;290(2):451-61.
13. Messineo L, Perger E, Corda L, Joosten SA, Fanfulla F, Pedroni L, Terrill PI, Lombardi C, Wellman A, Hamilton GS, Malhotra A, Vailati G, Parati G, Sands SA. Breath-holding as a novel approach to risk stratification in COVID-19. Crit Care. 2021;25(1):208.
14. Cao J, Zheng X, Wei W, Chu X, Chen X, Wang Y, Liu Q, Luo S, Weng J, Hu X. Three-month outcomes of recovered COVID-19 patients: prospective observational study. Ther Adv Respir Dis. 2021;15:17534666211009410.
15. Sonnweber T, Sahanic S, Pizzini A, Luger A, Schwabl C, Sonnweber B, Kurz K, Koppelstatter S, Haschka D, Petzer V, Boehm A, Aichner M, Tymoszuk P, Lener D, Theurl M, Lorsbach-Kohler A, Tancevski A, Schapfl A, Schaber M, Hilbe R, Nairz M, Puchner B, Huttenberger D, Tschurtschenthaler C, Asshoff M, Peer A, Hartig F, Bellmann R, Joannidis M, Gollmann-Tepekoylu C, Holfeld J, Feuchtner G, Egger A, Hoermann G, Schroll A, Fritsche G, Wildner S, Bellmann-Weiler R, Kirchmair R, Helbok R, Prosch H, Rieder D, Trajanoski Z, Kronenberg F, Woll E, Weiss G, Widmann G, Loffler-Ragg J, Tancevski I. Cardiopulmonary recovery after COVID-19: an observational prospective multicentre trial. Eur Respir J. 2021;57(4).

16. van den Borst B, Peters JB, Brink M, Schoon Y, Bleeker-Rovers CP, Schers H, van Hees HWH, van Helvoort H, van den Boogaard M, van der Hoeven H, Reijers MH, Prokop M, Vercoulen J, van den Heuvel M. Comprehensive health assessment 3 months after recovery From acute coronavirus disease 2019 (COVID-19). Clin Infect Dis. 2021;73(5):e1089-e98.

17. Guler SA, Ebner L, Aubry-Beigelman C, Bridevaux PO, Brutsche M, Clarenbach C, Garzoni C, Geiser TK, Lenoir A, Mancinetti M, Naccini B, Ott SR, Piquilloud L, Prella M, Que YA, Soccal PM, von Garnier C, Funke-Chambour M. Pulmonary function and radiological features 4 months after COVID-19: first results from the national prospective observational Swiss COVID-19 lung study. Eur Respir J. 2021;57(4).

18. Thomas M, Price OJ, Hull JH. Pulmonary function and COVID-19. Curr Opin Physiol. 2021;21:29-35.

19. Gervasi SF, Pengue L, Damato L, Monti R, Pradella S, Pirronti T, Bartoloni A, Epifani F, Saggese A, Cuccaro F, Bianco M, Zeppilli P, Palmieri V. Is extensive cardiopulmonary screening useful in athletes with previous asymptomatic or mild SARS-CoV-2 infection? Br J Sports Med. 2021;55(1):54-61.

20. Bosco G, Rizzato A, Martani L, Schiavo S, Talamonti E, Garetto G, Paganini M, Camporesi EM, Moon RE. Arterial blood gas analysis in breath-hold divers at depth. Front Physiol. 2018;9:1558.

Neuropsychological Implications to Diving After COVID-19

Dr. Lindell Weaver, MD

Patrick A. Mackie

Let's start out with this, COVID-19 is a rather mysterious disorder just like the Utah monolith.

I'm going to talk about brain fog and a few other things. But really what we're talking about with brain fog from COVID-19 is long-term cognitive effects. And really what we're talking about is brain injury. All these terms are synonymous. A person I collaborated with, with some of our DOD efforts of which I have a lot of respect is Dr. David Cifu. He's a physical medicine and rehabilitation physician. He's at Virginia Commonwealth University and is theChief Veterans Administration, TBI researcher. He has a large grant to study traumatic brain injury in veterans across 20 years of time, and that's an ongoing project. But he often said "brain injury is brain injury." What do I mean by that? I mean, that basically, it doesn't really matter what the cause of brain injury is, which is myriad. But the clinical expression of brain injury is often rather similar between TBI, hypoxia, carbon monoxide poisoning, COVID-19, encephalitis, you name it.

> Brain injury is brain injury
>
> *David Cifu, MD, Chief USA Veterans Administration TBI research*

And I want to refresh the audience's memory or knowledge that brain injury is clinically as expressed really across several domains. The brain injury can be divided into the following domains: cognitive, affective and personality, neurological, and somatic. We had some discussion earlier about POTS. Well, I've captured that under neurological as heart rate variability, but it's a bigger problem than that.

So how about outcome after brain injury? Well, it's really a myth that brain injury recovery is uniformly good even in mild traumatic brain injury. The recent TRACK study, a prospective study of over 300, patients, all seen in Emergency Departments, and followed for one year of time shows that over half still had brain related problems a year later. Recovery is variable after brain injury. And often recovery is not back to baseline. And I think we're seeing that of course with these COVID-19 patients and people who tell us that they just are not quite right.

I think all of you know that many people who are hospitalized with COVID have neurological manifestations. Many of them have impaired cognition. And those who survive their ICU stay, of course, have impaired problems. They mimic about a third of the ICU COVID-19 survivors and have sequelae mimicking moderate traumatic brain injury, not mild but moderate. Moderate TBI is quite different than mild TBI. But even those with mild illness, who were never engaged the medical system or if they did only transiently, were never hospitalized. Many of those people complained of brain injury complaints too, affecting the expected customary domains. Cognitive and affective complaints, fatigue, and sleep problems are pretty common in this group of people. As you all know, COVID-19 results in anything from no illness all the way to death.

This is data from Intermountain Healthcare across multiple hospitals here in Utah. Our mortality of intubated, mechanically COVID-19 patients mirrors what has been published elsewhere, showing a 42% mortality. Of the ICU, non-intubated group the mortality is 21% and overall hospitalized, mortality is 5%. Of course, you can be home and be rather ill too.We have had patients at home who had been proned and treated with supplemental oxygen. And comorbid conditions, of course, influence how people are going to fare with this injury or this disease. Now, of course, if a person is in the ICU, often there are episodes, of hypoxia, and they're inflamed which contribute to brain injury. There are medication issues too, that can leave people with brain-related problems. Sleep deprivation, of course, as you all know, and just spending a time on a ventilator in the ICU is linked with about a 30% rate of PTSD.

It's well accepted and well known that patients who survive an ICU stay, especially if they were intubated for a prolonged period of time have brain injury. Well, moving to COVID-19. How does it cause brain injury? And there's a lot of discussion about this, of course, COVID-19 can cause hypoxia as you know, COVID-19 has a predilection to cause microvascular thrombosis. Megakaryocytes have been found in brain capillaries at autopsy. And these really are not seen in people who've died from non-COVID-19 severe illness. These clotscan result in micro-infarcts in the brain, resulting in silent strokes.

Everyone here has heard about the cytokine storm, and inflammation, that can play out in the brain too. There can be direct invasion of virus, the medications that are used often do have significant implications for brain-related outcomes, especially benzodiazepines. And of course, the comorbid factors that they already have with underlying brain injury or microvascular disease can be a factor. Hypertension, those who smoke, diabetes, and so forth are known risk factors for worse ICU outcomes. There are three papers, referenced at the bottom of the slide. One of them at the NIH used high resolution MR imaging to look at postmortem brains. And they found what I've just mentioned, inflammation, bleeding, clots, very thin vasculature, capillary leakage, and evidence of an immune reaction, yet they did not see the virus.

In mice, when they injected the COVID-19 spike protein into the vasculature, they actually could discover the spike protein in the brain. And an autopsy series of only three people, again by the NIH found living virus in that study in the brain, but yet they didn't discover it by their MRI study. And at least in 3D culture models, the virus can cross the blood-brain barrier. So maybe it's the type of disease expression. If the person died very quickly from this infection, people have found the virus in the brain, but in other people who died late, finding the virus in the brain is not expected.

Moving on to diving, COVID-19 divers may have other problems too. You know that COVID-19 has predilection to cause lung injury, we've heard about that, we're going to hear more about other organ systems later, it can certainly affect the heart, affect stamina, peripheral neuropathy directly, but you can also have peripheral neuropathy from what we do to patients in intensive care such as proning. And for brain injury, again, really, our tools are fairly simple, in the sense that we just evaluate people as if they have any other type of brain injury, because that's really what our toolbox comprises. The brain injury evaluation of anybody, including somebody who complains of brain fog is cognition, affect and mood, neurological problems and somatic.

I'm going to spend a moment about somatic. Often physicians kind of blow off the patient with somatic complaints. A brain injured person will come in or somebody who might have brain injury, and you might even be suspicious, but they say, "My neck hurts, my back hurts. Even my legs hurt, I just have these pains." Well, there's sound rationale for these pains, these patients really should not be dismissed. What is felt to be happening here is all of us probably have pains from time to time, but our brain suppresses it, our brain filters it but the injured brain has trouble with that. Also, people who have other problems, they are deconditioned, they lack motivation. They are depressed again, from their brain injury largely. Well, they may think about their problems more; they have a predilection to sort of worry and fret more about their problems. And, the stress of being different can cause somatic pain, too.

COVID-19 and "brain fog"

Regardless of the cause of brain injury, the clinical expression is similar (TBI, anoxia, CO poisoning, encephalitis, COVID-19, etc.)

Brain injury is **clinically expressed** across several domains:

- **COGNITIVE**
  (Executive function, attention, concentration, memory, speed of processing, speech)
- **AFFECTIVE/MOOD/PERSONALITY**
  (Depression, anxiety, PTSD, behavior)
- **NEUROLIGICAL**
  (Headache, vestibular, balance, vision, hearing, heart-rate variability)
- **SOMATIC**
  (Pain sensation, GI disturbance)

Post-COVID-19 brain injury clinical expression is the same as if TBI, anoxia, CO poisoning, etc.

Rivermead Post-Concussion Questionnaire (Now v. pre-COVID-19)

Compared with before the accident, do you now (i.e., over the last 24 hours)

Feeling Dizzy	O	O	O	O	O
Poor coordination, clumsy	O	O	O	O	O
Headaches	O	O	O	O	O
Nausea	O	O	O	O	O
Vision problems, blurring trouble seeing	O	O	O	O	O
Sensitivity to light	O	O	O	O	O
Hearing difficulty	O	O	O	O	O
Sensitivity to noise	O	O	O	O	O
Numbness or tingling on parts of my body	O	O	O	O	O
Change in taste and/or smell	O	O	O	O	O
Loss of appetite or increased appetite	O	O	O	O	O
Poor concentration, can't pay attention, easily distracted	O	O	O	O	O
Forgetfulness, can't remember things	O	O	O	O	O
Difficulty making decisions	O	O	O	O	O
Slowed thinking, difficulty getting organized, can't finish things	O	O	O	O	O
Fatigue, loss of energy, getting tired easily	O	O	O	O	O
Difficulty falling or staying asleep	O	O	O	O	O
Feeling anxious or tense	O	O	O	O	O
Feeling depressed or sad	O	O	O	O	O
Irritability, easily annoyed	O	O	O	O	O
Poor frustration tolerance, feeling easily overwhelmed by things	O	O	O	O	O

I'm encouraging you not just to dismiss this as these guys are crazy or embellishing because this is actually a real phenomenon that affects people pretty dramatically. So how about the history? Well, we have certain questionnaires and tools that we use to take a history of a brain injured individual and the two that I use, just because it's a roadmap to keep me on track. These questionnaires are the Rivermead Post-traumatic questionnaire and the Neurobehavioral Symptoms Questionnaire, and here they are displayed. On one side you see the Rivermead, the other side the Neurobehavioral so these are easy questionnaires for the patient to complete but they are each alittle different.

The Rivermead really wants the person to compare themselves now to before illness or injury. Where as the Neurobehavioral Symptoms Questionnaire compares the person's symptoms or ranks their symptoms over the last two weeks. They are a little different in that regard. But what I do is I'll use these questionnaires. And then during my interview, I will focus on the high scores. I mean, if these they score threes and fours I really want to focus on those areas, so it's really just a guideline for a more indepth interview. But also, these are helpful to track people across time as we involve therapy. Now, of course, in diving, as you all know, there's all sorts of issues, right? I mean, if there's brain injury and diving, again, not necessarily unique to COVID-19. Well, okay, how good is this diver's attention and concentration? How good is their short-term memory? Do they have executive dysfunction? Speed of processing problems? And, how about headaches?

A lot of brain injured people have headaches, some even with migraine features, and they can be quite sensitive to light. Does the diver have dizziness and vertigo from their injury? As you know, brain injured people have quite a lot of fatigue. Do they make good decisions? We know in brain injured people in general, they often don't make good decisions. They, in fact, even have increased rates of accidents. How about irritability? Sure, brain injured people often have mood disturbances including irritability and can make judgment decisions that are off. A lot of brain injured people and divers included potentially take medications that can have spillover effects into relationships and worsening with diving with increased partial pressures of nitrogen.

And as you all know; dives are not all equal. And this has been talked about and it's common sense. For example, here could be a strong current or no current, maybe it's a drift dive. Is it warm? Is it cold? Does it require thermal protection? Is the visibility great, or is it terrible? Is it a boat dive? Or is it going through a crashing surf? Is the diver familiar with the terrain, or is it unfamiliar? Are they required to do unfamiliar skills? Do they have new or different equipment

that they are unfamiliar with? Brain injured individual will have more challenge with that. What's their skill level before diving? It's kind of self-evident. But if a person has dived 1000s of times versus 10 times, they are going to have a very different muscle memory, so to speak about what their skill level.

What is their motivation to dive? Maybe they really don't want to dive, but they're being coerced into diving. Is there an obligation for the brain-injured diver to inform their diving partner about their potential limitations? Recreational no decompression all the way up to technical, commercial, and military where you might not have much say about diving. So obviously, the demands on the diver are very different. And I think that needs to be factored in about fitness to dive; the allowance of a person to dive or at least the recommendation to support them to dive or not. Many factors go into this. And it's really case by case decision making. You can have a skilled diver post-COVID-19, who does have new brain injury problems. He may have cardiac and lung problems too. And yet, perhaps could dive safely juxtaposed to a new diver who's fearful and inexperienced and never had COVID-19. But we all know that some of those inexperienced divers can get into trouble diving.

How about other aspects of diving? What does the increased partial pressure of nitrogen affect? If the person has symptomatic brain injury, a fixed brain injury, increased partial pressures of nitrogen will likely potentiate some of their problems, I can't tell you that will happen, but given what we think we know about nitrogen narcosis with brain injury, this is likely to occur at a lower partial pressure of nitrogen. Therefore with brain injury do we recommend depth limitation? Well, probably at least 60 feet of water pressure because more than that, we know that the effects of nitrogen are increasing. Of course, we have a mitigation strategy which is enriched air Nitrox breathing, so perhaps that would offer some advantage.

Neurobehavioral Symptoms Questionnaire (Sx over past two weeks)

Symptoms

Feelings of Dizziness	0	1	2	3	4
Nausea and/or Vomiting	0	1	2	3	4
Noise Sensitivity, easily upset by loud noise	0	1	2	3	4
Sleep Disturbance	0	1	2	3	4
Fatigue, tiring more easily	0	1	2	3	4
Being irritable, easily angered	0	1	2	3	4
Feeling Depressed or Tearful	0	1	2	3	4
Feeling Frustrated or Impatient	0	1	2	3	4
Forgetfulness, poor memory	0	1	2	3	4
Poor Concentration	0	1	2	3	4
Taking Longer to Think	0	1	2	3	4
Blurred Dision	0	1	2	3	4
Light Sensitivity, Easily upset by bright light	0	1	2	3	4
Double Vision	0	1	2	3	4
Restlessness	0	1	2	3	4

How about seizures? A year or so after mild traumatic brain injury, seizure risk is still quite low. But it's greater than in the non-injured general population by about three-fold. And of course, if they've had more substantial traumatic brain injury the risk for seizure will be higher. If the traumatic brain injury is acute, to six months after injury, or if they had bleeding in the brain, if they have a temporal lobe injury, the seizure risk is much higher. Should brain injured divers even be breathing increased partial pressures of oxygen? Of course, all divers are breathing increased partial pressures of oxygen as depth increases. But what I mean increased oxygen partial pressures into the seizure-provoking range. Clearly, brain injured divers should never breathe partial pressures of oxygen greater than 1.3 atmospheres but you might argue perhaps no greater than 1.2 atmospheres because of course, a seizure in the water is likely going to be lethal for your typical recreational diver.

Fatigue is very common in brain injury. And fatigue may be one of the major limitations to having a diver return to diving. This fatigue is undoubtedly multifactorial. And in COVID-19, it's even more multifactorial, because if they were hospitalized, they're very deconditioned. It may take weeks to months for them to even get back some semblance of their exercise capacity. Brain injury results in lack of motivation, people don't want to exercise. It results in depression. And again, people lack interest in exercising who are depressed. But how about the workup of fatigue? We'll take a history and examine the patient. I think it's sensible to rule out correctable causes of fatigue, such as anemia, thyroid dysfunction, perhaps low testosterone, even growth hormone deficiency. Brain injury can certainly result in growth hypothyroidism, testosterone and growth hormone deficiency.

It's a somewhat challenging to evaluate for growth hormone deficiency. Because if you really want to work it up, you need to do glucagon or insulin stimulation tests, but looking at insulin growth factor 1 (IGF-1) can give you some insight if they have growth hormone deficiency, but it's not perfect. How about their heart? We know that, COVID-19 can seriously adversely affect the heart and can leave people with disability. Therefore fatigue due to a cardiac problem should be considered.

The evaluation in a person who is complaining of fatigue, should contemplate the degree of fatigue and whether or not they are okay to dive. And we've heard about perhaps doing formal exercise studies. If that is done, you'll find out their metabolic limitations and when they achieve their lactate threshold or VO2max and actually what their heart can tolerate and their lungs to some degree. But generally, in brain injured people, we don't really find an underlying cause for their fatigue, it's caused from their brain injury. And after this workup, sometimes CNS stimulants can help. Not always because there's always two edges to the sword, you put somebody on a CNS stimulant, like Adderall or Modafinil, or whatever your choice is, then it can interfere with sleep and sleep is also another big problem in people with brain injury.

Let's consider if a person with COVID-19 were to have a decompression sickness or gas embolism.They already have brain injury from their COVID-19 or from whatever happened to them. And if they get decompression sickness, or certainly gas embolism, the brain injury is just going to get worse. Repetitive insults tothe brain can be additive or often synergistic. The point here is that decompression illness after any brain injury will worsen brain injury. Also, the COVID-19 individual may have had prior brain injuries before COVID-19. COVID-19 could have worsened their pre-existing injury expression, and if they get decompression illness, they will have worse outcome.

Brain injury is very common, especially in athletes and active people where they've had concussions in the past. These concussive injuries add up in a way and it may be that the COVID-19 injury has now tipped them over the scale. And if they get decompression illness, well, they're just going to be in worse shape than if they'd never had it in the first place. So conservative diving is advised after brain injury from any cause.How about if a person has

decompression injury, be it DCS or arterial gas embolism and now they require hyperbaric oxygen? Well, it's fair to say they likely are going to have an increased risk for seizure from hyperoxic breathing but I can't quantify that. Should they be prophylactically treated with Ativan or something else? I think that's individually decided. Our rate of hyperoxic seizures is certainly not zero in patients that we treat on a US Navy Treatment Table six or other aggressive tables. And if they're brain injured, it's something I think for the clinician to certainly consider. Will Keppra work to prevent a hyperbaric oxygen-induced seizure? I don't know for sure. It might. Ativan probably will work at least based on what we think we know about this. So how do you evaluate the brain-injured individual for diving? Well, back to the history. Focus on brain-related symptoms. Key off the Neurobehavioral Symptoms Inventory, or the Rivermead, or just take an open-ended history. However, open-ended questions, don't work so well in brain-injured people, because they're often forgetful.

And that's where using these tools to guide history taking, is helpful. It is reasonable to focus on the neurologic exam, although most of the elements of the exam will likely be normal. Tandem gait often is off, high-level balance skill may be off, Sharpened Romberg, gaze problems, and convergence insufficiency—things like that are often abnormal. There are several computerized neurocognitive tests. We use the Automated Neuropsychological Assessment Metrics (ANAM). We've got familiarity with that one from the work we did in the military. BrainCheck, NeuroTrax, and there are other ones too. These can be helpful or not. I mean, they're brief and they may very well show what you think is normal, but the person may not be normal cognitively. But this is at least something you can do in the office if you have the proper software. How about a formal neuropsychological evaluation, a psychiatric evaluation, speech, auditory processing, neuro-ophthalmology, neuro-optometry? There's all sorts of things that can be done. And how about high-field-strength MRI, looking at diffusion tensor imaging, MR spectroscopy, functional paradigms, perfusion, and so forth?

In a patient with brain-injury complaints, I think it's reasonable to do computerized neurocognitive testing, if you have it. In our case, we do have it, but that's not for everybody. And if you don't have it, you don't have it. But the bottom line here is down below in the yellow on the slide, we can do all sorts of things, but how do these tests influence decision-making about diving? I would submit they probably really don't. Just like we've talked about, we can do all sorts of nice imaging studies of the chest, but you know what? Fundamentally, we might not really know how to advise the diver who happens to have some of these abnormalities. So that's the bottom line, isn't it? How do these tests influence decision-making? Well, we're going to hear more from Dr. Sadler and I look forward to that talk. But the UCSD guidelines seem very reasonable, but those guidelines really don't address brain injury.

HBO_2 months after brain injury?

Are cells ischemic months after injury?

- If so, can HBO_2 favorably modify injury?
- Possible mechanisms:
  - ☐ Improve brain perfusion (Harch, Efrati, Churchill)
  - ☐ Stimulate "idling" neurons
  - ☐ Neurogenic growth factors (e.g. wounds)
  - ☐ Stem cell upregulation (Shandley, UHM 2017)
  - ☐ Neurotransmitter modulation
  - ☐ Modulation of inflammation
  - ☐ Upregulation of hypoxia inducible factor (HIF)

Can Hyperbaric Oxygen help brain injury?

Hart, UHM 2018

- Systematic review of 4 DoD RCTs (n=254)
- **Trends for improvement favoring HBO_2 for mTBI and PTSD symptoms** (p=0.09) and improvement in **verbal memory** (p=0.01), mostly in PTSD

Harch

- n=16, mTBI and mod TBI: non-blind, no control; 1.5 ATA x 60 min 2/d x 60: **Sx, neuro exam, FSIQ, SPECT better**

Boussi-Gross

- Israel, n=90, civilian mTBI: RCT, no control; 1.5 ATA x 60 min 1/d x 40: **ALL Sx and SPECT better**

We're back to clinical judgment by a diving-knowledgeable clinician who I think understands what diving imposes on their patient. And I think involving physical medicine and rehabilitation clinicians, or sports medicine can be quite helpful, because I think they work with brain-injured people. That's their avocation. That's their skill set. And often, the brain-injured people they work with are going back to do whatever work or whatever skill and sports they did before. And I think having that dialogue with them or formal consultation with them, along with the information transfer that we can do as diving clinicians, can be meritorious.

Moving on to a different subject. This came up earlier, and I've got a few slides about this. Can hyperbaric oxygen help brain injury? Well, the work we did in the military with Dr. Brett Hart, in a systematic review, we found there was a trend for improvement, favoring hyperbaric oxygen for those US service members with mild traumatic brain injury and PTSD. Dr. Paul Harch has published a few papers about this, including a small series of 16 US service members in which patients improved after hyperbaric oxygen. The Israelis with Boussi-Gross's study of 90civilians with mild traumatic brain injury and SPECT scans got better with a course of hyperbaric oxygen. And if hyperbaric works, I don't know how does it work. I'm not sure we understand. I mean, there are papers, including from our group with Churchill about improved brain perfusion which may be one explanation. Some talk about hyperbaric oxygen stimulating dysfunctional idling neurons.

I have no idea. Perhaps magnetoencephalography could be insightful about that. Some talk about perhaps hyperbaric oxygen is stimulating neurogenic growth factors, just like in wounds, but we don't know. There is work from the Air Force about stem cell upregulation published in our own literature (UHM) a few years ago. Could hyperbaric influence neurotransmitter modulation? Can it modulate inflammation that may still be ongoing months to years after injury? The Israeli researchersbelieve there's upregulation of Hypoxia Inducible Factor (HIF) that's may be important for recovery of brain injury.

We have an ongoing brain injury trial and hyperbaric oxygen clinical trial ongoing here. This is not a COVID-19 trial. This is a brain injury trial. The trial is closed to enrollment and so you'll have to be patient and wait for results to come from this study in a year or so. But I can tell you at 12 months, the majority of people in this study felt they were better and would do it again and many wanted more hyperbaric oxygen. That's anecdotal. Again, maybe it's a strong placebo effect, but this is a sham controlled. Time will tell. Tel Aviv is really a hotbed for brain injury work with hyperbaric oxygen. They've published many papers. A handful of them are summarized here and the arrows from this research all point in the same direction, that if you have brain injury, stroke, traumatic brain injury, PTSD, and so forth, that hyperbaric oxygen helps.

When you look at the published literature across this, and maybe it's publication bias, of course, but the weight of the evidence supports that a course of hyperbaric improves brain injury.

Most of the data is coming from traumatic brain injury, a little bit from stroke, and even a little bit from the Israeli group about the expected mental deterioration in all of us with increasing age. Of course, there's no efficacy trials. I'm not sure there ever will be, because efficacy trials are very expensive and who's going to pay for it? Yet, the ramifications are quite huge, as I'm sure you can appreciate. I will present a 54-year-old previously healthy high-functioning executive who happened to also a trail runner here in Utah, which are challenging. He had COVID-19 in April last year. He was not hospitalized. He just was ill with fever, loss of sense of smell, all the usual kind of symptoms.

Following this, he could not work at his prior executive level, so he abandoned that work. He was in a financial situation where he was able to do so. His complaints across months, all the way up until now, were fatigue, speed of processing, motivation reduced. He couldn't run like he used to, in fact, hardly at all. He complained of new sleep problems for which he was taking Lunesta. He was evaluated by neurology, immunology, and infectious diseases. Finally, he ended up in a post-COVID-19 clinic run by a pulmonary colleague, who referred him for consideration of hyperbaric oxygen. And the patient said, "You know what? I'll just pay for it." Wee assessed him like our brain-injured participants in our clinical trial, and then treated him daily. And after 30 treatments at 1.5 ATA x 60 minutes a neurologist who saw him before and after 30 treatments, said, "Wow. He has resolved his focal neurological deficits. They're gone."

And after 36 daily hyperbaric oxygen treatments, the patient said, "You know what? My fatigue is much better. I'm up earlier. I'm out doing a lot of the stuff I used to do before, walking, and running, in fact, but not trails. Sleep is much better and almost off Lunesta." Our original plan was to go to 60 treatments, because that's what the Israelis say you need to do. Again, case of one. Who knows what it really means, but at least it's been helpful for him.

fIf you go to clinicaltrials.gov, you will find a trial hyperbaric oxygen trial at Tel Aviv about post-COVID-19 syndrome. They plan to enroll 70 individuals. This trial is ongoing. It's randomized, it's double blind, and sham controlled. In the past criticism of the their trials and the lack of a sham was raised, but now they have added what seems to be a reasonable sham. In the COVID-19 trial, the prime outcome is a neurocognitive test using NeuroTrax. This trial has many secondary outcomes: Brain perfusion, microstructure , functional MRI, balance testing, testing of smell and taste, exercise, echocardiography and moreIt will be interesting to see what they discover.

Back to brain injury and diving –. Clinical judgment by diving-knowledgeable clinicians and by perhaps sports medicine and PM&R clinicians, is helpful. Careful dialogue with the diver about, what kind of diving do you plan to do? Are you willing to sit a dive out if the conditions are inclement or you don't feel so well? All that kind of stuff. And of course, our evaluation is a snapshot in time. The patient may be very different a year or two, or more from now, and I think we need to remind the patient about that too.

HBO_2 Brain injury, older people

University of Tel Aviv–HBO_2

- **Cognitive enhancement** of healthy odler adults 2020 (N=63)

Improves telomere length and **decreases immuno-senescence** 2020 (N=35)

- Treatment of **post-concussion syndrome** due to mTBI, overview 2016
- The Hyperoxic-Hypoxic Paradox 2020
- **Improved neurocognitive functions of post-stroke** patients–a retrospective analysis 2020 (N=162)
- **Brain and cognitive outcomes of mildly cognitively impaired elderly with type 2 diabetes**: Study design 2019 (planned N=154)

DISCUSSION:

Jim Chimiak: A caller asks, what HBOT protocol would you recommend if you were to treat someone with PASC in a clinical trial.

Lindell Weaver: Sure. Well, I think I would rely on, okay. I'm treating at 1.5 atmospheres for 60 minutes, because that's what we did in our DOD work and that's what we're doing in our clinical trial. However, I've had conversations with Dr. Shai Efrati from Tel Aviv, and he said, "You know what? We used to do that, but two atmospheres is better." And I said, "Well, okay, Shai. Where's the evidence?"He said, "You just got to trust me. We haven't published it, but it's better." And he said, "This is the protocol. It's two atmospheres for 20 minutes of oxygen, 5 of air, 20 of oxygen, 5 of air, 20 of oxygen, 5 of air." And then he goes on, "They all go on oxygen to a total of 90 minutes of oxygen breathing." The last period I think works out to be 30 minutes or something, if you do the math. It's a two-hour schedule. And he basically says on this protocol, it's safe. It won't cause seizures, but the switching of oxygen to air and oxygen to air is quite important for the upregulation of HIF-1. And he's emphatic about this. And in terms of the number of treatments, he's emphatic it must be at least 60. In fact, he was critical of our DOD work, because we did only 40. Now at the time, Shai was also doing 1.5 atmospheres for 60 minutes, and that's what we did, but we stopped at 40 sessions. And he said, "We've learned that you have to do more than 40. 40 will show an effect, but it won't be durable." And that's kind of what we found in the military study, although with a lot of confounds about that point. So that's what Shai would do, and if we had our preference and if insurance would pay or whatnot, I think I would likely do that, as opposed to what I'm doing in this patient I'm treating now. I presented what Shai was doing with this patient, and he chose, really, over economic reasons, to go with 1.5 for 60, because it's half as expensive and he's paying for this out of pocket.

Jim Chimiak: And in your own personal experience recovering from COVID-19, you recovered with time. You did not subject yourself to this HBOT protocol You resolved spontaneously, correct?

Lindell Weaver: Yes, correct. I just got really better and better. The night sweats were really aggravating, to be candid with you, as was the weakness. I mean, it was really weird. It was around Christmas time and you'd put a decoration on the tree and I had to go sit down. And again, I mean, I was running and stuff a lot last fall, I mean, 20 miles, 25 miles a week. But now I'm back to baseline. Now, some might argue that's not quite true. But no, I'm back, really. I keep running. I feel really fortunate. We heard about a guy who was an athlete this morning, who was very fit, and he died. I mean, good heavens. That's why this illness is so remarkably mysterious.

Jim Chimiak: Can you comment on a screening tool that will identify those with neuropsychiatric problems? Particularly, most patients will come to you and say they're having problems, but those whose occupation rest on it. And I was struck by one of the presenters at asthma recent aviation webinar remark how prevalent brain fog was post infection in the general population, but how few pilots reported this common problem. To be able to objectively identify those with this condition, are there certain things in the history and physical that might steer us to order formal neuropsych evaluations, especially for patients reluctant to reveal they are having mental status

difficulties such as a professional diver that is highly motivated to get back to work and may be downplaying his problems?

Lindell Weaver: Well, yeah. I mean, hopefully you would rely on symptom reporting, but I appreciate the motivation issues here in they may not be disclosing everything that they want to. That's pretty difficult, Jim. I mean, if the person isn't willing to tell you they have a problem, what can you do to discover it? You can do all sorts of tests, but I'm not sure that you're going to discover it. I mean, you could do an ANAM. You really could do ANAM, I suppose, because there's validity information buried in the ANAM, although I find the validity information quite confusing every time I look at it. But the ANAM is probably reasonable. But let's say you do ANAM and the z-score comes out minus or around the mean or something. That still doesn't tell you the individual doesn't have a speed of processing problem necessarily, that might impact the kind of activity that you're thinking about. I think this is really hard and I think is going to require probably a committee discussion.

Jim Chimiak: But you think a blunt instrument, like the typical mental status examination that we do during history and physical, might uncover someone that was having problems?

Lindell Weaver: No, not at all. The MMSE was designed really to pick up dementia. So if you have an MMSE of 28 in an otherwise healthy person, and you think it's legitimate, I would be concerned. Even about a 28, although 27 to 30 is considered "normal." But that tool is so crude. Again, it's designed for dementia. So anyone who's less than 27, that's a big problem on an MMSE. I might give them one point off if they just forgot what today's date was or something, but 29 to 30 is stone-cold normal. But anything less than that in the kind of people we're talking about is low. I don't think you can use that as a screening tool, because it's just too easy to score 29 to 30.

Jim Chimiak: Your advice about utilizing conservative diving measures upon returning to diving after recovery is important. The first part of your talk discussed the possibility of oxygen toxicity concerns that especially for anyone diving with higher partial pressures of oxygen that include in-water oxygen stops. Later on in your discussion, you discuss using HBOT for the experimental treatment of COVID-19 infection, and I am not aware of any increased risk of hyperoxic seizure in those patient's while being treated. Not a direct correlation of the toxicity risk in the dry chamber experience, but should there be a period of time where the recovered diver should limit his oxygen exposure in the water upon his initial return . I know this is a difficult question that has no evidence, but you had mentioned this concern early on in your discussion.

Lindell Weaver: Well, I think we have a lot of uncertainty. Is the COVID-19 diver going to behave to hyperoxia as a person who's prone for temporal lobe epilepsy from an injury? Well, I don't know the answer to that. Maybe. But maybe not. Do we have MR tools that could help or EEG tools that could help? Maybe. Maybe not. I mean, EEGs is pretty simple and not very expensive. If you're going to have somebody who's going to be breathing increased partial pressures of oxygen into the range that can cause seizures, it's probably reasonable to do provocative EEG.But you're still going to be left with the dilemma. Let's say it's negative. Has that ruled out a risk for a hyperoxic seizure? No, not at all.

Cardiopulmonary Considerations After COVID-19 Infections

Mathew W. Martinez, MD, FACC

Evaluation of cardiovascular symptoms after SARS-CoV-2 infection is imperative. Myocarditis has been recognized as a rare but serious complication of SARS-CoV-2 infection. For some patients infected with SARS-CoV-2, cardiac symptoms (e.g., chest pain, shortness of breath, fatigue, and palpitations) occur at the initial presentation and can persist months after the initial illness.1,2 Laboratory and imaging evidence of myocardial injury and inflammatory myocardial involvement has also been observed in both symptomatic and asymptomatic individuals.[3,4,5]

Early in the pandemic, reports of significant myocardial injury among patients hospitalized with COVID-19 raised concern about risks to highly active individuals including divers as part of RTP after SARS-CoV-2 infection. Since then, the prevalence of clinical myocarditis, inflammatory myocardial involvement, and myocardial injury has been further defined among young and otherwise healthy individuals.

Myocardial injury with COVID-19 has been extensively reported, with widely varying rates based on the population studied.[3] The underlying causes are numerous and include, but are not limited to, myocarditis.[6] acute coronary syndrome (myocardial infarction type 1)[7], demand ischemia (myocardial infarction type 2),[8-12] multisystem inflammatory syndrome in children (MIS-C) and adults (MIS-A),[13-15] takotsubo/stress cardiomyopathy,[16,17] cytokine storm,[11] acute cor pulmonale resulting from macro or micro pulmonary emboli[9,18], myocardial injury from chronic conditions like pre-existing heart failure,[19-22] and acute viral infection unmasking subclinical heart disease.[19] Because one or more of these etiologies may coexist, it can sometimes be challenging to identify a specific underlying cause. In patients with SARS-CoV-2 infection, pre-existing cardiovascular disease and other risk factors (e.g., advanced age, male sex, immunosuppression) represent important determinants of clinical presentation.[23-28]

Chest pain and dyspnea are the most common symptoms with SARS-CoV-2 myocarditis, reported by about half of those hospitalized with this condition (personal communication). Additional symptoms include other types of chest discomfort, exertional dyspnea, post-exertional fatigue, palpitations, and syncope.[29-31] Although symptoms may resolve within 3 months of initial diagnosis, persistence of symptoms for greater than 12 months has been reported.[29]

With COVID-19, the true incidence of myocarditis has proven challenging to assess because of ambiguous definitions, evaluation of non-representative populations, and lack of systematic data collection. Echocardiographic data from prospective, cross-sectional studies of hospitalized patients infected with SARS-CoV-2 suggest that myocardial dysfunction may be present in up to 40%.[32] In selected studies, these findings correlate with cTn levels[4] and risk of mortality.[33] The

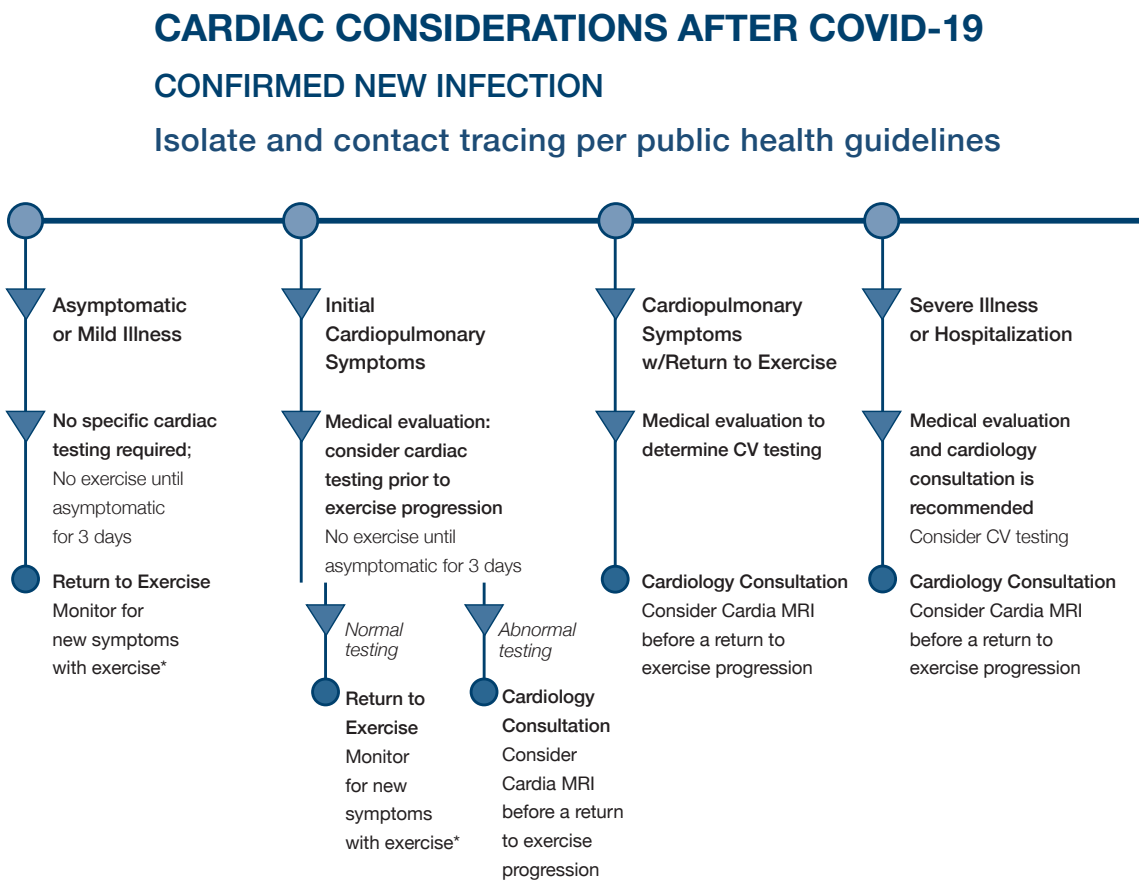


Figure 1. Cardiac Considerations after COVID-19

underlying mechanisms for this (e.g., myocarditis, demand ischemia, stress cardiomyopathy), however, have not always been clearly defined. CMR is the most sensitive imaging modality for identifying inflammatory myocardial involvement. It has been used in several studies to evaluate symptomatic and asymptomatic individuals with COVID-19, both in hospital and ambulatory settings. In a study of 100 patients (33% hospitalized) imaged a median of 71 days after testing positive for COVID-19, non-ischemic LGE was found in 20% and prolonged native T1 and T2 relaxation times in 73% and 60%, respectively.[5] Similar findings have been observed in other CMR studies, with variable degrees of LGE and mapping abnormalities in those convalescing from COVID-19.[34-38] While CMR is a powerful diagnostic tool capable of identifying tissue necrosis, inflammation, and edema, significant limitations exist when used as a screening tool for those infected with SARS-CoV-2. Importantly, to date, there have been no confirmed cases of cardiac demise in the registries of athletes with COVID-19.[39-41] In addition, most athletes at all levels of competition resume participation without undergoing CMR.

Prevalence of myocardial involvement in athletes with COVID-19 were largely single-center studies using CMR as an additional screening tool. In the first published case series of largely asymptomatic US collegiate athletes who underwent triad testing along with screening CMR,[42] 4 of 26 (15%) athletes met modified CMR Lake Louise Criteria[43] for myocarditis, 8 (30.8%) had

evidence of LGE without edema, and none had pericarditis.[42] This was followed soon thereafter by a study of 54 asymptomatic or minimally symptomatic student-athletes, of whom 19 (39.5%) demonstrated evidence of pericarditis with pericardial enhancement and/or pericardial effusion; no athlete, however, fulfilled CMR criteria for myocarditis.[44] It is noteworthy that no other COVID-19 athlete study has reported similar degrees of pericardial involvement.

Current data suggest that those recovering from COVID-19 with mild, non-cardiopulmonary symptoms are unlikely to have myocarditis and clinically significant inflammatory myocardial involvement.[39,40] Consistent observations have been noted in an unselected, non-athletic cohort of infected health-care workers (N=149, age range: 18–63 years), where mild symptoms were not associated with discernable cardiovascular pathology.[37] Instead, cardiopulmonary symptoms that are persistent are likely to be of greater relevance than age or competition level when assessing the probability of clinically-important myocardial disease.[39]

For those recovering from COVID-19 with ongoing cardiopulmonary symptoms concerning for myocarditis or inflammatory myocardial involvement which include progressive exertional chest pain or tightness, dyspnea, palpitations, lightheadedness, or syncope and/or those requiring hospitalization, further evaluation should be performed prior to resuming exercise. For all others that are asymptomatic or with symptoms of only fever [temperature ≥100.4°F], chills, lethargy, myalgias and an absence of cardiopulmonary symptoms, additional cardiac testing is not recommended.

For individuals with mild non-cardiopulmonary symptoms, exercise training should generally be withheld until symptom resolution, excluding anosmia or ageusia, which may be prolonged course. For athletes with cardiopulmonary symptoms, intense exercise training should be limited until symptoms resolve, self-isolation is complete, and further cardiac testing can be obtained. In addition, a graded return to exercise regimen should be emphasized in all individuals with prior COVID-19 to ensure close monitoring for new cardiopulmonary symptoms.

For those with cardiopulmonary symptoms, initial evaluation should ideally be with an ECG, cTn (high-sensitivity assay preferred), and an echocardiogram. The presence of abnormal findings with triad testing or persistence of cardiopulmonary symptoms (specifically chest pain or tightness, palpitations, or syncope) after initial testing suggest that additional evaluation with CMR should be performed. Maximal-effort exercise testing may also be a useful adjunct in cases of persistent cardiopulmonary symptoms, only after myocardial injury, inflammatory myocardial involvement, and myocarditis have been excluded.

Use of CMR to screen athletes who are asymptomatic or with non-cardiopulmonary symptoms is likely to be low yield. Such testing may, however, be considered in those with abnormal triad testing along with increased concern of cardiac involvement or in those with either persistent or new cardiopulmonary symptoms. Importantly, further research is needed to better understand the significance of inflammatory myocardial disease detected by CMR,[41,42] particularly in the absence of symptoms.

In general, routine surveillance monitoring and/or additional testing of those who have successfully returned to play after COVID-19 is not recommended. If <1 month has elapsed since

resolution of cardiopulmonary symptoms, triad testing should be performed. If >3 months have elapsed since resolution of cardiopulmonary symptoms and no exercise limitations are present, no further cardiac testing is likely required. The rationale for this stems from prior guidance recommending avoidance of exercise for at least 3 months in cases of confirmed myocarditis.[45] Finally, if 1–3 months have elapsed since cardiopulmonary symptom resolution and athletes have returned on their own to training without exercise limitation, it is reasonable to allow continued exercise training without further cardiac evaluation. This decision should be individualized and based on clinical judgement, informed by the type and severity of prior symptoms. Factors warranting further cardiac evaluation include prior worrisome cardiopulmonary symptoms (e.g., syncope, sustained exertional palpitations, and/or exertional chest tightness or dyspnea. Because patients hospitalized with an elevated cTn face higher risk of adverse outcomes,[11] closer monitoring for potential deterioration is usually warranted.

The decision-making regarding return to exercise should be based on 1) absence of cardiopulmonary symptoms, 2) resolution of laboratory evidence of myocardial injury, 3) normalization of LV systolic function, and 4) absence of spontaneous/inducible cardiac arrhythmias on ECG monitoring and exercise stress testing.

REFERENCES

1. Carfi A, Bernabei R, Landi F, et al. Persistent Symptoms in Patients After Acute COVID-19. JAMA. 2020;324:603-5.
2. Logue JK, Franko NM, McCulloch DJ, et al. Sequelae in Adults at 6 Months After COVID-19 Infection. JAMA Netw Open. 2021;4:e210830.
3. Sandoval Y, Januzzi JL, Jr., Jaffe AS. Cardiac Troponin for Assessment of Myocardial Injury in COVID-19: JACC Review Topic of the Week. J Am Coll Cardiol. 2020;76:1244-58.
4. Giustino G, Croft LB, Stefanini GG, et al. Characterization of Myocardial Injury in Patients With COVID-19. J Am Coll Cardiol. 2020;76:2043-55.
5. Puntmann VO, Carerj ML, Wieters I, et al. Outcomes of Cardiovascular Magnetic Resonance Imaging in Patients Recently Recovered From Coronavirus Disease 2019 (COVID-19). JAMA Cardiol. 2020;5:1265-73.
6. Singer ME, Taub IB, Kaelber DC. Risk of Myocarditis from COVID-19 Infection in People Under Age 20: A Population-Based Analysis. medRxiv. 2021.
7. Thygesen K, Alpert JS, Jaffe AS, et al. Fourth Universal Definition of Myocardial Infarction (2018). J Am Coll Cardiol. 2018;72:2231-64.
8. Cornelissen A, Kutyna M, Cheng Q, et al. Effects of simulated COVID-19 cytokine storm on stent thrombogenicity. Cardiovasc Revasc Med. 2021.
9. Halushka MK, Vander Heide RS. Myocarditis is rare in COVID-19 autopsies: cardiovascular findings across 277 postmortem examinations. Cardiovasc Pathol. 2021;50:107300.
10. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet. 2020;395:497-506.
11. Lala A, Johnson KW, Januzzi JL, et al. Prevalence and Impact of Myocardial Injury in Patients Hospitalized With COVID-19 Infection. J Am Coll Cardiol. 2020;76:533-46.

12. Wang D, Hu B, Hu C, et al. Clinical Characteristics of 138 Hospitalized Patients With 2019 Novel Coronavirus-Infected Pneumonia in Wuhan, China. JAMA. 2020;323:1061-9.

13. Nune A, Iyengar KP, Goddard C, et al. Multisystem inflammatory syndrome in an adult following the SARS-CoV-2 vaccine (MIS-V). BMJ Case Rep. 2021;14.

14. Theocharis P, Wong J, Pushparajah K, et al. Multimodality cardiac evaluation in children and young adults with multisystem inflammation associated with COVID-19. Eur Heart J Cardiovasc Imaging. 2021;22:896-903.

15. Webster G, Patel AB, Carr MR, et al. Cardiovascular magnetic resonance imaging in children after recovery from symptomatic COVID-19 or MIS-C: a prospective study. J Cardiovasc Magn Reson. 2021;23:86.

16. Meyer P, Degrauwe S, Van Delden C, et al. Typical takotsubo syndrome triggered by SARS-CoV-2 infection. Eur Heart J. 2020;41:1860.

17. Nguyen D, Nguyen T, De Bels D, et al. A case of Takotsubo cardiomyopathy with COVID 19. Eur Heart J Cardiovasc Imaging. 2020;21:1052.

18. Pellegrini JAS, Rech TH, Schwarz P, et al. Incidence of venous thromboembolism among patients with severe COVID-19 requiring mechanical ventilation compared to other causes of respiratory failure: a prospective cohort study. J Thromb Thrombolysis. 2021.

19. Alvarez-Garcia J, Jaladanki S, Rivas-Lasarte M, et al. New Heart Failure Diagnoses Among Patients Hospitalized for COVID-19. J Am Coll Cardiol. 2021;77:2260-2.

20. Goyal P, Reshetnyak E, Khan S, et al. Clinical Characteristics and Outcomes of Adults With a History of Heart Failure Hospitalized for COVID-19. Circ Heart Fail. 2021;14:e008354.

21. Kirkegaard C, Falco-Roget A, Sanchez-Montalva A, et al. Incidence and risk factors for early readmission after hospitalization for SARS-CoV-2 infection: results from a retrospective cohort study. Infection. 2021.

22. Yoo J, Grewal P, Hotelling J, et al. Admission NT-proBNP and outcomes in patients without history of heart failure hospitalized with COVID-19. ESC Heart Fail. 2021;8:4278-87.

23. Inciardi RM, Lupi L, Zaccone G, et al. Cardiac Involvement in a Patient With Coronavirus Disease 2019 (COVID-19). JAMA Cardiol. 2020;5:819-24.

24. Kotecha T, Knight DS, Razvi Y, et al. Patterns of myocardial injury in recovered troponin-positive COVID-19 patients assessed by cardiovascular magnetic resonance. Eur Heart J. 2021;42:1866-78.

25. Hendren NS, Drazner MH, Bozkurt B, et al. Description and Proposed Management of the Acute COVID-19 Cardiovascular Syndrome. Circulation. 2020;141:1903-14.

26. Collet JP, Thiele H, Barbato E, et al. 2020 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation. Eur Heart J. 2021;42:1289-367.

27. Guo T, Fan Y, Chen M, et al. Cardiovascular Implications of Fatal Outcomes of Patients With Coronavirus Disease 2019 (COVID-19). JAMA Cardiol. 2020;5:811-8.

28. Dweck MR, Bularga A, Hahn RT, et al. Global evaluation of echocardiography in patients with COVID-19. Eur Heart J Cardiovasc Imaging. 2020;21:949-58.

29. Sudre CH, Murray B, Varsavsky T, et al. Attributes and predictors of long COVID. Nat Med. 2021;27:626-31.

30. Blomberg B, Mohn KG, Brokstad KA, et al. Long COVID in a prospective cohort of home-isolated patients. Nat Med. 2021;27:1607-13.

31. Mandal S, Barnett J, Brill SE, et al. 'Long-COVID': a cross-sectional study of persisting symptoms, biomarker and imaging abnormalities following hospitalisation for COVID-19. Thorax. 2021;76:396-8.

32. Szekely Y, Lichter Y, Taieb P, et al. Spectrum of Cardiac Manifestations in COVID-19: A Systematic Echocardiographic Study. Circulation. 2020;142:342-53.

33. Rath D, Petersen-Uribe A, Avdiu A, et al. Impaired cardiac function is associated with mortality in patients with acute COVID-19 infection. Clin Res Cardiol. 2020;109:1491-9.

34. Huang L, Zhao P, Tang D, et al. Cardiac Involvement in Patients Recovered From COVID-2019 Identified Using Magnetic Resonance Imaging. JACC Cardiovasc Imaging. 2020;13:2330-9.

35. Knight DS, Kotecha T, Razvi Y, et al. COVID-19: Myocardial Injury in Survivors. Circulation. 2020;142:1120-2.

36. Kotecha T, Knight DS, Razvi Y, et al. Patterns of myocardial injury in recovered troponin-positive COVID-19 patients assessed by cardiovascular magnetic resonance. Eur Heart J. 2021;42:1866-78.

37. Joy G, Artico J, Kurdi H, et al. Prospective Case-Control Study of Cardiovascular Abnormalities 6 Months Following Mild COVID-19 in Healthcare Workers. JACC Cardiovasc Imaging. 2021.

38. Galea N, Marchitelli L, Pambianchi G, et al. T2-mapping increase is the prevalent imaging biomarker of myocardial involvement in active COVID-19: a Cardiovascular Magnetic Resonance study. J Cardiovasc Magn Reson. 2021;23:68.

39. Moulson N, Petek BJ, Drezner JA, et al. SARS-CoV-2 Cardiac Involvement in Young Competitive Athletes. Circulation. 2021.

40. Martinez MW, Tucker AM, Bloom OJ, et al. Prevalence of Inflammatory Heart Disease Among Professional Athletes With Prior COVID-19 Infection Who Received Systematic Return-to-Play Cardiac Screening. JAMA Cardiol. 2021;6:745-52.

41. Daniels CJ, Rajpal S, Greenshields JT, et al. Prevalence of Clinical and Subclinical Myocarditis in Competitive Athletes With Recent SARS-CoV-2 Infection: Results From the Big Ten COVID-19 Cardiac Registry. JAMA Cardiol. 2021.

42. Rajpal S, Tong MS, Borchers J, et al. Cardiovascular Magnetic Resonance Findings in Competitive Athletes Recovering From COVID-19 Infection. JAMA Cardiol. 2020.

43. Ferreira VM, Schulz-Menger J, Holmvang G, et al. Cardiovascular Magnetic Resonance in Nonischemic Myocardial Inflammation: Expert Recommendations. J Am Coll Cardiol. 2018;72:3158-76.

44. Brito D, Meester S, Yanamala N, et al. High Prevalence of Pericardial Involvement in College Student Athletes Recovering From COVID-19. JACC Cardiovasc Imaging. 2020.

45. Maron BJ, Udelson JE, Bonow RO, et al. Eligibility and Disqualification Recommendations for Competitive Athletes With Cardiovascular Abnormalities: Task Force 3: Hypertrophic Cardiomyopathy, Arrhythmogenic Right Ventricular Cardiomyopathy and Other Cardiomyopathies, and Myocarditis: A Scientific Statement From the American Heart Association and American College of Cardiology. Circulation. 2015;132:e273-80.

COVID-19: Cardiac Implication for Divers

Douglas Ebersole, MD

When the list of presentations came out, I saw that Dr. Martinez would be talking about athletes. As a result, my discussion on cardiac implications for divers is going to emphasize the mainstream kind of scuba diver that we see. I have only been diving once with a professional athlete, but I have been diving with lots of middle aged and older obese, poorly conditioned divers and that's the patient population I'm going to talk about.

I'm a cardiology consultant to the Divers Alert Network, but this talk actually has an even more personal component to me as I'm also a COVID-19 survivor. I came down with COVID-19 a little over a year ago after having been exposed to a patient in my office. He was seeing me for an elective procedure, totally unrelated to his symptoms and somehow got past the screening procedures at our clinic. He was very short of breath in my office and I directly admitted him to the hospital. He was in the ICU for about four or five days, luckily did not require intubation, and was hospitalized for a couple of weeks. I was wearing my N95 mask at the time so I was told quarantine and look for symptoms. About 10 days later, I started having fever to 102 degrees Fahrenheit, non-productive cough, shaking chills, and so forth. My symptoms resolved after about 10 days. At at about 10 days, I thought I was back to normal, but I wasn't. I thought to myself, "Okay, I feel pretty good," but then said, "Let me see what my exercise tolerance is." I sat down on my home rowing machine thinking I would do my usual 30 minutes, but within five minutes I was totally exhausted. It took me about two more weeks to get my exercise tolerance back to normal. There were not any "return to diving" guidelines at the time so after work one day when I thought I was back to normal on my rowing machine, I put a pulse-ox on my finger and jogged for about 10 or 15 minutes on a treadmill at work and made sure my oxygen saturations remained > 98%. I then returned to diving about a month later. I started with easy drift diving, then some short cave dives, and then moved on to deep technical dives with significant decompression.

So that's my personal story and why I'm especially interested in the topic of divers returning to diving after having COVID-19. The way I set this up, I'm going to speak briefly on the history of COVID-19. I will then talk about COVID-19 in patients with cardiovascular disease or risk factors for cardiovascular disease as the diving population is an aging one with the average diver these days being middle aged or older and having risk factors for cardiac disease or having established cardiovascular disease.

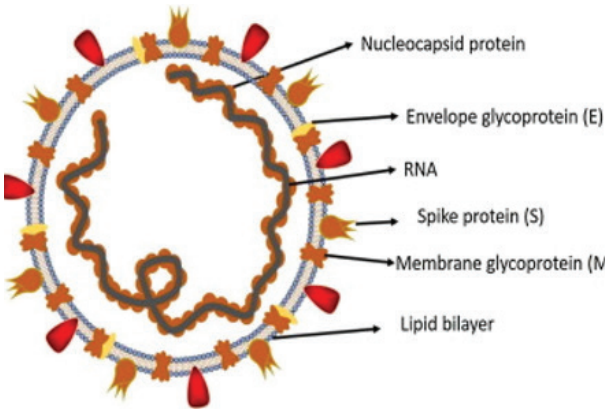
I'll then talk a little bit about the cardiac involvement. This is where things are going to overlap with Dr. Martinez's talk. I'll talk a little bit about elevated troponin, myocarditis and acute coronary syndromes. I'll then talk a little bit about the cardiac prognosis after COVID-19 and then finish up discussing returning to diving after having had COVID-19 with cardiac involvement.

BACKGROUND

SARS-CoV-2 is the coronavirus that causes COVID-19. Coronaviruses are spherical envelope positive strand RNA viruses. They cause about 15 to 30% of the common colds, and there have been two major outbreaks in the past. The SARS epidemic from SARS-CoV-1, and then the MERS virus, the Middle Eastern virus as well. The SARS-CoV-1 caused a global epidemic back in early 2002 and 2003. It was much, much smaller than the current pandemic with only about 8,000 cases but a mortality rate of a little under 10%. The MERS, which we didn't hear a lot abouthere in the United States was the Middle Eastern respiratory virus recognized in 2012. It had about 2,500 cases, and the problem with this virus was its mortality rate was over one in three. Thankfully it had an R0, a marker of its infectivity, that was very, very low, so there were only about 2,500 cases and it did not spread widely. The COVID-19 or SARS-CoV-2 virus was first recognized by the WHO on December 3rd, 2019. It was linked back to Wuhan City and was isolated. It was then termed the severe acute respiratory syndrome coronavirus 2, or SARS-CoV-2. As of today (June 9, 2021), there've been 174 million cases worldwide, 33 million in the USA with 3.75 million deaths worldwide and almost 600,000 deaths now in the United States. I know a lot of people when this first came out said, "Oh, it's just the flu." Clearly this is not the flu.

BACKGROUND

- SARS-CoV-2 is the coronavirus that causes the disease called COVID-19
- Coronaviruses
  - ☐ Spherical envelope positive strand RNA virus
  - ☐ Commonly cause respiratory illnesses in humans
  - ☐ Cause 15–30% of the "common cold"
- Two severe outbreaks in the past
  - ☐ SARS-CoV-1
  - ☐ MERS-CoV



We're going to talk initially about patients with underlying coronary disease. We know usually COVID-19 is a relatively mild condition. It's usually a respiratory issue, goes away in a week or two, and there's not much of a problem. However, we have learned that there are certain groups that have a much greater risk of serious disease and dying from this illness. The elderly are at the highest risk.

The mortality rate starts to climb as patients get into their fifties and sixties. As they start getting over the age of 80, the mortality rate can be as high as 15 or 20%. So our middle-aged diving population is somewhere in the middle with mortality rates in the low single digits. Obviously, it is also known that people with co-morbidities, specifically conditions like hypertension, diabetes, and obesity are at an increased risk of mortality. And patients with cardiovascular disease clearly have a much higher risk of serious disease and death. We know that coronary artery disease patients or people who just have significant risk factors like diabetes, smoking, hypertension and so forth have a heightened risk of having an acute coronary syndrome associated with a COVID-19 infection. This could be unstable angina, a non-STEMI, a true STEMI, or sudden death. This is not unique to COVID-19 and can occur with lots of infections as well.

CORONARY ARTERY DISEASE PATIENTS

COVID-19 has been shown in patients with coronary disease to make them more likely to have acute coronary syndromes. So, during these acute infections, and COVID would be included with that, people can have heart attacks. That can be caused by a variety of different mechanisms. Frequently, what we've been seeing in our hospital over the last year or so is lots of people who we call "type two myocardial infarctions." These are people that have some level of stable, underlying coronary disease, which is not getting them into trouble until you put an increased demand on their body. So they have fever, they have tachycardia, they have hypertension or hypotension. And these stressors increase the myocardial oxygen demand and exceed the supply that can be provided by their diseased coronary arteries, resulting in a myocardial infarction, not from the usual rupture of a coronary artery plaque, but from a "supply-demand" mismatch.

Additionally, the cytokines that are circulating in the bloodstream during acute infections like COVID-19 can destabilize what would otherwise be very stable coronary plaques, causing them to rupture. And this ruptured coronary plaque releases enzymes that cause blood clots to form, and suddenly you've now got a very unstable patient. Additionally, lots of viruses, COVID included can induce a hypercoagulable state so that patients even without any kind of significant underlying coronary artery disease, could suddenly clot off a coronary artery, clot off a blood vessel in the brain causing a stroke. They can clot off the blood vessels in their legs risking amputations. We've seen numbers of people in their thirties and forties over the past year coming into our cath lab in the middle of the night with no obvious underlying coronary artery disease by cardiac cath, but have an occluded vessel with a large clot in who then test postitive COVID-19 positive. So that's a third cause of myocardial infarction in the COVID-19 population, this viral induced hypercoagulable state.

The other issue that you get into with these middle-aged or older people with coronary disease that come in with COVID-19 is they don't have a lot of cardiac reserve. They're not the young, healthy people. They're clearly not the athletes that Dr. Martinez was talking about, and this can cause them to lose the ability to tolerate this illness and have hemodynamic collapse. And unfortunately, we've had several people over the last year who have ended up on a left ventricular assist devices because of hemodynamic collapse due to COVID-19 with their underlying coronary disease.

ELEVATED TROPONINS

Dr. Martinez talked about this in detail, but we'll go over it a little bit more. In patients with COVID-19, somewhere between 7 and 28% of patients will have elevated troponins. Now, this can be anything from a very minimal elevation, like Dr. Martinez mentioned just a few minutes ago during the questions or it can be very high. And obviously the higher the elevation, the more concerning they are, but it has been shown that any elevation in troponins is associated with a higher in-hospital mortality.

There could be an elevated troponin because of true myocarditis, a true inflammation in the myocardium. Like I mentioned before, there could be a coronary plaque that was ruptured because of the release of these cytokines and there is an acute coronary syndrome that needs to be treated just like any other unstable angina or myocardial infarction. There could be thrombosis from this hypercoagulable state in patients with normal coronary arteries, resulting in elevated troponins. You could have this type 2 MI I talked about previously where you've got a mismatch of the supply and demand. And there's lots of non-cardiac causes of elevated troponins. As a cardiologist, I get a great deal of elevated troponin consults, which may or may not have anything to do with a true unstable angina or myocardial infarction.Classic noncardiac causes of elevated troponins are pulmonary embolism, chronic kidney disease, and underlying sepsis. People with chronic kidney disease will have kind of chronically mildly elevated troponins that don't really peak and fall, they just kind of stay elevated at a mild level and that has no bearing on their cardiac conditions.

So what about the prognosis? If you do have elevated troponins in COVID-19, there's two studies that were reported in JAMA Cardiology just after the beginning of the pandemic, so back in March of last year. The first by Shi et al.[1] looked at 416 hospitalized patients with COVID-19. They found almost 20% had some level of elevated troponins, and the mortality for those patients with elevated troponins was over 50% compared to 4.5% in those with normal troponins. A similar finding was found by Guo et al.[2], where they looked at 187 hospitalized patients of which almost 28% had elevated troponins. And, again, they saw hospital mortalities of close to 60% in those with elevated troponins versus fewer than 10% with normal troponins. So these do show the markers that elevated troponin is a bad actor for patients in the hospital and may be a patient that needs more carefully monitoring in the hospital and even once they get out of the hospital.

Additionally in Guo's trial, the highest mortality, as you would expect, was in patients who had underlying coronary artery disease who were admitted with COVID-19 and developed abnormal troponins. These patients had mortalities in the hospital of close to 70%, but even the coronary artery disease patients who came in with COVID-19 and had negative troponins still had mortalities of 13% which was much higher than the risk for the non-coronary artery disease patients. So we need to be aware that the middle aged and elderly population that we see in divers, who hsave underlying coronary disease and then had evidence of COVID-19, are going to be high risk patients for complications. They will need to be evaluated carefully before returning to diving.

In summary, there are multiple reasons COVID-19 patients may present with elevated troponins. It doesn't just have to be an acute coronary syndrome, but could also be myocarditis, like was mentioned in Dr. Martinez's talk in detail.

MYOCARDITIS

So as he mentioned, the SARS-CoV-2 virus has an affinity for the host ACE2 receptor, which is true of lots coronaviruses, but this allows for direct viral infection of the vascular endothelium and of the myocardium in myocarditis. So these elevated troponins, like we mentioned, can be an acute viral myocarditis. These cases normally present not just with elevated troponins, but frequently with chest pain. You can have just dyspnea or shortness of breath, but you also can have people with cardiogenic shock. And we've actually had a handful of people at our hospital over the last year with COVID-19 who presented with true fulminant myocarditis resulting in cardiogenic shock.

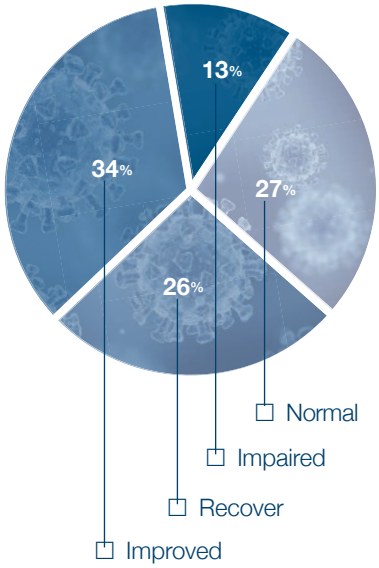
A couple of those, unfortunately, passed away. Some others required support with left ventricular assist devices, and one actually went on to cardiac transplantation months later. Thankfully, most patients will recover without any significant residual damage, but if a patient has symptoms of myocarditis—elevated troponins, chest pain, wall motion abnormalities, LV-dysfunction and so forth—they should all be admitted because there are patients who within the first couple of days can rapidly decline and end up requiring inotropic support or device support. Therefore, any COVID-19 patient with myocarditis should be admitted to the hospital for observation. Thankfully, the vast majority of people will recover.

The following is not COVID-19 data, but is just viral myocarditis in general. This was published back in Circulation Research in 2019.3 You'll see that over one quarter of patients with viral myocarditis have normal ejection fractions, 27% of those. Of the remaining patients that started out with an abnormal ejection fraction, 26% will fully recover, another 34% will be markedly improved so that really only about 13% of people with viral myocarditis, two years after the diagnosis are left with poor LV function.

How do we evaluate for this? Obviously, by troponins and by echocardiography. So by echocardiography, we're looking for evidence of hypokinesis, and in more of a global pattern. Sometimes right ventricular endomyodardial biopsy can be helpful if you've got very high risk patients such as patients with cardiogenic shock, high-grade AV block or recurrent ventricular tachycardia, because it can sometimes help steer therapy. But in the vast majority of people, there's no need for any kind of biopsy, and they're treated conservatively and the diagnosis made by troponins and by echo.

A paper came out in 2020 looking at the autopsy data and it was interesting, but again, just confirmed that there is a lot of the virus that can be cultured from heart muscle in patients who have passed away from the disease.4 I bring it up because it garnered a lot of press when it first came out. These were autopsy cases consecutively in Germany in April 2020. All these cases had tested positive for COVID-19. The vast majority had a pulmonary cause of death—89% had pneumonia. None had had any clinically fulminant myocarditis. So they basically had pulmonary symptoms that were causing their problems, but did have evidence of elevated troponins.

MYOCARDITIS



Left ventricular ejection fraction two years after diagnosis

Circulation Research 2019; 124:1568-1583

They looked at 39 consecutive autopsy cases. The median age was age of 85 years, and ranging from 70 to 89 years. Over half were women. They did have a lot of underlying disease, which you would not find surprising. So the people who died from this illness tended to be people who had hypertension, coronary artery disease or diabetes, but they were able to isolate the SARS virus in 61.5% of cases. As we know, since it has the affinity for binding the ACE2 receptor, it gets into the myocardium in lots of patients. The vast majority of the time, this is not clinically important, but it is there and something we just need to be aware of, especially when we start thinking about how to decide what divers can we let return to diving.

ACUTE CORONARY SYNDROMES

What about true acute coronary syndrome? So how often do people come in and actually have a heart attack as a result of their COVID-19? These people need to have their underlying coronary disease treated in addition to their COVID-19. You're going to need to rehab them from their coronary disease and so forth before you can even consider getting them back into the water. These patients can present with unstable angina, with non-ST segment elevation myocardial infarction, or with an acute ST segment elevation myocardial infarction.

To make this diagnosis, you need to have an elevated troponin and at least one of the following. You'd want to have some sort of signs and symptoms of ischemia, so people coming in with chest pain, shortness of breath and so forth. You'd want to have new ischemic EKG changes on their EKG, and you want to have either a development of pathologic Q waves on an EKG or some evidence with imaging that you've lost some myocardium, or you've got some sort of a new regional wall motion abnormality, or if people have to go directly to the cath lab, you'd want to see coronary thrombosis by the angiogram.

As I mentioned earlier, there are both Type 1 and Type 2 myocardium infarctions. These type two, which would be the people like I mentioned before, who have a mismatch of supply and demand would not get into any trouble until they have the stress of this infection. Those people you just treat conservatively with regards to their coronary artery disease and probably risk stratify them as an outpatient with stress testing to make sure that that patient doesn't require revascularization with stenting or coronary artery bypass surgery before letting them recover and return to diving.

The Type 1 myocardial infarctions are the classic plaque rupture and thrombosis of the vessel. This can be caused by the COVID-19 like we mentioned earlier, because of the cytokines disrupting the plaque, and these patients need to be treated just the way you normally would treat anybody with an acute myocardial infarction. So they all get revascularization. They then get aspirin, a PGY2 inhibitor like Plavix or one of the newer agents, beta blockers, statins, and so forth and so on. And these patients, before returning to diving, are going to have two issues. One, obviously you want them to recover from their COVID-19, but secondly, they need to recover from their coronary artery disease and you treat them the same way you would any kind of coronary artery disease patient, where you'd want to assess them for exercise tolerance. You'd want to assess their LV systolic function. And you want to look for evidence of ischemia before allowing them to get back in the water. If patients have recovered from their COVID-19 illness, they have normal LV systolic function, they have normal exercise tolerance, and they have a normal stress test with no evidence of ischemia, they should be able to return to diving.

How are the outcomes for these unfortunate patients who have this bad combination of having COVID-19 and then having this COVID-19 trigger and acute myocardial infarction? It's kind of having two bad luck events all at once. So there actually has been a registry which has been developed, it's called the North American COVID 19 Myocardial Infarction Registry. The data from this was presented at the Society for Cardiac Angiography and Intervention May 2021 Scientific Sessions. The investigators found if a patient has the combination of an ST elevation myocardial infarction (STEMI) and COVID-19 the mortality was 33%. In a pre-pandemic control group, the in-hospital mortality was only 4%. So the combination of COVID-19 in addition to a STEMI increases your mortality 8–9 times compared to baseline.

LONG HAULERS

In JAMA earlier this year, investigators looked at four-month outcomes for 478 patients who survived hospitalization for COVID-19.5 They contacted these patients to look for evidence of long COVID or what we now call "long haulers." They looked at their histories, they survey them for quality of life, fatigue, dyspnea, anxiety, depression, and so forth. They did pulmonary function testing on all patients. They did high resolution CT scans of the chest on all patients, and they looked at echocardiograms on all these patients. Of the 834 eligible patients for this survey, they got about a little over half of them to consent. And half of those had at least one new symptom. These symptoms were most commonly fatigue, but there were symptoms of dyspnea, and there were some episodes of chest discomfort. Of the patients who were invited, they had 60% consented. I won't spend a lot of time on the pulmonary stuff because we had a lot of that earlier today, but they found chest CT abnormalities and a lot of these patients usually kind of ground glass infiltrates. PFTs were commonly preserved, and the mean DLCO was actually quite good at 87% in most of these patients. The best news from a cardiac standpoint was that 83% of the patients met criteria for an echo and of those, none had ejection fractions of under 40%, only eight had ejection fractions of less than 50%. A normal ejection fraction is 50 to 60% or so. So only eight of 83 had left ventricular ejection fractions (LVEF) of less than 50% and none had LVEF < 40%. Thus, no patient had moderate or severe LV systolic dysfunction. That was very good news from that standpoint.

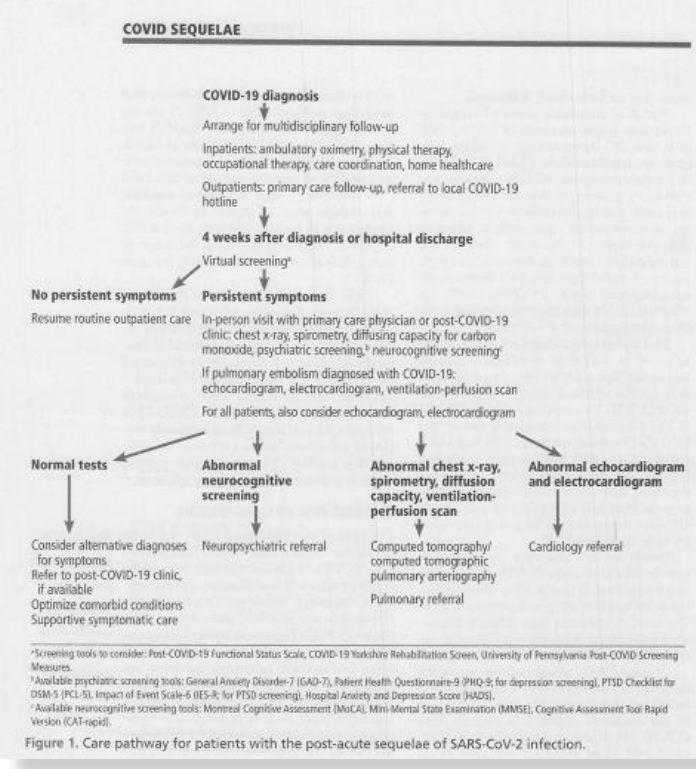


Figure 1. Care pathway for patients with the post-acute sequelae of SARS-CoV-2 infection.

Looking at the long haulers, we had a lot of people that show up at our cardiac clinic who had COVID-19, they may have had a little bit of elevated troponin and now they're having symptoms and they want us to evaluate them for their cardiac situation because they want to return to work, sports, other activities. Classically COVID-19 symptoms last about two weeks. The incidence of long haulers is difficult to assess, but it looks like it occurs in greater than 10% of people having symptoms more than three weeks out. About one fifth of these are young adults.

Cleveland Clinic Journal
2021; 88(5):267-271

If you look at hospitalized patients, the numbers are much higher. About two thirds of hospitalized patients continue to have symptoms six months after recovery from an acute COVID-19 infection. So from a diving standpoint, if you're looking at a hospitalized patient who wants to return to diving, you want to really make sure first and foremost that they're completely symptom free and realize that a large number of these patients may take several months before they become symptom free.

This is from the Cleveland Clinic Journal last month showing what symptoms these long haulers tend to have.6 Chest pain occurs in a significant number of people at onset (40%)and at 60 days (22%), along with fatigue (79% and 56% at onset and 60 days, respectively) and dyspnea (67% and 42%), all of which could or could not be cardiac symptoms. Their work up is as follows. If patients have no persistent symptoms at four weeks, they resume their normal care. For patients with persistent symptoms they allow them to return. For abnormal neurocognitive screening, they get a neuropsychiatric referral. If they have an abnormal chest x-ray, they get a pulmonary referral. And for those that have had persistent symptoms with an abnormal echo or an abnormal EKG, they are referred to cardiology for further evaluation.

RETURNING TO DIVING

So currently, when can someone safely return to diving after contracted COVID-19? This is my bias as of June 2021. I've given lots of Zoom type meetings to dive clubs and other organizations around the country over the last year with this. And the problem with a lot of this, like with a lot of medicine, is people hear anecdotes and there was this report from a Dr. Hartig in the summer of last year, where he reported on six divers that had severe changes on their CT scans and the translation into English from German in this diving magazine was that these patients would quote, "never be able to return to diving." That generated lots of issues and so forth for people in the diving medicine world last year.

So first and foremost, I tell all these people, get your diving recommendations and your information from organizations like this, like from the UHMS , or Divers Alert Network or for SPUMS and please avoid media and anecdotal kind of information. Obviously, because this is an extremely variable illness, it's not going to be a one size fits all approach where you can say, "Well, everybody can return to diving at such a point," or, "No one can return diving," and so forth and so on. That's because the signs and symptoms of this disease are very highly variable.

I tell divers that want to return to diving that the first thing before anything else is they have to return to their normal level of fitness. Of course, that assumes a diver had an exercise program before the illness, which I stress to all of my students. I tell people, if you are diving to get into shape, you are doing it wrong because diving should be a fairly relaxed activity. So you should get into shape to dive not the other way around. The first thing is all divers need to get back to their normal level of fitness. Once they've achieved that, then we can decide what does or doesn't need to be done. If they're not back to that level of fitness, there's no way they're returning to diving.

And the diver should be evaluated by physician knowledgeable in diving medicine prior to returning to diving. That can be aided through Divers Alert Network. There's a network of over

700 doctors around the country that they could speak with to try and help them decide about returning to diving. And I think in my opinion, this is the best approach we have at the moment while we are waiting for further data. I know Frauke is going to be speaking a little bit later that DAN has a study that organized to try and follow divers who've had COVID-19. For anyone who is interested, you can contact them at medic@dan.org, I'm actually a participant in that study so I'm looking forward to seeing what Frauke has to say a little bit later.

Here are the current guidelines for returning to diving after COVID-19. This has been published by the group at UC San Diego. We came up with almost identical guidelines here in Florida, where we had myself, an interventional radiologist, a critical care physician, an emergency physician, and a retired Navy diver who has a PhD in biomedical engineering and is an expert in hyperbaric medicine.

You can categorize people into no symptoms, mild symptoms, moderate symptoms, or severe symptoms. Patients who had had a positive screening test or positive antibodies can just return to diving no additional testing is required other than as outlined by the Recreational Scuba Training Council (RSTC).

The same basically goes for mild disease. These are people who did not seek healthcare and received only outpatient treatment with no evidence of hypoxemia. They did not require any supplemental oxygen, and they had either a chest x-ray which was normal or was felt not to be required. So the evaluation of those people should, again, just be a periodic exam with their physician. You may want to consider spirometry in these people depending on how symptomatic they were from a pulmonary standpoint and maybe a chest x-ray if they did not get one previously, and you could consider doing exercise tests mainly for exercise capacity and for oxygen saturations with exercise.

The people that we need to be a little bit more cautious with, which is exactly what Dr. Martinez was saying, was either the patients who have moderate or severe disease. So this would be people who were hypoxic and required supplemental oxygen. These are people who on admission had an abnormal chest x-ray or an abnormal CAT scan. They were admitted to the hospital, but did not require going on a ventilator or a CPAP or BiPAP. And if they're admitted, they had documentation of normal cardiac workups. These are people who've had normal EKGs and normal troponins.

But these people did have moderate disease and they were hypoxemic, so they're going to require a little bit more evaluation prior to returning to diving. So again, the typical kind of exam and these people we suggested probably spirometry, chest x-ray and then from a cardiac standpoint, an EKG, an echo if it was not done in the hospital to look for LV systolic function, look for any evidence of myocardial or pericardial involvement with a fusion so forth, and then strongly consider performing an exercise tolerance test with oxygen saturation before allowing these people to return to diving.

And then the worst case scenario would be the patients with severe disease. These people will be out of the water at least several months. These are people who required intubation or some level of ICU care. They may have had cardiac involvement with an abnormal EKG. They may have

had an abnormal echo or elevated troponins, or some sort of thromboembolic complications like a pulmonary embolism, DVT, or some other coagulopathy. These people are going to need to be out of the water for several months, mainly because it will take them that long to get their exercise tolerance back up. And then the recommendation will be the same sorts of things as before, but including repeat cardiac troponins to make sure those have gone back to normal. If they had elevated BNPs from LV dysfunction, we need to make sure those have returned to normal, and an echocardiogram to assess LV function. And again, exercise tolerance tests with oxygen saturation should be done to make sure that they are not having oxygen desaturation with exercise before they return to diving.

SUMMARY AND RECOMMENDATIONS

In summary, a relatively high percentage of patients admitted with COVID-19 will have underlying coronary disease or at least some sort of risk factors for coronary disease. The current diving population is in this group. The average diver is getting older over the last couple of decades and is a middle aged to older person so there is a high incidence of divers with risk factors for coronary disease or underlying coronary disease. COVID-19 can either directly or indirectly affect the cardiovascular system. As we've discussed, it can directly infect the myocardium causing myocarditis, but can cause an acute coronary syndrome that could happen either because of supply demand mismatch or can occur because of plaque disruption from the cytokines circulating from the illness, or it could occur from just thrombosis of an artery with underlying normal coronaries just from the hypercoagulable state of the virus.

For COVID-19 patients who suffer acute coronary syndromes, management is similar to that for patients without COVID-19 and you need to make sure that they are safe to return to diving from that standpoint, as well as from the COVID 19. After hospital discharge, acute coronary syndrome patients would need to be on standard medications and visit a cardiac rehab before returning to diving.

Myocarditis patients, according to guidelines, should not exercise for at least three months and then be evaluated to decide when they can return to diving. And hospitalized COVID-19 patients with elevated troponins should not return to diving for at least for three months after discharge. You need to make sure that their troponins have been documented to have normalized, you need to make sure they have an echocardiogram showing normal LV function (if that was not already done at the hospital) to show normal function. And then strongly consider an exercise test with oxygen saturation to make sure they do not develop oxygen desaturation with exercise before clearing them to return to the water.

DISCUSSION

Jim Chimiak: Pulmonary edema while diving continues to be an issue of concern and episodes continue to been reported to the DAN hotline. Dr Lindholm described elevated PA pressures with COVID 19 infection. Persistent SOB, tachycardia and tachypnea with exercise seen post infection could generate increased inspiratory pressures. Could these present additional risk factors for the development of pulmonary edema despite normal screening investigations that may not detect these issues. Should we advocate that individuals that have recovered from acute COVID infection and return to their exercise baseline, conduct vigorous dive refresher training/swimming in the pool before returning to the open water especially those with other cardiac risk factors or planning to dive remotely?

Douglas Ebersole: I think that's a very reasonable thing. I mean, again, I've stressed people get back to their baseline exercise tolerance before returning to diving. So if walking or jogging or ellipticals of the gym or whatever. Obviously swimming would be much, much better test for diving. Depends a lot on what their resources are to do that. But yeah, I think that's a very reasonable idea to recommend say if you've had COVID, before getting back in the water, consider going to your local dive shop or your local YMCA if you don't have a pool or a clubhouse and make sure you can still do at least your 200 yard swim or whatever number you want to use, that we would only require divers to be able to accomplish. I think that'd be a very reasonable thing to suggest to people.

Richard Moon: One of the questions that comes up since we're all in the somewhat plausible rationale stage of guidelines, have you seen any, should we say, major problems in divers who have gone back to diving, whether without screening, and had an issue? Jim actually raised the issue of immersion pulmonary edema previously, but anything else, anyone who's not come back from their dive, presumably really underwater or had some clinical problem associated with diving?

Douglas Ebersole: I have not personally. I've kind of asked people to share that with me, but I've not had that. I've been a strong proponent of making sure people are completely back to a good level of fitness before getting back in the water and making sure their oxygen saturations were okay. And I think people who will follow that up with the people I've heard from have not had any issues. So I've not heard of anything that sounds like a COVID-19 either sudden death, unstable angina, pulmonary edema type of episode in diver. There's been lots of concerns from divers about can they return or when they can return but as far as once they get back in the water, I personally haven't heard of any individual cases of problems.

Richard Moon: Any experience with COVID vaccine associated with myocarditis?

Douglas Ebersole: I have not seen that at all. I know that that's a concern with a small number of people. I have not seen that at all. But again, that's my small sample size.

Richard Moon: Matt responded in the chat, he said, "We've had five patients with COVID vaccine myocarditis," he suggests a cardiac MRI in that group who will generally have elevated troponins.

Douglas Ebersole: Sounds very reasonable. Yeah, that'd be a very good use of cardiac MRI because it's a small number of people, you're not going to be exposing a large number of people to that expense, but for that group, that'd be a very reasonable thing to do.

Richard Moon: Well, one thing that we haven't heard much about today is physical examination. Is there any role for physical examination in these patients? A third heart sound, elevated JVP, friction rub, or is physical examination out the window?

Douglas Ebersole: I was trained by a very clinical guy, so I always say there's always a role for physical examination. But I honestly, in this day and age with echocardiography and so forth, the sensitivity for picking up things like an S3 Gallop or a fourth heart sound for a stiff ventricle, the sensitivity specificity can be much worse than an echocardiogram. So any of these people are hospitalized, you can get an echo, that's going to be a much better exam. It's going to be like anything else, it'd be like you were mentioning with the ultrasound for lung things and it's helpful if it's positive, if it's negative, doesn't mean much. Obviously if you examine somebody and they have a third heart sound or they clinically have rales or a pulmonary edema, obviously that's very helpful. But the absence of those is not going to be particularly helpful. I think an echocardiogram is a much better test for that.

REFERENCES

1. Shi S, Qin M, Shen B, Cai Y, Liu T, Yang F, Gong W, Liu X, Liang J, Zhao Q, Huang H, Yang B, Huang C. Association of Cardiac Injury With Mortality in Hospitalized Patients With COVID-19 in Wuhan, China. JAMA Cardiol. 2020 Jul 1;5(7):802-810. doi: 10.1001/jamacardio.2020.0950. PMID: 32211816; PMCID: PMC7097841.

2. Guo T, Fan Y, Chen M, Wu X, Zhang L, He T, Wang H, Wan J, Wang X, Lu Z. Cardiovascular Implications of Fatal Outcomes of Patients With Coronavirus Disease 2019 (COVID-19). JAMA Cardiol. 2020 Jul 1;5(7):811-818. doi: 10.1001/jamacardio.2020.1017. Erratum in: JAMA Cardiol. 2020 Jul 1;5(7):848. PMID: 32219356; PMCID: PMC7101506.

3. Tschöpe C, Cooper LT, Torre-Amione G, Van Linthout S. Management of Myocarditis-Related Cardiomyopathy in Adults. Circulation Research. 2019 May;124(11):1568-1583. DOI: 10.1161/circresaha.118.313578. PMID: 31120823.

4. Lindner D, Fitzek A, Bräuninger H, Aleshcheva G, Edler C, Meissner K, Scherschel K, Kirchhof P, Escher F, Schultheiss HP, Blankenberg S, Püschel K, Westermann D. Association of Cardiac Infection With SARS-CoV-2 in Confirmed COVID-19 Autopsy Cases. JAMA Cardiol. 2020 Nov 1;5(11):1281-1285. doi: 10.1001/jamacardio.2020.3551. PMID: 32730555; PMCID: PMC7385672.

5. Writing Committee for the COMEBAC Study Group, Morin L, Savale L, Pham T, Colle R, Figueiredo S, Harrois A, Gasnier M, Lecoq AL, Meyrignac O, Noel N, Baudry E, Bellin MF, Beurnier A, Choucha W, Corruble E, Dortet L, Hardy-Leger I, Radiguer F, Sportouch S, Verny C, Wyplosz B, Zaidan M, Becquemont L, Montani D, Monnet X. Four-Month Clinical Status of a Cohort of Patients After Hospitalization for COVID-19. JAMA. 2021 Apr 20;325(15):1525-1534. doi: 10.1001/jama.2021.3331. Erratum in: JAMA. 2021 Nov 9;326(18):1874. PMID: 33729425; PMCID: PMC7970386.

6. Vehar S, Boushra M, Ntiamoah P, Biehl M. Cleveland Clinic Journal of Medicine May 2021, 88 (5) 267-272; DOI: https://doi.org/10.3949/ccjm.88a.21010

Vascular Injury Implications for DECO and VGE

David M. Eckmann, PhD, MD

Coronavirus Disease 2019 (COVID-19) has changed our world above and below the water surface. A major question being asked within the diving community is, "I had COVID-19, when may I dive again?" This is a significant issue, as policy and safe practice need be established based on careful evaluation of available evidence in order to protect diver health without being overly restrictive. It is known that COVID-19, the disease caused by the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), can manifest as asymptomatic, mild, moderate or severe illness. Extent of illness is related directly to its effects on vasculature, as COVID-19 is in many respects an endothelial cell disease.[1-2] The implications for return to diving for those recovering from an asymptomatic or mild case may be considerably different from the implications for those who have suffered critical illness. Understanding these differences requires detailed exploration of any pulmonary vascular injury incurred and the associated implications of such injury in the face of diving risks for decompression sickness (DCS) and vascular gas embolism (VGE).

Experience-based and laboratory-based data to guide decision making for return to the water are scant at this time. However the knowledge base for COVID-19-associated vascular injury in general, and pulmonary-related injury specifically, is growing as research reveals more about the pathophysiology, cellular and molecular events occurring and long-term clinical outcomes. The mechanisms by which these effects manifest as elevated or increased risk for diving activity remain unclear. Establishing direct connections between the effects of diving complications (e.g., DCS, VGE) on the endothelium and abnormalities of endothelial function resulting from COVID-19 can help guide decision making for safe return to diving based on the extent of illness and recovery.

First, the basic functions of the endothelium must be considered. Endothelial cells typically form a confluent cell layer lining the entire vasculature, providing a continuous interface between blood and the blood vessel wall. That interface serves many purposes, including barrier function so that water, proteins, electrolytes and cells are maintained within the bloodstream and are transported across the barrier with physiological regulation. Endothelial cells also have chemo- and mechano-sensing functions, responding to various chemical and mechanical inputs such as nitric oxide signaling or sheer stress that regulate and modulate vasomotor tone and vascular resistance. Other endothelial cell signaling function can trigger thrombotic events or lead to various kinds of immune responses. The endothelium plays a key role in running an incredible physiological balancing act. It maintains stability between vasodilatory function and vasoconstrictive functions, between thrombolytic events and thrombosis, between cell proliferative and anti-proliferative effects, between inflammatory and anti-inflammatory processes, and between oxidant and antioxidant effects, as shown in Figure 1. It has become evident that in COVID-19, there is endothelial injury resulting in cell dysfunction that favors thrombosis,[3-5] inflammatory responses,[6]

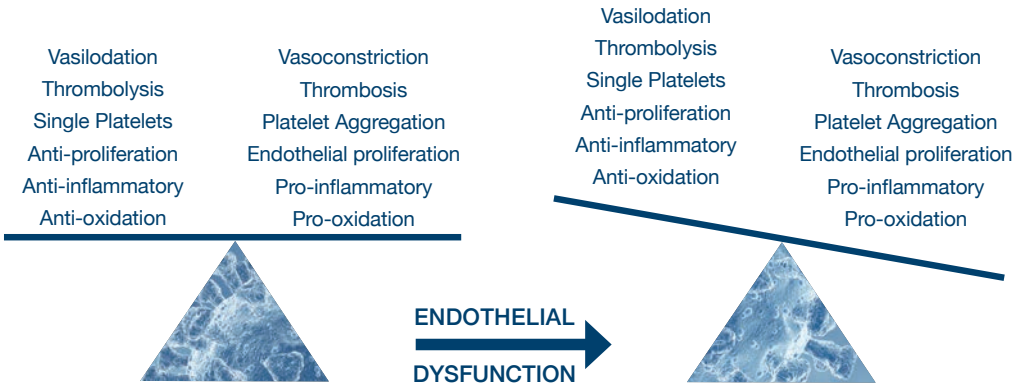


Figure 1.
Effects of endothelial dysfunction on balance of physiological processes.

and oxidative function dysregulation.[1, 7] While it is therefore appropriate to consider COVID-19 to be in large part an endothelial cell affliction, it is also necessary to note that the published literature does not delve very deep into the mechanisms of cellular injury involved in SARS-CoV-2 infection.

Infection and development of COVID-19 occurs via inhalation of virus particles, which attach to epithelial cells on the airway side of the lung. Virus is transferred to the endothelium within the lung microvasculature[1] and is then disseminated in the body. There is a key role of endothelial dysfunction that occurs in the genesis of infection resulting in the release of inflammatory cytokines. This cytokine storm as a marker of the disease itself, but it has additional and profound biological implications. Viral attachment to angiotensin converting enzyme 2 (ACE2)-positive endothelial cells leads to production of reactive oxygen species. As a result, these cells acquire a pro-thrombotic, and pro-inflammatory phenotype, which serves as a hallmark of moderate and severe disease. The cytokine storm drives vascular leak in pulmonary alveolar-endothelial interface, and this promotes lung injury. An apoptotic process involving the ACE2-positive lung microvascular bed follows.[8] It is unknown when or how that stops, or how that heals. With regard to diving, these effects on the lung microvascular bed may enhance or potentiate effects of DCS and VGE. Recognizing that microbubbles occurring with diving are most likely to occur within the venous circulation and distribute to the lung microvascular bed, it is anticipated that this has some implication for how long pulmonary endothelium may remain abnormal despite after symptomatic recovery from disease. This remains unclear. However, one clinical sign that this apoptotic process is occurring is an increase in circulating levels of D-dimer[9], which is part of the endothelial cell induced coagulopathy identified in patients. The endothelial cell damage is also

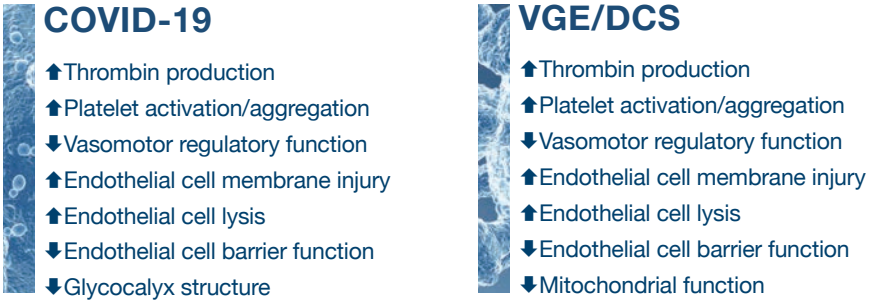


Figure 2.
Effects of COVID-19 and VGE/DCS on endothelial function are similar.

mediated by compliment activation, inflammation, hypoxia, the involvement of platelets, tyrosine kinases. These are all ignited secondary to the cytokine storm. Of relevant concern is how these possibly relate to diving, and diving physiology and post-COVID-19 states and the lung.

The apparent biggest risk to consider in the face of COVID-19 illness and recovery is that of DCS and VGE, even if "bubbling" is occurring as an asymptomatic consequence of diving. Similarities between COVID-19 and VGE/DCS effects on endothelium are indicated in Figure 2. A critical question to be addressed is whether or not the post-COVID-19 lung is a physiologic setup for serious complications of decompression sickness, and/or vascular gas embolism? It is vital to consider if pulmonary endothelial cells manifest any consequences of infection, including potential additional effects associated with decompression stress. If the endothelium does have some dysfunctional aspects resulting from infection, what additional provocation will result from bubbles passing through this microvascular bed in terms of vascular integrity, inflammatory reaction or in terms of any coagulation function? There is strong evidence that gas embolism bubbles promote platelet aggregation[10-11] and thrombin production[12], thus igniting the thrombosis cascade via both mechanisms. If there is an infection-damaged endothelium, there will already be increased thrombin and fibrin production as well as increased platelet aggregation and adhesion, all resulting in enhanced thrombus formation.[3-5] It is reasonable to anticipate that VGE could potentiate underlying COVID-19 effects on thrombosis, leading to worse blood clot-related events in at-risk divers.

Questions: VGE and COVID-19 Endothelium

- What happens to a system primed for platelet aggregation when pro-aggregant VGE bubbles are introduced?
- What happens to a system primed for thrombin production / thrombosis when pro-thrombotic VGE bubbles are introduced?
- What happens to a system primed for endothelial cell membrane injury when pro-stretch injury VGE bubbles are introduced?
- What happens to a system primed for exposure of heparin sulfate molecules participating in VGE bubble adhesion/blood flow obstruction when VGE bubbles are introduced?
- How long might any of these cell/molecular effects persist after apparent recovery from illness?

Figure 3.
Questions regarding VGE and post-COVID-19 diving.

An additional mechanism for increased thrombosis events with VGE in the post-COVID-19 individual relates to endothelial cell membrane dysfunction and cellular destruction. Infection-related membrane dysfunction and associated impairment of barrier function can lead to cell swelling. The endothelium can be more easily disrupted by mechanical forces leading to cell lysis, exposure of underlying basement membrane and resultant thrombotic effects as well as vascular tone dysregulation effects. Passage of gas embolisms through the vasculature also leads to alterations in vascular tone. In vivo experiments have demonstrated the provocation of endothelial cell dysfunction by embolism bubbles.[13] Endothelial cell membrane is also adversely stretched by bubble passage due to a coupling of local fluid mechanical shear stress forces with membrane dynamics.[14-15] This has been identified as one mechanism of cellular injury from

VGE.[3-5] It is also reasonable to anticipate that VGE could potentiate underlying COVID-19 effects on membrane mechanics and vasomotor tone regulation and cause increased cell trauma or death through shear stress events.

Endothelial cells also have, on their luminal surface, the endothelial cell surface layer, or glycocalyx. This structure is less than one micron thick and is a molecular assemblage of proteoglycans and glycoproteins bound to the endothelial cell membrane lipid bilayer. Degradation of the glycocalyx can occur in critical illness, including COVID-19, with biologically active heparan sulfate fragments and other components of the glycocalyx being cleaved and disseminated in the circulation.[8, 16] Endothelial injury in COVID-19 occurs especially in the microcirculation, in which decreases in red blood cell velocity, capillary density and glycocalyx thickness have been noted. Components of the glycocalyx, including syndecan-1, hyaluronic acid fragments, and heparan sulfate fragments, are present in the plasma and signal glycocalyx injury and glycocalyx dysfunction as a result of COVID-19. Circulating levels of both syndecan-1 and hyaluronic acid have been shown to be elevated in patients who required mechanical ventilation, compared to healthy controls.[8] This is important because it relates to loss of vasomotor tone, as mediated by endothelial dysfunction, and other endothelial involvement in the pathophysiology of illness.[17] Previous work with endothelial cells in culture has elucidated the

Questions: DCS and COVID-19

- What happens to a system primed for response to ROS when stimuli provoking ROS production are present?
- Is there an exacerbation of cytokine production occurring in DCS in the post-COVID-19 setting have ?
- Is the post-COVID-19 lung more susceptible to edema and increased leukocyte trafficking?
- Does the post-COVID-19 lung have additional abnormalities of vascular tone regulation or other calcium-related functions in the setting of DCS?
- How long might any of these cell/molecular effects persist after apparent recovery from illness?

Figure 4.
Questions regarding DCS and post-COVID-19 diving.

mechanotransduction of embolism bubble contact via glycocalyx to incite intracellular calcium overload, with calcium release from the sarcoplasmic reticulum, as the cause of loss of vasomotor regulatory function as well as mitochondrial βdysfunction.[18-20] Heparan sulfate, attached to a syndecan-4 molecule is the mechanosensor involved. The fact that heparan sulfate is being cleaved in COVID-19 suggests a possible protection from a VGE-related injury: If there are less heparin sulfate molecules of sufficient length to be able to interact with the bubble surface, then perhaps microvascular bed passage of small bubbles produces less response. On the other hand, syndecan-1 is being shed in COVID-19, which increases the exposure of syndecan-4 and may increase the likelihood of interactions with bubbles to produce injury. This has not been studied, leaving open the possibility that either situation could occur.

Also undetermined is how long might any of the cell and molecular effects described above persist, after apparent recovery from illness. A recovering or recovered patient saying, "I feel fine," doesn't mean that the individual has returned to a baseline state of health. For instance, in terms of DCS and reactive oxygen effects, it is known decompression introduces oxidative stress, and reactive oxygen species formation.[21] These mediate endothelial cell dysfunction, primarily through nitric oxide availability. In COVID-19, the serum levels of nitric oxide are reduced. This implies there is significant oxidative stress. Also, in acute inflammatory states, including COVID-19, excess reactive oxygen species production leads to cellular apoptosis, particularly of endothelial cells. This can activate calcium NFκ-β signaling, and lead to pro-inflammatory cytokine release along with overexpression of adhesion molecules. All these can alter and participate in the adverse responses of endothelial cells, in terms of vascular permeability,

What is Lung Recovery After COVID-19?

- Structural recovery of the lung?
  We know from imaging that structural recovery is delayed.
- Functional recovery of the lung?
  We know from 3–4 month follow-up from hospitalization that functional recovery appears complete after mild/moderate illness but not after severe/critical illness
- Other?
  We don't know much in terms of tissue histopathology, cellular function, organelle status and molecular modification

Does "I feel fine" equal "I'm OK to dive?"

leukocyte adhesion, and glycocalyx function. Overall these considerations suggest that DCS, in the post-COVID state, could potentially be severe.

There are additional serious questions which need to be addressed. What happens to a system that's primed for response to reactive oxygen species when stimulating when stimuli that provoke ROS production are present? Is there an exacerbation of cytokine production occurring in DCS and the post-COVID-19 setting? Is the post-COVID-19 lung more susceptible to edema and increased leukocyte trafficking? Does the post-COVID-19 lung have additional abnormalities of vascular tone regulation or other calcium-related functions in the setting of DCS? There is not yet any evidence to provide answers since such patients have not presented for care, animal models for studying these factors do not exist and cell culture methods and modeling do not readily lend themselves to providing answers. What is not answered is how long any cellular and molecular effects will be present after apparent clinical recovery from illness. While a form of physiologic recovery may have occurred (formerly sick person now feels better), at the cell and molecular levels there may not be the same degree of recovery. For instance, an individual returning to their regular level of exercise does not indicate that cellular and molecular functions have necessarily

Figure 5.
Lung recovery after COVID-19 illness.

returned to pre-illness baselines. A Swiss study examining patients at four months of recovery after COVID-19 demonstrated that those who had a severe or critical illness, but not those who had a mild or moderate illness, had persistent alterations in pulmonary function.[22] Their diffusing capacity for carbon monoxide was markedly depressed, they had a foreshortened six minute walk distance, they desaturated with exercise more significantly, and CT imaging of their lungs demonstrated structural abnormalities were still present. These findings provide information regarding the implications for a deranged lung vasculature that does not exchange gas normally. While the injury from COVID-19 certainly involves aberrations of pulmonary mechanics, this work and other studies[6, 23] do not describe what has occurred involving the vasculature (e.g., there are no biopsy samples to provide histological evidence of vessel alterations).

Hence, what truly is lung recovery after COVID-19? Is it structural recovery of the lung? Imaging[22-23] reveals that structural changes do not resolve very quickly. Functional testing also indicates that return to normal following significant illness occurs slowly. Degree of illness is also a key factor: functional recovery appears to be more complete within four months after mild or moderate illness, but not after severe or critical illness. Might that be uses as a guide in evaluating those who had a mild or moderate illness versus a severe illness in terms of returning to the water? A reasonable starting point is to assess the post-COVID-19 diver for exercise capacity in relation to their normal exercise tolerance. At this time, without further scientific insights regarding tissue histopathology, cellular function, organelle status such as mitochondrial performance, and molecular modification that has occurred as a result of illness, it is appropriate to be cautious when attempting to equate "I feel fine" with "I'm okay to dive." COVID-19 provokes a systemic vascular inflammatory endotheliopathy[24-25] of unknown duration that likely elevates the risks of VGE and DCS. The degree of illness—stratified from asymptomatic to severe—undoubtedly correlates with risk severity. Hence, readiness for return to the water following asymptomatic illness or recovery from mild disease may be appropriate for those whose associated symptoms have resolved and for whom exercise tolerance is normal. However, those whom have suffered moderate illness may benefit from waiting to dive until there is clear evidence that their symptoms have abated completely and that their exercise capacity has returned to baseline. Individuals who have had critical COVID-19 illness, may in fact, never return to the water simply because they may never fully recover a state of pulmonary or cardiovascular function or that will permit safe diving activity. Individuals in the critical illness population may not fully recover a state of underlying vascular health, including endothelial cell health, that permits them to undergo a risk of VGE or DCS. Hopefully availability of additional evidence as the post-COVID-19 literature matures will provide will enable more refined guidance to be provided to those who wish to return to diving after contracting and recovering from the disease.

REFERENCES

1. Teuwen, L. A.; Geldhof, V.; Pasut, A.; Carmeliet, P., COVID-19: the vasculature unleashed. Nat Rev Immunol 2020, 20 (7), 389-391.
2. Huertas, A.; Montani, D.; Savale, L.; Pichon, J.; Tu, L.; Parent, F.; Guignabert, C.; Humbert, M., Endothelial cell dysfunction: a major player in SARS-CoV-2 infection (COVID-19)? Eur Respir J 2020, 56 (1).
3. Rodriguez, C.; Luque, N.; Blanco, I.; Sebastian, L.; Barbera, J. A.; Peinado, V. I.; Tura-Ceide, O., Pulmonary Endothelial Dysfunction and Thrombotic Complications in Patients with COVID-19. Am J Respir Cell Mol Biol 2021, 64 (4), 407-415.
4. Nagashima, S.; Mendes, M. C.; Camargo Martins, A. P.; Borges, N. H.; Godoy, T. M.; Miggiolaro, A.; da Silva Deziderio, F.; Machado-Souza, C.; de Noronha, L., Endothelial Dysfunction and Thrombosis in Patients With COVID-19-Brief Report. Arterioscler Thromb Vasc Biol 2020, 40 (10), 2404-2407.
5. Ackermann, M.; Verleden, S. E.; Kuehnel, M.; Haverich, A.; Welte, T.; Laenger, F.; Vanstapel, A.; Werlein, C.; Stark, H.; Tzankov, A.; Li, W. W.; Li, V. W.; Mentzer, S. J.; Jonigk, D., Pulmonary Vascular Endothelialitis, Thrombosis, and Angiogenesis in COVID-19. New Engl J Med 2020, 383 (2), 120-128.
6. Myall, K. J.; Mukherjee, B.; Castanheira, A. M.; Lam, J. L.; Benedetti, G.; Mak, S. M.; Preston, R.; Thillai, M.; Dewar, A.; Molyneaux, P. L.; West, A. G., Persistent Post-COVID-19 Interstitial Lung Disease. An Observational Study of Corticosteroid Treatment. Ann Am Thorac Soc 2021, 18 (5), 799-806.
7. Kaur, S.; Tripathi, D. M.; Yadav, A., The Enigma of Endothelium in COVID-19. Front Physiol 2020, 11, 989.
8. Rovas, A.; Osiaevi, I.; Buscher, K.; Sackarnd, J.; Tepasse, P. R.; Fobker, M.; Kuhn, J.; Braune, S.; Gobel, U.; Tholking, G.; Groschel, A.; Pavenstadt, H.; Vink, H.; Kumpers, P., Microvascular dysfunction in COVID-19: the MYSTIC study. Angiogenesis 2021, 24 (1), 145-157.
9. Yao, Y. M.; Cao, J. T.; Wang, Q. Q.; Shi, Q. F.; Liu, K.; Luo, Z.; Chen, X.; Chen, S. S.; Yu, K. H.; Huang, Z. Y.; Hu, B. J., D-dimer as a biomarker for disease severity and mortality in COVID-19 patients: a case control study. J Intensive Care 2020, 8 (1).
10. Eckmann, D. M.; Eckmann, Y. Y.; Tomczyk, N., Dose response of surfactants to attenuate gas embolism related platelet aggregation. Heat and Mass Transfer 2014, 50, 323-331.
11. Eckmann, D. M.; Armstead, S. C.; Mardini, F., Surfactant reduces platelet-bubble and platelet-platelet binding induced by in vitro air embolism. Anesthesiology 2005, 103, 1204-1210.
12. Eckmann, D. M.; Diamond, S. L., Surfactants attenuate gas embolism-induced thrombin production. Anesthesiology 2004, 100 (1), 77-84.
13. Zhang, K.; Wang, M. M.; Wang, H. W.; Liu, Y. N.; Buzzacott, P.; Xu, W. G., Time Course of Endothelial Dysfunction Induced by Decompression Bubbles in Rats. Frontiers in Physiology 2017, 8.
14. Swaminathan, T. N.; Ayyaswamy, P. S.; Eckmann, D. M., Surfactant properties differentially influence intravascular gas embolism mechanics. Annals of Biomedical Engineering 2010, 38 (12), 3649-3663.
15. Swaminathan, T. N.; Ayyaswamy, P. S.; Mukundakrishnan, K.; Eckmann, D. M., Effect of a soluble surfactant on a finite sized bubble motion in a blood vessel. J Fluid Mech 2010, 642, 509-539.
16. Yamaoka-Tojo, M., Endothelial glycocalyx damage as a systemic inflammatory microvascular endotheliopathy in COVID-19. Biomed J 2020, 43 (5), 399-413.

17. Suzuki, K.; Okada, H.; Tomita, H.; Sumi, K.; Kakino, Y.; Yasuda, R.; Kitagawa, Y.; Fukuta, T.; Miyake, T.; Yoshida, S.; Suzuki, A.; Ogura, S., Possible involvement of Syndecan-1 in the state of COVID-19 related to endothelial injury. Thromb J 2021, 19 (1).

18. Klinger, A. L.; Pichette, B.; Sobolewski, P.; Eckmann, D. M., Mechanotransductional basis of endothelial cell response to intravascular bubble contact. Integrative Biology 2011, 3, 1033-1042.

19. Sobolewski, P.; Kandel, J.; Eckmann, D. M., Air bubble contact with endothelial cells causes a calcium-independent loss in mitochondrial membrane potential. PLOS One 2012, 7 (10), e47254.

20. Sobolewski, P.; Kandel, J.; Klinger, A. L.; Eckmann, D. M., Air bubble contact with endothelial cells in vitro induces calcium influx and IP3-dependent release of calcium stores. American Journal of Physiology-Cell Physiology 2011, 301 (3), C679-C686.

21. Ranganathan, A.; Owiredu, S.; Jang, D. H.; Eckmann, D. M., Prophylaxis of mitochondrial dysfunction caused by cellular decompression from hyperbaric exposure. Mitochondrion 2020, 52, 8-19.

22. Guler, S. A.; Ebner, L.; Aubry-Beigelman, C.; Bridevaux, P. O.; Brutsche, M.; Clarenbach, C.; Garzoni, C.; Geiser, T. K.; Lenoir, A.; Mancinetti, M.; Naccini, B.; Ott, S. R.; Piquilloud, L.; Prella, M.; Que, Y. A.; Soccal, P. M.; von Garnier, C.; Funke-Chambour, M., Pulmonary function and radiological features 4 months after COVID-19: first results from the national prospective observational Swiss COVID-19 lung study. Eur Respir J 2021, 57 (4).

23. Zhao, Y. M.; Shang, Y. M.; Song, W. B.; Li, Q. Q.; Xie, H.; Xu, Q. F.; Jia, J. L.; Li, L. M.; Mao, H. L.; Zhou, X. M.; Luo, H.; Gao, Y. F.; Xu, A. G., Follow-up study of the pulmonary function and related physiological characteristics of COVID-19 survivors three months after recovery. EClinicalMedicine 2020, 25, 100463.

24. Jin, Y.; Ji, W.; Yang, H.; Chen, S.; Zhang, W.; Duan, G., Endothelial activation and dysfunction in COVID-19: from basic mechanisms to potential therapeutic approaches. Signal Transduct Target Ther 2020, 5 (1), 293.

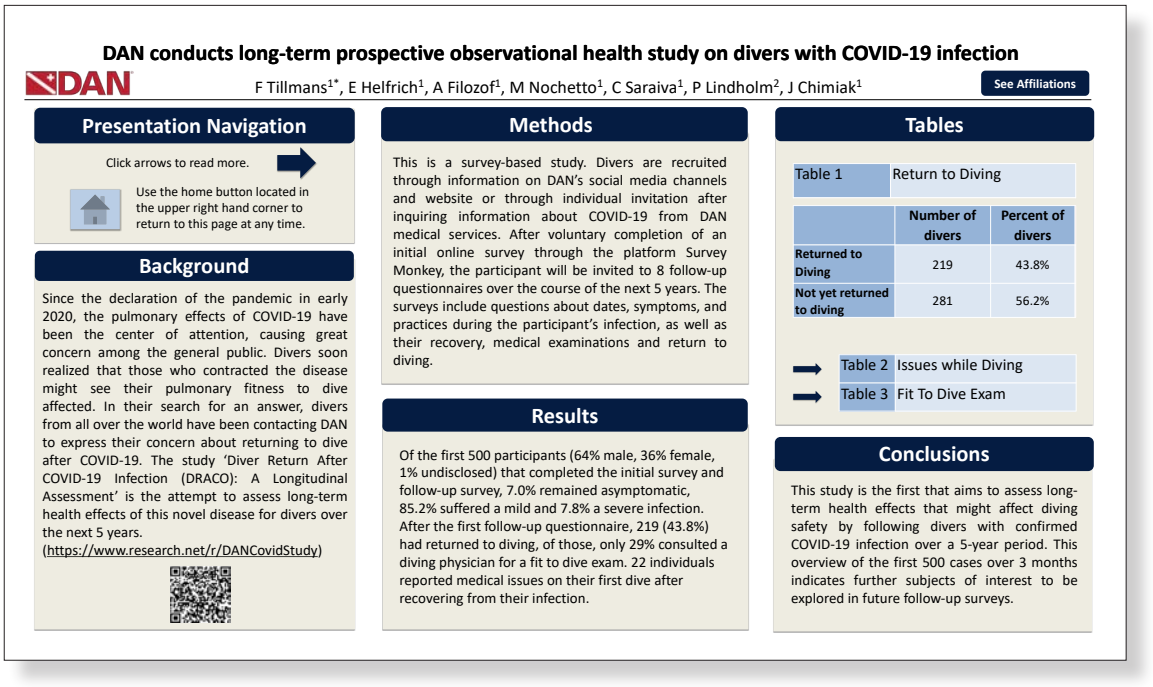
25. Okada, H.; Yoshida, S.; Hara, A.; Ogura, S.; Tomita, H., Vascular endothelial injury exacerbates coronavirus disease 2019: The role of endothelial glycocalyx protection. Microcirculation 2021, 28 (3), e12654.

DRACO: Diver Return After COVID-19

A Longitudinal Assessment

Frauke Tillmans, PhD

In March 2020, a global pandemic was declared in response to the COVID-19. After the immediate shutdown of many countries in efforts to curb the spread of COVID-19, many divers began to wonder what would happen after they caught COVID-19. Initial studies suggested the residual pulmonary and respiratory problems would impact return to diving, even for asymptomatic patients; divers called the DAN hotline for medical information and guidance. In response, DAN Research proposed a 5-year longitudinal study on Diver Return After COVID-19 (DRACO).



DAN conducts long-term prospective observational health study on divers with COVID-19 infection

DAN

F Tillmans[1*], E Helfrich[1], A Filozof[1], M Nochetto[1], C Saraiva[1], P Lindholm[2], J Chimiak[1]

See Affiliations

Presentation Navigation

Click arrows to read more.

Use the home button located in the upper right hand corner to return to this page at any time.

Background

Since the declaration of the pandemic in early 2020, the pulmonary effects of COVID-19 have been the center of attention, causing great concern among the general public. Divers soon realized that those who contracted the disease might see their pulmonary fitness to dive affected. In their search for an answer, divers from all over the world have been contacting DAN to express their concern about returning to dive after COVID-19. The study 'Diver Return After COVID-19 Infection (DRACO): A Longitudinal Assessment' is the attempt to assess long-term health effects of this novel disease for divers over the next 5 years.
(https://www.research.net/r/DANCovidStudy)

Methods

This is a survey-based study. Divers are recruited through information on DAN's social media channels and website or through individual invitation after inquiring information about COVID-19 from DAN medical services. After voluntary completion of an initial online survey through the platform Survey Monkey, the participant will be invited to 8 follow-up questionnaires over the course of the next 5 years. The surveys include questions about dates, symptoms, and practices during the participant's infection, as well as their recovery, medical examinations and return to diving.

Results

Of the first 500 participants (64% male, 36% female, 1% undisclosed) that completed the initial survey and follow-up survey, 7.0% remained asymptomatic, 85.2% suffered a mild and 7.8% a severe infection. After the first follow-up questionnaire, 219 (43.8%) had returned to diving, of those, only 29% consulted a diving physician for a fit to dive exam. 22 individuals reported medical issues on their first dive after recovering from their infection.

Tables

Table 1 Return to Diving

	Number of divers	Percent of divers
Returned to Diving	219	43.8%
Not yet returned to diving	281	56.2%

Table 2 Issues while Diving

Table 3 Fit To Dive Exam

Conclusions

This study is the first that aims to assess long-term health effects that might affect diving safety by following divers with confirmed COVID-19 infection over a 5-year period. This overview of the first 500 cases over 3 months indicates further subjects of interest to be explored in future follow-up surveys.

Figure 1: Published results from first 500 participants

The initial goal of DRACO was to enroll 1,000 divers who had confirmed or suspected cases of COVID-19 and ask them to fill out surveys detailing their medical history, COVID-19 infection, post-infection health, and return to diving. After the initial follow up questionnaire, about 20% of participants dropped out; the enrollment was then raised to 1,200 divers. This precourse presentation details results from the initial enrollment for the first 1,000 participants.

This study is purely observational, and currently unfinished. These are just preliminary results and we have not yet published any papers detailing the results from DRACO. These preliminary results are meant to be thought-provoking, but inconclusive until more data can be collected and analyzed.

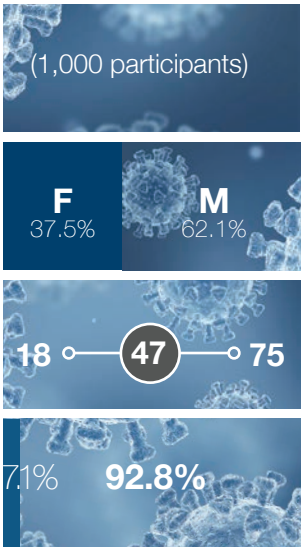


Figure 2:
Demographics —
self-reported

INITIAL SURVEY (SIGN-UP)

Any diver with a confirmed or suspected COVID-19 infection and who intended to return to diving was eligible to enroll in DRACO. While many later participants had confirmed COVID-19 infections, there was a notable testing shortage early in the pandemic, so several participants isolated and proceeded believing they had COVID-19, but unconfirmed. All participants enrolled by completing the initial survey through the HIPAA-compliant platform Survey Monkey. The initial survey took 10–15 minutes to complete with an average of 11 minutes.

The survey begins by asking about participant demographics and background. This information includes weight, height, lifestyle, tobacco use, medical history, and dive certification and experience. The survey then moves to COVID-19 infection—specifically dates and descriptions of symptoms and tests, severity of infection, recovery, and self-described exercise capacity.

The second part of the initial survey covers post-COVID-19 infection, return to diving, and fitness to dive exam. Participants are first asked about any residual or new medical conditions, then return to diving. In return to diving, there is room for the participants to describe what their return looked like—how long after their infection was their dive, was it a decompression dive, multiple dives on the first day, how many dives total, and issues on any of these dives. If participants reported issues in dives, they were primarily pulmonary in nature, such as wheezing or coughing, dyspnea, or shortness of breath.

The most interesting initial results were with participants' fitness to dive examinations (FTD exams). Participants could self-report that they had gotten a FTD exam, planned to get a FTD exam, or did not plan to get a FTD exam. From those who had gotten a FTD exam, they would then be asked about the examinations their physician performed, results, any residual conditions, and if members of the DAN team could reach out to get copies of and further discuss test results.

FOLLOW UP QUESTIONNAIRES

There are a total of 8 follow up questionnaires planned at one month, three months, six months, one year, two years, three years, four years, and five years after the initial enrollment. At this time, follow up questionnaires one through three have been sent to eligible participants.

All follow up questionnaires begin with asking participants if they were willing to continue the survey, and then to input the same identifier as in the initial study. The next question to all surveys is to ask about any updates since the previous survey—most participants have none to add. Follow up questionnaires are quite similar in that they ask about changes to weight, smoking habits, COVID-19 diagnosis (tested, retested, or possibility of reinfection), medical conditions, and diving participation. Like the first survey, participants then self-reported their recovery, exercise capacity, return to diving and issues with return to diving, and FTD exam.

RESULTS

Results from the first 500 participants were presented at the 2021 UHMS annual scientific meeting (Figure 1).

Since the submission of this poster, enrollment hit 1,000 participants. Accordingly, these demographics are outlined in Figure 2.

From the first 1,000 participants, 37.5% are female and 62.1% are male. The average, as well as the median age is 47 years with a range from 18 to 75. 92.8% of participants are non-smokers; only 7% report that they do smoke. Previous medical conditions seem to be fairly consistent with normal population data with 3.6% sleep apnea, 2.4% diabetes, and 1.3% cancer.

Obesity with 4.4% seems low in comparison, however, for self-reported data this is not surprising.

Of high interest with this study was looking at the severity of infection within the diving population, shown in Figure 3. 6.2% of patients were asymptomatic and 6.1% had a very severe outcome, defined as requiring hospitalization. About 11 cases total were in the ICU and ventilated. Of these 1,000 participants, 61% felt fully recovered when they signed up for the study, and 40% had consulted a physician sometime during the infection or right after. However, 8%, or 80 participants, reported residual pulmonary issues. 13% reported residual medical issues resulting from COVID-19.

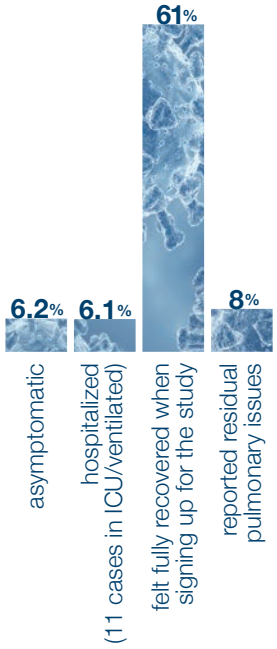


Figure 3:
Severity of COVID-19 infection (1,000 participants)

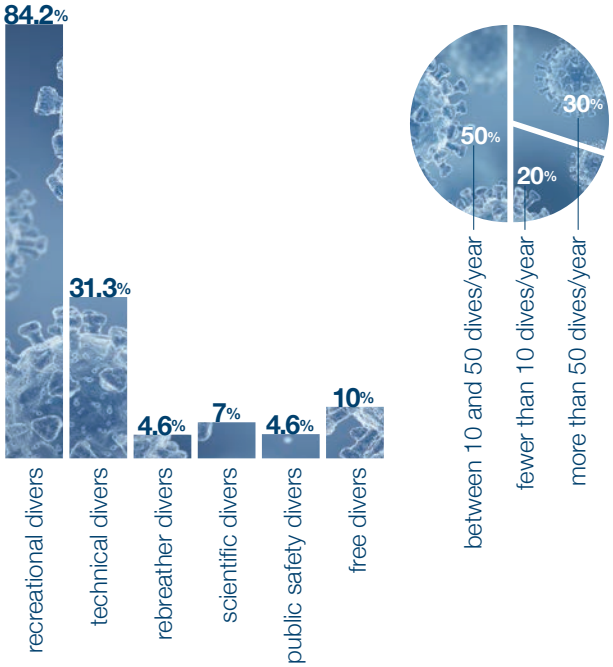


Figure 4:
Dive history (experience and frequency) of first 1,000 participant (on average 14 years certified)

From the dive history, there is a slight discrepancy between the average population of divers and those enrolled in the study. Although 85% recreational divers is about accurate, there are about 31.3% technical divers, including all divers with some type of technical rating, 4.6% rebreather divers, 7% scientific divers, 4.7% public safety divers, and 10% free divers. The free diving population is likely biased by two organizations' training agencies that massively supported DRACO and helped share information. It is also not a surprise that technical, scientific, and public safety divers would be more apt to follow DAN and enroll in the study, leading to higher numbers of those divers in the study. This slight skewing of data from dive professionals and the technical, scientific, and public safety diving communities is also why the average experience is a bit higher at 14 years, although participants had experience that ranged from beginning diving after their COVID infection to 55 years of certification.

As this is an active study, new data was continuously collected through follow up surveys until about a week prior to the DAN/UHMS precourse. Of greatest interest here is the updated return to diving and FTD exam information presented in Figure 5.

Preliminary Data

(1,000 participants *including follow-up surveys until May 31st, 2021*)

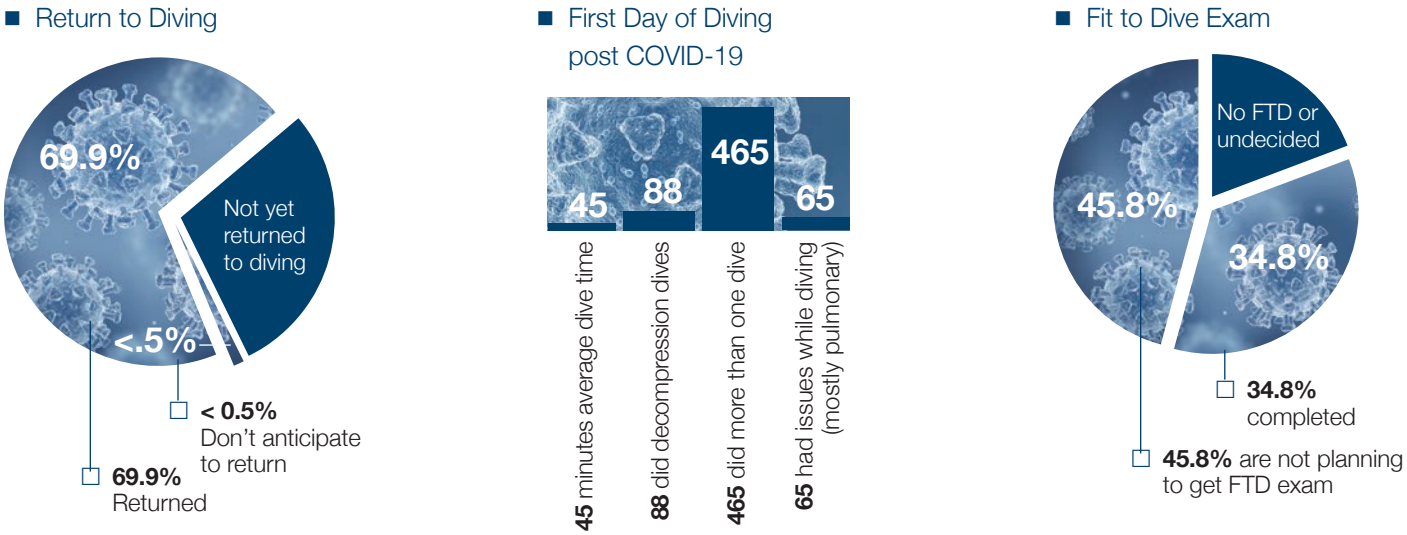


Figure 5: Preliminary return to dive and fitness to dive examination results from the first 1,000 participants

Until 31 May 2021, 699 participants (69.9%) reported return to diving. Under 1% of participants do not anticipate returning to diving, with causes both related and unrelated to COVID-19. On average, the first dive was 45 minutes long. Despite the recommendation to begin with a refresher dive or a check-out dive, 88 of the 699 divers did dives with mandatory decompression, and 465 divers did more than one dive. Almost 10% of divers had issues while diving, primarily pulmonary. After enrollment of 1,200 participants, these issues on return to diving are something that will be closely examined with potential correlation to severity of illness or hospitalization.

Until 31 May 2021, 34.8% of participants completed a FTD exam, and 45.8% are not planning to get a FTD exam. Those who are not intending to get a FTD exam include participants with severe outcomes and progressions of their infection. From the 348 FTD exams, seen in Figure 6, there should have been 123 chest x-rays; however, participants have either been unable to access their results or unable to send the results to the DRACO team. This issue is consistent across all tests. Some tests, like the chest x-rays, pulmonary function tests, and exercise stress tests may also have been so prevalent due to the mandate for scientific divers and aquarium divers to have yearly examinations. Also notable is that 44 divers were not cleared to dive, which is more than 10% of the participants who had FTD exams; not all divers plan to return for re-evaluation.

FUTURE FOLLOW UPS

Follow Up Questionnaire 4 is now planned, including questions on vaccination status and if applicable, vaccination information, side effects, re-infection, and impact on dives. Once more, all of this information is purely observational and individual in nature and will be factors to consider when analyzing the completed data set.

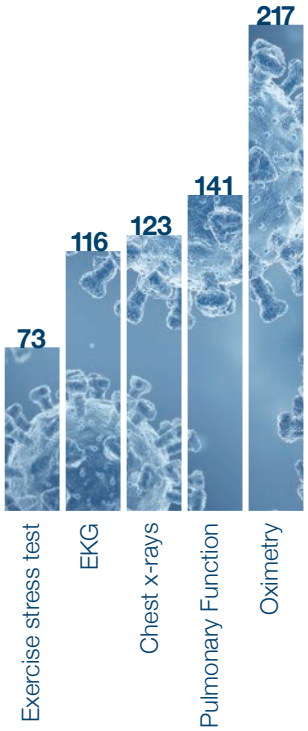


Figure 6:
Fit to Dive Exam tests performed (348/1,000 participants)

Diving After COVID-19–UCSD Algorithm

Charlotte Sadler, MD

Well, first of all, thank you so much for having me. It's an honor to be here and it's always a bit of pressure speaking at the end of the day after a lot of really great speakers. But I think the good news is that all of our lecturers have been fairly complimentary to each other.

As Dr. Chimiak mentioned, I have no disclosures to make. But I want to start off by acknowledging my colleagues ((Ian Grover, Tom Neuman, Karen Van Hoesen, Miguel Villela Alvarez, Michael Lang, and Peter Lindholm) who helped develop these guidelines; they were definitely a joint effort. We have also been given some grant funding by UCSD and by PADI to help research putting these guidelines into place.

I'm going to give a brief introduction to these guidelines. I am certainly not going to go through an exhaustive list of the challenges to diving medicine from COVID. We've heard all about that, and in different degree of detail this morning. The other speakers have all done a much better job than I could do, but we'll go over just a brief summary. I'm going to walk you through the process and give you some insight into how we developed our guidelines and what we've done with the implementation of our guidelines. If we have time, we'll take us through a case from our dive clinic. And then at the end, I want to touch on some of the unanswered questions, which unfortunately, there are many, as we have seen today.

To give you a brief background about myself, I work at UCSD. I have a background in emergency medicine and hyperbaric medicine and I'm currently practicing in both spectrums: I am in the ER and I'm also at the chamber. Which made for a very interesting COVID experience, because you can see this lecture is going to be mostly about my experience with my divers, but we also saw quite a bit of COVID in the emergency room. I am the program director for our fellowship here at UCSD and I also work at our dive clinic. The UCSD dive clinic is a really unique space and I am very fortunate to work there with Dr. Van Hoesen and Dr. Grover. We see a mix of recreational, scientific and commercial divers. As for the spectrum of our divers: for many of them, we see them for their yearly physicals. Sometimes they come to us after they've had an acute injury or illness and then we also see recreational divers who may have a fitness to dive question, or are following up after a diving injury. It was with our dive clinic and with our divers in mind, that we actually developed and wrote our guidelines.

I'm going to give you a little bit of a backtrack to February, March of 2020. This is what I call blissful ignorance. These are actually real pictures of my vacation in Hawaii with my family right before COVID really hit the fan. This was the end of February 2020, and we were all very happy and had just started hearing about COVID, but I think were still in this somewhat ignorant mindset of "that's probably not going to be a problem that we're going to have to deal with." Until I flew back to San Diego on March 1st and within the next 10 days we started seeing headlines like this and that little spiky protein became very, very familiar to all of us. This is one of the

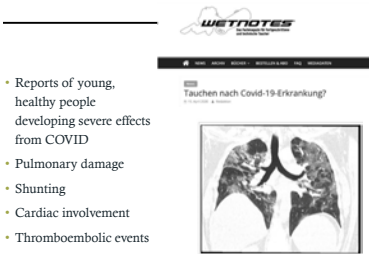


Figure 1.

The Problem

- Reports of young, healthy people developing severe effects from COVID
- Pulmonary damage
- Shunting
- Cardiac involvement
- Thromboembolic events

wetnotes.eu/tauchen-nach-COVID-19–erkrankung/

headlines that was in the newspapers and I thought, "Yeah, that pretty much sums up how we felt by the end of March, but by that point we were in lockdown."

I think I'm the third lecturer today who has brought up this article, which is funny. This physician probably never realized that he was going to get so much press about a single blog post. But I think this is one of the things that really spiked a lot of panic, for lack of a better word, about going back to diving. This was a physician in Germany who published a blog post essentially saying, "Look, I'm seeing these really sick young divers, they have horrible looking CT scans and even after they've fully recovered, they're still have hypoxemia. They still have terrible imaging and they're never going to be able to dive again." And of course that was scary for all of us.

On a macro level, I was thinking, "What's going to happen to our emergency department? What's going to happen to my colleagues and my family and the world?" And then a smaller level I'm thinking, "What's going to happen to our divers and what are we going to do in dive clinic? Because if this is true, people are never going to be able to dive again after they get COVID-19." And there were lots of reports of pulmonary damage, shunting, cardiac involvement, and I'll go through all of those things again, but this is really when we started to really think, " A, what are we going to do? And B, are these people going to be out of diving forever?" So fast forward about a month and we got to the point, at least here in San Diego, and in the United States in general, that we realized that it was inevitable that our divers were going to get COVID-19.

This was no longer an epidemic that was not going to reach our region or our country. It became quite clear that we were going to have to deal with this. And we really had two questions. The first question was, can you ever return to dive after COVID-19? And that was a real question. I think someone earlier mentioned that there was a thought at the beginning that people were not going to be able to serve in the military after they had COVID-19. And again, we've learned a lot since that time, but I'm trying to take you back to the head space of where we were when we developed these guidelines. And the answer to this was, we thought, "Hopefully, and probably yes, but if so, how are we going to do this safely?"

THE CHALLENGE: CAN YOU RETURN TO DIVE AFTER COVID 19? IF SO, HOW DO WE DO THIS SAFELY?

Our goal was to develop a set of guidelines that would screen divers who had had COVID-19 for specific medical conditions that may prevent them from returning to diving safely. We wanted them to be both sensitive and specific to a degree. We joked about this, if we wanted to make guidelines that were a hundred percent sensitive, they'd be very easy to make. You would just say, "No one who has had COVID-19 could ever dive again." But that's not what we wanted to do. We wanted people to get back in the water if they could. I'll fully admit that the authors of these guidelines are a little bit biased because we're also all divers and so we wanted to make sure that we'd be able to get back in the water if we had COVID-19. But mostly, we realized that we were serving a population where diving isn't just a recreation or a hobby, but this is also their livelihood. We wanted to make sure that we were keeping them safe, but also getting them back in the water if they could.

There were also other factors involved. The first was cost. As I mentioned, we see a variety of divers in our clinic. We have scientific and commercial divers where (for the most part) their organizations or their businesses will pay for their workup at the dive clinic, but which also means that, they have a financial interest and we are limited in how much testing we're going to order. We have recreational divers who sometimes pay out of pocket. Sometimes their insurance will cover some of the things that we order, but we are very cognizant of the fact that we could not be ordering exorbitant, cost-prohibitive workups because they were not going to be able to get them done. Secondly, we were challenged by testing availability. In the beginning, part of this was testing for COVID-19. As Frauke mentioned in her talk, they are including some people in their study who had suspected COVID-19, because, especially at the beginning of the pandemic, you couldn't get a COVID-19 test unless you were very ill. There were some people who we were not sure if they had COVID-19, but we were going to presume that they had COVID-19.

We also had to consider testing availability for clearance and this was really impacted by a couple of things. One, there was and is limited availability at clinics and hospitals. Especially at the beginning, we had a lot of ambulatory clinics and testing centers shut down. We were very lucky, we did not shut down our dive clinic, but we did have limitations. In fact, we're still not doing pulmonary function testing in our clinic like we used to do. We now have contracted with the hospital and some other clinics to outsource that, but it's really limited how much pulmonary function testing and spirometry we can do right now.

There's also limitations, again, for things like exercise testing. We do not have a treadmill in our office. We don't have the ability to monitor someone on a 30 minute exercise test. These are all the things that we had to consider when we were making these guidelines. And then I know everyone is really sick of this phrase, but it was a novel infection and at that point we still didn't really know what we were dealing with. At the beginning, there was just a lack of evidence and I think we were all very hungry to read every single paper published on COVID-19. That quickly changed and it turned into a lack of good evidence. Very quickly there was a high volume of evidence and a high volume of literature, but it was very hard to sort through and actually find high quality evidence.

Now I think we're at this point, and this is getting better too, but there is a lack of good evidence on mild disease. And that makes sense. People, one, I think have an interest in severe disease because a lot of people got severe disease. Two, it is much easier to study inpatients or post discharge patients than it is to study people who either A, never went to the hospital and never really had a lot of interaction with the medical system, or B, people who are outpatient the whole time. And that's something that's actually still a challenge because statistically speaking and especially for our divers, most of them were outpatients. Most of them did not have severe disease and so trying to find good evidence to base and revise our guidelines on, good evidence for those with mild disease, is still really challenging to find.

As we were developing these guidelines, we asked the question, "What specific challenges did COVID-19 pose to divers?" I think the first one is obvious—this was the pulmonary challenges. As we've heard earlier today, I'm not going to rehash all of the pulmonary effects of COVID-19, but it's generally the primary mechanisms of infection. We were concerned that there could

Pulmonary

- Primary mechanism of infection
- Chronic changes?
- Air trapping
- Pulmonary Fibrosis
- Shunting Physiology
- "Happy Hypoxemics"

Figure 2.
Chest x-ray of diver with COVID-19

potentially be chronic changes (and I will use the word chronic loosely because I don't think we really know the timeline of these changes yet) and whether or not they are truly chronic or permanent. We were concerned that people may develop structural changes that would predispose them to air trapping. We were concerned that they could develop changes that would put them at risk for a fibrotic disease. We were concerned that they were going to be developing shunting physiology and problems with gas exchange.

We were also very concerned about the cardiac complications of this disease, quoted anywhere between 8–28%. Again, this is where I see the quality of literature at the beginning of this pandemic and when we were trying to write these guidelines was mixed. You were hearing and seeing variable reports of how much cardiac involvement there was, but this is really scary for us and it's really scary for divers. One of my particular interests is cardiovascular disease in divers and we were very concerned about what this could potentially mean for divers after they recovered from COVID-19.

Lastly, we were focused on the thromboembolic effects. And it seems very clear back then and still to this day, that COVID seems to produce a hypercoagulable state. And I think that even by now when we know that as a fact, I think the question still remains, "How long are you hypercoagulable? Is this permanent damage? Is this semi chronic damage?" I don't think we really know. And, "Does this increase your risk of decompression sickness?" And I think the answer to that is still unknown. Even though we faced these challenges, we still felt that we needed to develop guidelines. We realized that we were going to be faced with these divers in our clinic. We wanted to be uniform in our practice and as a clinic about how we were approaching them. We wanted to be methodical about it and do the best that we could with the best evidence that we had.

GUIDELINE DEVELOPMENT

Recognizing that we had fairly limited evidence and fairly limited literature on COVID-19 at this point, we decided to look back at similar conditions and draw from them to help develop our guidelines. We looked at MERS and SARS which were two most recent respiratory illness pandemics and are both Corona viruses. We found that both of these illnesses had fairly high rates of long-term morbidity. In some papers, it was quoted that up to a third of MERS patients developed pulmonary fibrosis. We were concerned and went through the literature for evidence on some similar conditions and drew what we could from that. And as you also heard in someone's earlier talk, there's actually not a ton of fitness to dive evidence-based literature. There are a lot of expert consensuses, and there's a lot of things that have been put together and advice that we give based on what we believe to be theoretical risk, but as far as evidence, it's pretty lacking.

We published the guidelines on our website at UCSD in May 2020. And then we put them out again, and this time as part of a larger review article, in Diving and Hyperbaric Medicine in September 2020. The reason that we published these is that we intended them to be an aid if needed to other practitioners. They have been subsequently adopted by some organizations. ADCI and AAUS are both using these, which has been great, and makes our life a lot easier at our clinic. And actually I'm glad to hear, I think these have been adopted and used by a lot of different people. Some of those texts may actually seem familiar to you because Dr. Ebersole was quoting

it in his talk earlier. And it's good to know that they're being used down in Florida as well. It always makes me happy that some of the work that we did would be able to be used by other practitioners.

The goals of these guidelines were to try and balance safety with cost and capability, and also taking into consideration the risk of incidental findings. We are very cognizant of the fact that if we do extensive testing on every single diver, we are going to find incidental findings that may disqualify them from diving, or at least disqualify them from diving as a career. We wanted to be cautious about that and not go looking for things that we didn't need to. As I mentioned, we initially started by categorizing our divers by severity of initial illness. This is a table taken directly from our article, which I have cited at the bottom if anyone is interested, it's open access on PubMed. But this is it broken down just in a text format.

Category zero are the people who had no history of COVID-19. These are our divers who are coming to our clinic for their regular physical or those who had an incidental positive test, probably on either an employee screen or a school screening, but never developed any symptoms—and we really made sure that they never had any symptoms.

Category one we described as mild and these are people who were outpatient, did not require oxygen, and if they had a chest x-ray, it was normal, or they didn't even require chest imaging. The reason that we added and clarified no oxygen there is that normally in a respiratory illness, if you required oxygen, you would automatically get admitted to the hospital. During times of resource scarcity, some of which we reached here in surrounding areas of San Diego and certainly reached in New York and other parts of the world, people were getting sent home on oxygen, so that's why there was a special clarification in that category.

Category two, we described as moderate disease. This is anyone who had an oxygen requirement and a non ICU hospitalization. There's more details about these categories in the paper, but these are just the basics.

Category three we described as severe. This was anyone who ended up in ICU, anyone who had any documented cardiac involvement or thromboembolic disease. I would also add in category two for the moderate, this would also be outpatients who had any abnormalities on their chest x-rays.

Based on their initial category of illness, we then subsequently developed guidelines from what we thought their workup should be post COVID-19. There was a couple of points that I wanted to emphasize. The role of these guidelines was to be used on recovered, asymptomatic divers. This was really important and it's still really important in using these guidelines; they are not for the people who were still symptomatic and they are not for people who are acutely ill with COVID-19.

These were the people who came to my clinic and said, "Hey, I had COVID-19. I'm fully back to baseline. Clear me, I want to go back to work."

The other thing that's a really important caveat in these guidelines is the emphasis on a normal exercise tolerance. And for our divers, this meant two things for us. One, it meant that they

Cardiac

- Autopsy series with myocyte necrosis, lymphocytic infiltration
- Elevated troponins and BNPs
- cardiac involvement initially reported in 8–28%***
- Dilated right ventricles


ESC RESEARCH LETTER

The ACE2 expression in human heart indicates new potential mechanism of heart injury among patients infected with SARS-CoV-2

Liang Chen, Xiangjie Li, Mingquan Chen, Yi Feng, and Chenglong Xiong

Review J Am Coll Cardiol. 2020 May 12;75(18):2352-2371. doi: 10.1016/j.jacc.2020.03.031 Epub 2020 Mar 19.

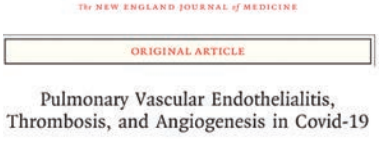
Cardiovascular Considerations for Patients, Health Care Workers, and Health Systems During the COVID-19 Pandemic

Figure 3.

Cardiac

Thromboembolic

- COVID seemed to produce a hypercoagulable state
- Many case reports published of particularly high incidence of DVT/PE, as well as microthrombi on autopsy
- Also raised questions about increased risk for DCS


The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Pulmonary Vascular Endothelialitis, Thrombosis, and Angiogenesis in Covid-19

Figure 4.

Thromboembolic

UC San Diego Guidelines for Evaluation of Divers during COVID-19 Pandemic

Recommendations for evaluations of divers or diving candidates. Recommendations for evaluation are based upon the divers' severity of COVID-19 suspected illness (see Table 1). If results are unknown or unavailable, recommendations are for more extensive cardiac and pulmonary evaluations. BNP=brain natriuretic peptide; CK-MB=creatine kinase MB fraction; CT=computed tomography; ECG-electrocardiogram; PA=posterior-anterior; RSTC=Recreational Scuba Training Council. *If there is doubt that the diver's self-reported exercise level meets appropriate criteria or concern it would not reveal underlying cardiac or pulmonary disease, further testing is warranted.

CATEGORY 0 NO history of COVID-19-suspected illnesss	**CATEGORY 1** MILD COVID-19-suspected illness	**CATEGORY 2** MODERATE COVID-19-suspected illness	**CATEGORY 3** SEVERE COVID-19-suspected illness
■ Initial/periodic exam per professional group or RSTC guidelines. ■ Chest radiograph only if required per professional group or RSTC guidelines. ■ No additional testing required.	■ Initial/periodic exam per professional group or RSTC guidelines. ■ Spirometry. ■ Chest radiograph (PA and lateral); if abnormal, obtain chest CT. ■ If unknown (or unsatisfactory) exercise tolerance*, perform exercise tolerance test with oxygen saturation.	■ Initial/periodic exam per professional group or RSTC guidelines. ■ Spirometry. ■ Chest radiograph (PA and lateral); if abnormal, obtain chest CT. ■ ECG ■ Echocardiogram (if no work up was done as an impatient. Can forgo if had negative work up). ■ If unknown (or unsatisfactory) exercise tolerance*, perform exercise tolerance test with oxygen saturation. ■ Investigation and management of any other complications or symptoms per provider and professional group or RSTC guidelines.	■ Initial/periodic exam per professional group or RSTC guidelines. ■ Spirometry. ■ Chest radiograph (PA and lateral); if abnormal, obtain chest CT. ■ ECG ■ Repeat cardiac troponin or CK-MB and BNP to ensure normalization. ■ Echocardiogram. ■ Exercise Echocardiogram with oxygen saturation. ■ Investigation and management of any other complications or symptoms per provider and professional group or RSTC guidelines.

Figure 5.

UC San Diego Guidelines for Evaluation of Divers during COVID–19 Pandemic

Sadler C, Alvarez Villela M, Van Hoesen K, Grover I, Lang M, Neuman T, Lindholm P. Diving after SARS-CoV-2 (COVID-19) infection: Fitness to dive assessemnt and medical guidance. Diving Hyperb med. 2020 Sep 30; 50(3):278-287.

Note: guidelines to be used on divers who have recovered from COVID-19 and are now asymptomatic and returned to baseline exercise tolerance

had the same level of pre-illness exercise tolerance. We have divers in our clinic who are in extraordinarily good shape; they were running marathons before their illness. If after their illness, they can only run 10 miles, although that's probably an adequate exercise tolerance for diving normally, that's a significant change from their pre-illness exercise tolerance. That's a red flag and something that'll trigger further testing.

The second caveat is that their pre-illness exercise tolerance is adequate for diving safely. Because on the other end of the spectrum, I have patients who are recreational divers and they don't exercise. Diving is their exercise and their pre-illness exercise tolerance was walking around the block. That's inadequate for judging if someone has an adequate exercise tolerance for diving, so that also would trigger further workup, even if they were back to walking around the block. For us, the minimum workup post COVID-19 was a good physical exam (so we are seeing all of our divers in person in our clinic), a PA and lateral chest x-ray, and pulmonary function testing. And the reason that I have an asterisk over the pulmonary function testing is that this may seem to you that this was probably very similar to a yearly exam, which would be true. However, most of the dive clinics, including ourselves, are actually deferring PFTs and audiograms this year and will resume them next year. So this is an exception, and this is for people who've had COVID-19. We are mandating that they have PFTs before we clear them to go back to dive.

There are some things that the guidelines don't have and questions that are still unanswered. We do not specify time intervals for evaluating patients or "mandatory time out of the water." Based on the fact that people have to quarantine before we are seeing them in clinic, we generally have a minimum of two weeks from people having illness before they actually come to see us, and most of the time it is actually quite a bit longer. We also have not addressed a mechanism for evaluating patients with persistent symptoms. We have not discussed a prescriptive exercise test. In our category twos and threes, we do talk about doing an exercise tolerance test with oxygen saturation and a further cardiac workup, but we have not defined a satisfactory exercise test .The reason for that is that one, we don't do the exercise testing ourselves. We actually refer that out to the exercise testing lab at our university. And this was meant to be a guideline that other people could also use at other institutions. We recognize that exercise testing varies between sites. We also did not give a definition of satisfactory exercise tolerance. We we see quite a variety of divers at our clinic and some of that has to be defined by the type of diving they are doing. It's going to be quite different for our commercial diver versus someone who's doing only warm water recreational diving.

Guideline implementation: as you can see here, at least in San Diego, we really did not get our spike in COVID-19 cases until quite late-end of 2020 and early 2021. During most of 2020, we were actually quite lucky, which also meant that our divers for the most part did not really get sick until the end of 2020. In the last few months, we are seeing an increase in divers back who are recovered from COVID-19 and want to go back to diving. We've had 12 patients present so far. Most of our patients have had very mild disease. We've had one person who had a moderate illness and was hospitalized. That's his chest X-ray on the right, at the top, in is his initial illness. (Figure 7) And then at the bottom there, that's his follow-up chest X-ray, which you can see actually does still have some persistent abnormalities and some scarring in his lungs. Two of our

What the guidelines don't have

- Specific time intervals for evaluating patients or mandatory time out of the water
- Mechanism for evaluating patients with persistent symptoms
- Prescriptive exercise test
- Definition of "satisfactory" exercise tolerance

Figure 6.

What the guidelines don't have

divers have had abnormal spirometry and both had mild disease and felt they were asymptomatic. This is another reason that we are continuing to do spirometry on all of our patients.

The good news is that most of our divers were able to continue diving safely throughout the pandemic—we have a lot of divers who are diving for their livelihood. We take care of a lot of the divers who dive for the US Navy Marine Mammal Program. You can see them playing with our dolphins and our sea lions in the San Diego Harbor. They've had some changes with their safety protocols, but they've really been able to stay open and keep diving throughout this pandemic. For the sake of time, I'm going to skip this case. I encourage all of you who are listening to come to the plenary session on Friday. I'm going to be part of a panel with Dr. Lindholm, and a few others, and we're going to be discussing some actual cases. And so I'm going to save that case for then, just for the interest of time. And just skip ahead for a sec here.

Figure 7.

Chest x-ray of a diver during his acute COVID 19 illness and with residual scarring on his follow up x-ray four months later.

As I said, there are still a lot of unanswered questions. We did not address all of the organ systems in our guidelines. As Dr. Weaver brought up today, there are some persistent symptoms and other organ systems impacted, such as the neurologic symptoms that we have not given guidance on. We also have not given guidance on how you deal with long COVID-19 or people who are having symptoms. I think the question really remains, "How are you counseling divers that have ongoing lung damage?" Especially those who are recreational divers. I think it's a little bit easier when you have guidance from a professional society, and you can say, "Listen, you don't meet criteria to be a commercial diver." It's very different when someone is already a certified recreational diver and they want to go back. A lot of those conversations have really turned into risk/benefit and risk mitigation conversations. We have not talked about how soon after having COVID-19 you should assess a diver or how often you need to reassess them.

In conclusion, I think what we've seen with our guidelines is that changes in PFTs and chest imaging can be seen even after mild disease. And caveat, this can be seen in mild disease that is not COVID-19. So you see changes in PFTs as people with other viral respiratory illnesses, such as influenza or the " common cold." I don't really think it's clear if there's such a significant, higher incidence in COVID-19. I think there may be, but we don't know, but because of that, we are continuing to be conservative and we're recommending PFTs to all of our patients. I think again, the chronicity and permanence of some of the changes that we're seeing, we just don't know. As Dr. Lindholm mentioned in his talk, I think it's encouraging that there have been some changes that have been seen on people's CT scans post COVID-19 that have seemingly resolved and healed. So when counseling patients and looking at these changes, I can't tell them that this is going to be permanent.

The implications of what they mean on fitness to dive is a separate question that is also still unanswered. The good news is that I think a lot of divers are going to be able to return to dive safely after COVID-19, which is fantastic. And I think as other people have mentioned, returning to a good baseline exercise tolerance is really going to be key for evaluation of these divers. It's still really the lynchpin of our guidelines and something that we really emphasize when we're talking with our patients and evaluating them. So with that, I will open it up to questions. That's my contact information. So if anyone would like to reach out or has further questions that we don't get answered today, I'd be happy to talk.

DISCUSSION

Bob Sanders: I follow ADCI/UCSD guidelines to perform PFTs on all divers as you recommend. Yet in most of the earlier presentations, PFT seemed to be missing from the recommendations, although the only abnormality we found was in the PFTs. While I agree with the recommendation, would modify it now or do you feel your guidelines still hold?

Dr. Sadler: I still feel that the guidelines hold as recommending pulmonary function tests, and I'd be happy to discuss that with other people because maybe other people have different opinions. I also think, one thing that some of the other people have put up, for example the military, which I think is quite impressive, is that they are actually exercise testing all of their divers. And I think some of this is also just based on the fact that, what do you have available? I cannot exercise test all of my divers in clinic. I do not have the ability to do that. Is there equal sensitivity between exercise someone and doing pulmonary function tests for detecting any sort of abnormality? I don't know. My suspicion is probably not. I think you're looking for slightly different things. But at this point we are still recommending pulmonary function tests. And to Dr. Weaver's point, so we're doing FEV, FEV-1, FVC ratios. We also are recommending DLCO. Again, some of these, it's funny working in a clinic where you see scientific commercial and recreational. Sometimes you make recommendations and sometimes they're ordered by the company, sometimes they're ordered by primary care doctors and you can make recommendations and then they still choose to order something different. All we can say is, we give our best advice.

Dr. Weaver: Do we have any advice for the patients with brain related symptoms?

Dr. Sadler: That's really tough. I don't have great advice for that now. Dr. Lindholm actually, who's on the call, maybe you can speak to this more. We're actually going to be trying to start a study here at UCSD for hyperbarics in post COVID-19 and long COVID-19 symptoms. So that may be potentially an option. But other than that, I don't have great specific advice for that.

Concluding Remarks

Jim Chimiak: Let's begin discussion of today's presentations and establish some definitions before we discuss specific actions for the asymptomatic diver who has fully recovered from a COVID-19 infection. First, the degree of acute infection impacts the subsequent investigative action. For instance, that action could include the consideration of a PFT, chest radiograph or a triple screen (EKG, echo and troponin) when indicated. Second, the time interval from recovery to return to diving is also a factor. Our presenters today have clarified those issues.

Charlotte Sadler: I think we probably need to have a clear definition of what moderate to severe is, because I think some of the presenters have been using that differently. So I would just say, that probably that needs to be defined before we make recommendations based on it.

Speaker 17: I completely agree with that. I think that's the crux of who needs to be tested or not.

Jim Chimiak: How would you like to go about that? At one point it was suggested to group mild and asymptomatic together and would include those not requiring oxygen. Is that a reasonable group: putting the mild and those who never had symptoms together?

Richard Moon: Those who have not been diagnosed with pneumonia, the ones who are home-bound with a brief illness and recovered within two weeks could be grouped with asymptomatic patients. Moderate would include those who have required hospitalization with or without oxygen, ICU and more intense therapy.

Lindell Weaver: I guess I'm biased, I think I had moderate disease. I had a chest CT with infiltrates, elevated inflammatory markers; I didn't need hospitalization; I didn't need supplemental oxygen, but it was close. Does this matter, in terms of classifying such a case as mild/complicated, or moderate, of which there are subdivisions as well?

Bob Sanders: You just used the term complicated versus uncomplicated, and maybe that's an easier way to define it. Complicated including structural changes as detected on imaging.

Lindell Weaver: I borrowed that from our brain injury literature, because we have mild TBI with a normal CT, but if the CT scan is abnormal, then we call it mild, complicated TBI. And again, I'm not proposing we do this, but it might be a reasonable thing to think through. That's to say, a group of people in between mild and complicated, that is, people who don't require supplemental oxygen yet they otherwise have the full constellation of symptoms. So is that the arbiter, whether or not they require supplemental oxygen?

Richard Moon: Based on the study of soccer players' study, of the ones who had mild symptoms or no symptoms, none of them had abnormal CT's. So the presence of abnormalities on imaging could be chest x-ray or a CT, would put somebody in the moderate category.

Lindell Weaver: Agreed. Whether they required supplemental oxygen or not. Right.

Speaker 17: I agree with that.

Bob Sanders: So you are suggesting that a simple pneumonia, still walking, talking, treated at home would be considered moderate?

Jim Chimiak: Agree

Lindell Weaver: Agreed.

Richard Moon: I think we've agreed, wait two weeks if asymptomatic, no further testing necessary, can go back to their usual activities, which may include diving.

Peter Lindholm: I have a slightly different opinion about this. There are people who are considered mild or no symptoms walking in the street, where they were pulled in and did chest x-rays or CT's on them, and you saw pulmonary findings. But the question here is, are we really interested in mild or moderate disease now, when we have the long COVID or the long haulers? It's one thing when this was acute, and we were thinking, if you have someone who's been intubated, do we wait for so-and-so long before we clear them for diving? But if we're now deciding on who should we treat, there are people who had mild disease, which means they were never hospitalized, they were never on oxygen, and they still, one year after COVID can't walk because they have postural orthostatic tachycardia syndrome POTS. As soon as they stand up, they fall over.

Richard Moon: The mild asymptomatic are the ones who have no symptoms after two weeks. So, it would exclude all of the long COVID cases since they are by definition symptomatic

Charlotte Sadler: I guess my concern about these mildly symptomatic divers is that I would be very hesitant to return them back to diving if they're not exercising fully. I would probably still want PFT's. We are seeing people with mild disease, even people who did not have pulmonary symptoms, who had PFT abnormalities. I would be concerned about clearing such patients without PFT's.

Richard Moon: I'd be perfectly happy with putting PFT's in that group who have not returned to their pre-COVID baseline exercise levels.

Bob Sanders: I would second that, and I agree with Charlotte. Granted we only had 10 cases that we dealt with, but one of those had 29% predicted on his mid flows, and he was exercising at his baseline, which is a concern during diving due to the increase in gas density.

Jim Chimiak: Bob, did he come back to full exercise capacity? Did he have a stress test, or any other formal study?

Bob Sanders: I didn't do a provocative stress test on him because he is back to running five to 10 miles in one stint, back to his baseline. So with that level, and his swimming and able to pass our

fitness tests for swimming. So I consider him back to functional baseline but not baseline on his PFT's.

Richard Moon: Do we want to say, consider PFT's or recommend PFT's?

Bob Sanders: I like *recommend*, I think *consider* is a little more of a waffle.

Lindell Weaver: But, let's say someone has moderate or whatever degree of disability, but in several months they are back to baseline, seem to be healthy, have no exercise limitation and no wheezing. If PFTs demonstrate some mild obstructive or restrictive disease, but they are fully functional without change, are you going to recommend they don't dive? I wouldn't. I would have a conversation with them.

Bob Sanders: If you saw 50% of baseline or 52% of baseline, you'd still say go ahead and dive?

Lindell Weaver: No, probably not. But if they're that far down Bob, I don't think they're going to be back to their level of function, if indeed their level of function was quite vigorous.

Charlotte Sadler: I think it also depends on who you're talking to, because there are some very objective guidelines for commercial and scientific divers that we have to follow as far as PFT's go. It's one thing to have that conversation with a recreational diver and discuss it. It's another thing when you're talking about people who have objective guidelines.

Lindell Weaver: A good point. So is this document going to include recreational, technical, commercial and military divers?

Richard Moon: We can't set the standards or guidelines for every single organization; anyone in a particular organization is going to have to fulfill their particular guidelines. We're talking about the generic question, is this person safe to dive? If an organization wants stricter guidelines, then so be it.

Peter Lindholm: Isn't DAN handling recreational divers, primarily?

Jim Chimiak: There are several issues to consider.

We planned to address diving in general. Richard summed it up nicely when he pointed out that whether a specific organization wants to require a more conservative or more liberal approach will be up to that organization. We are attempting to provide the necessary information that can be used to create guidelines that effectively determine when a diver can safely return to the water.

We should make additional considerations for special types of diving such as saturation diving or breath hold diving.

Should we increase the level of surveillance for those with underlying chronic medical conditions? Conversely, should there be a relaxation for those healthier and extremely fit. The military created an algorithm that appears to consider this for return to diving after mild and asymptomatic illness.

One PFT-related issue that we have discussed is DLCO. Should that be included? This test seems to have some merit, but we need to consider Charlotte's point regarding availability and costs.

Bob Sanders: I think we can *recommend* PFT's *and consider* DLCO, which might be the right wording. I think we need to recommend it specifically in asymptomatic people

Richard Moon: On the other hand DLCO seems to be a fairly sensitive indicator of abnormal imaging. So, if we're going to recommend PFT's, then I think we should also recommend DLCO. The additional cost is probably $50. It's not that costly, and it doesn't take much time.

Karen Van Hoesen: I'd like to make a comment on that. If you're in a major hospital, it's easy to get those PFT's. But, we deal a lot with the college kids who want to go take the scientific diving course on campus. And so they go to student health center, where they can get their chest x-ray and baseline spirometry on a machine in the student health center, which doesn't have the capacity to do DLCO. So for a healthy 23 year old, who had mild 'cold' symptoms from COVID, adding DLCO to the requirement may be a financial burden. A lot of times they're paying cash for this.

Richard Moon: On the other hand, in the study of professional soccer players, the distribution of the DLCO's was not normal, and some of them clearly had abnormal PFT's. So, while there are some practical problems, most college towns have a local facility where DLCO measurements can be obtained, perhaps not at the student health center, but elsewhere in town.

If they are planning on diving, they have already shelled out several hundred dollars for equipment, and here we're talking about safety. The important issue is, what do we believe is safe, rather than making compromises based on cost and availability.

Bob Sanders: I agree with what you're saying, but if I remember the soccer study, none of the mild patients had abnormalities on imaging. So if we recommend PFT's, *consider but not recommend* DLCO in the mild cases, but in the moderate or severe cases, those are the ones that need either DLCO or imaging with CT.

Richard Moon: You make a good point there Bob. There were only around 18 subjects with mild symptoms in that study, of which there were no imaging abnormalities.

Jim Chimiak: Does that look reasonable then? *Recommend PFT's w/DLCO*, for the moderate imaging abnormality and pneumonia?

Bob Sanders: Recommend both. I would still *recommend* PFT's and *consider* DLCO after mild cases. Spirometry is cheap and can be performed at a lot of clinics. Even our occupational clinics can do that, but won't be able to do DLCO.

David Southerland: I can't speak from a clinical situation, but I can speak from our pulmonary oxygen toxicity studies at NEDU. DLCO's were really not super good. There was a lot of variability, and it turned out that at least in one machine, our divers were able to over breathe the DLCO machine, thus it was giving wonky results, because it was designed for use with sick people, not really healthy people.

Lindell Weaver: There are actually three different normative groups for DLCO, but norms are pretty well-defined. We just did a study here, to show if the normal corrections for altitude were okay, and it turns out they were. DLCO consistency has improved since that work was done.

Kenneth LeDez: I wanted to point out that there is a pretty good correlation between low DLCO and oxygen de-saturation during exercise testing. That, is something that should be included.

Peter Lindholm: And I's like to add that there are cases of people who have had COVID and they de-saturate on exercise and they have normal DLCO. The case I had referred to who had a normal chest CT, yet de-saturated to 89% on six minute walk tests, a 28 year old physiotherapist who had normal DLCO.

I would say that DLCO is interesting, but it's not the solution to sort of weeding out the sick from the healthy.

Kenneth LeDez: But you could also have high hemoglobin, in compensation for previous lung dysfunction, and that high hemoglobin could affect your DLCO. So exercise de-saturation is a pretty reliable test. If, doesn't de-saturate with exercise, that's one thing. But if they do de saturate, they should be disqualified from diving.

Peter Lindholm: Yes.

Richard Moon: The issue here is not deciding whether or not someone should dive if their DLCO or their exercise de-saturation is abnormal. The issue here is to decide who gets imaged. Exercise de-saturation has no functional effect on diving safety; breathing elevated partial pressures of oxygen during a dive, there's no way that de-saturate can occur. I agree that low DLCO correlates with exercise de-saturation, but the important question is whether, if either of those is abnormal, it should be a trigger for imaging.

Kenneth LeDez: I would agree with that. But, if you're deep enough, you may not de-saturate, but you could still fatigue. And if you're not that deep, the PO-2 is actually not that high.

Jim Chimiak: The question is, with cardiopulmonary exercise testing (CPET) as a screening tool, the Navy actually uses DMT's to administer that test. What do you feel about that as a screening tool?

Richard Moon: In the mild asymptomatic group, I don't think they need to do CPET. So we've got consider PFT and DLCO, although I wouldn't object to recommend PFT and consider DLCO, but the arguments really are going to be in the next group, those with moderate to severe abnormalities.

Peter Lindholm: I would like to throw in a timeline in this too, because we say here, we recommend something. Telling a recreational diver to stay out of diving for three months, come back and re-check exercise capacity is reasonable. However, for someone who may be scheduled for a scientific mission to Antarctica, or a military diver with a planned mission, they may need a more immediate answer.

Richard Moon: We have a timeline for the mild asymptomatic: wait two weeks. If the patient is asymptomatic, then check the PFT's, and then proceed accordingly. If the PFT's are abnormal or the DLCO is abnormal, that may trigger imaging. If the PFT's is abnormal, that by itself may exclude diving based on the judgment of the examining physician.

Peter Lindholm: Then I would like to propose six weeks for imaging. We always do chest x-rays six weeks after regular pneumonia, which is usually a bacterial one, to see if there is a cancer as

a cause of the infection. The clinical consensus is that most pneumonia has resolved within six weeks. So, I think it's premature to image at two weeks after clinical recovery.

Richard Moon: I totally agree. The question now is, how long should we wait after moderate or severe disease? Should it be a month? Should it be two months? What does everybody think?

Bob Sanders: For mild cases, if the diver has no symptoms and normal exercise capacity after two weeks, I think it should be safe to return to diving. If it's moderate to severe, then as assessment should be according to the clinical presentation: when the diver can walk and exercise again, that's when it is appropriate to image for the return to diving question.

Kenneth LeDez: I want to agree with that because I think we need to ask about current respiratory and cardiac symptoms and fatigue, not just what happened in the past. We need to ask, "Are you getting short of breath? Can you do the same level of exercise you used to?" That has to be part of this.

Richard Moon: Yes, of course. Charlotte is exactly right, that she is focused on asymptomatic individuals in her recommendations. But the first question is, when should a diver be reevaluated after COVID? Should it be a month, two months? What do you think?

Bob Sanders: I would have to leave that one either as when the patient feels normal or has returned to baseline exercise capacity. I would love to see us agree to change the consider PFTs to 'recommend PFTs and consider DLCO'.

Richard Moon: I would agree with that.

Charlotte Sadler: I'll echo that too. I was going to echo Bob in saying one of the reasons that we didn't put timelines in our guidelines is that sometimes these people come back after two weeks and they feel fantastic. Then I tell them, "If your tests are all normal, you can get back in the water". If the diver is back to their exercise baseline and they are asymptomatic, do we have to specify a time for testing?

Jim Chimiak: You mentioned this earlier Peter that there be a no sooner than interval for imaging. When someone recovers from their pneumonia, typically how long does that take before the x-ray catches up with the clinical picture? Would you say six to eight weeks later?

Peter Lindholm: That's the timing we have been using, to resolve residual bronchial consolidation, in order to see the cancer if there is one, but the same timing is also appropriate for uncomplicated bacterial pneumonia. Some organizing pneumonias heal slower, but that's probably not a consideration here. If the patient is asymptomatic, back running or opening their beer that they got out of the fridge, as Dr. Moon pointed out earlier, I would not radiate somebody just two weeks afterwards. I would probably not recommend, for someone who is completely asymptomatic, any imaging at all?

Lindell Weaver: I'm still troubled with the PFT recommendation, Bob. I think this is burdensome and expensive. We're talking about mild asymptomatic people in this category. Literally, we're recommending PFTs, including DLCO, potentially, in the mild asymptomatic person?

Bob Sanders: Not necessarily recommending the DLCO, but PFTs really aren't that expensive.

My experience is one in ten patients had significant change in spite of feeling normal, and that's high enough that it makes me nervous to say don't do it.

Lindell Weaver: I guess it's up to dealer's choice, and perhaps we're all influenced by the divers that we see. I'm not talking about commercial or NASA divers as you are, Bob. But again, this seems. Charlotte, are you guys doing this in a mild asymptomatic person?

Charlotte Sadler: We are.

Lindell Weaver: When patients are back to their baseline, are you doing PFTs on everybody?

Charlotte Sadler: We are. We are doing PFTs on everyone who's had the COVID, even if they're mild and returned to their baseline.

This is supported by EUBS and Navy, data. They had a lot of divers with abnormal PFTs who were "asymptomatic" and did not have respiratory symptoms after their illness. We are being conservative and doing PFTs on everyone, but not necessarily DLCO on everyone.

Lindell Weaver: Well, then let's expand it. What if they had influenza? What if they had some other viral illness? Is this particular only to COVID, or if you just take a thousand asymptomatic divers who weren't sick and do PFTs? So what's your baseline, what's your denominator? What happens with other types of illnesses, that people often have evidently apparent recovery from? Well, no one probably knows, right? Can anyone answer that?

Bob Sanders: We do annual PFTs at birth month, so we know a range of our people are going to be getting their PFTs done during cold and flu season. We're not specifically tracking this, but we certainly don't see a post-influenza PFT spike several weeks after, when we're seeing our patients. So, I think that it's something we would have caught, certainly in the commercial world, if it were a problem.

Lindell Weaver: I'm really not thinking about the divers that you have, Bob – they are a pretty selective group. I'm thinking about all comers, all ages in the civilian recreational community, many of which are pretty unhealthy to begin with.

Bob Sanders: I understand. But where we have baseline, we can see change. And so when you ask the question about your typical influenza, your typical flu, are we seeing these changes? We're not that we're aware of. I would love to get Charlotte's comments because I'm sure she's doing a lot of PFTs at baseline as well on a lot of their scientific divers, but we're not seeing inexplicable bumps from colds and flu. We have seen bumps from reporters going out and filming fires and not wearing masks, thus acute lung injury, but then they shouldn't be diving.

Charlotte Sadler: Similar to what Bob's saying, we do PFTs on all of our divers in dive clinic, or most of our commercial divers. Sometimes after an acute illness, we will see a change in PFTs and then we just ask them to come back and repeat them a couple of weeks later. If someone comes back to get "cleared" for diving having had a bad respiratory illness, such as pneumonia or influenza, not COVID, we would still do PFTs on them. But we are actually, as part of our study on COVID, going to go back and do some case-controlled matches from our divers pre-COVID and their PFTs, and take a look and see at incidents of abnormal PFTs.

That's a great question and that's something that we're actually going to be looking into.

Peter Lindholm: At this point we don't know a lot of these things. We're basing our recommendations here on some evidence from series, some personal experience, but a lot of it is based on plausible rationale, which is going to change over time. This is not necessarily what will be in the textbooks in five years, but we need to come up with something just to start with, and then address issues as needed in times to come. We can leave the mild asymptomatic ones just for now and move on to the more severe cases. We have been focusing on lung, but we also have heart talk about.

Can I add a little housekeeping comment to this? When we did these guidelines last year, it took us a couple of weeks. We talked extensively, we were all on the same page, but in the same institution. Here we have multiple countries and organizations. I don't think there is time enough for us to reach a consensus. The question I have with this, is there anything in the guidelines that we put out that is really problematic or that needs to be changed? We have all said that we are going to update the guidelines in a year or so when we have some more real data, but maybe we could focus on whether there is any needed change in guidelines that we are currently using. If we're going to start over, discussing this from the start, taking through definitions of the disease and going through all these different data, there's just not time for that.

Richard Moon: I agree, but I think the mechanics of this would be to come up with something at this point, email it around and get everyone's comments. What needs to be added to the UCSD guidelines is what about the heart? Who needs an echo, who needs troponin, who needs an EKG, who needs a formal exercise test?

We need to look at, or at least consider over the next few months and years, the propensity to decompression sickness, the propensity for bubbles to injure the lung in a way, as David Eckmann has pointed out, may not occur in normals.

Jim Chimiak: The numbers of divers with asymptomatic and mild disease is quite large assuming they reflect the general population. Any testing, particularly this group, should be clearly indicated. Once asymptomatic and exercising without issue, leaving consideration of PFT/DLCO to the discretion of the examining physician would seem reasonable. The longer the period from recovery, the less pressing the need becomes.

Lindell Weaver: Well, think about the sheer numbers of people in the recreational community such that, if the word 'recommend' is used, are we going to go to all the certifying agencies and say, "You need to screen now your divers for COVID, and if they had it then they need PFTs." I think there may be a bit of pushback, but maybe we can see how that plays.

Richard Moon: Lin, I think that would be up to the recreational agencies. What we're focusing on here is, what do we think is right?

Lindell Weaver: I understand that, Richard, but I think you got to think about the ramifications of what we think is right. If you want to say *recommend*, I personally think it's overkill for the mildly symptomatic person, but you guys, Bob Sanders and Charlotte, certainly have more experience than I do because of I'm landlocked and I don't see that many of these people. I can

live with it either way, but I'm thinking, once the certifying agencies get hold of this, we're going to be doing a lot of PFTs, but maybe that's okay.

Kenneth LeDez: I think there needs to be a clear ladder too, so that if the patient has had mild or no symptoms, no shortness of breath at any time, then it may or may not be necessary, or you could suggest consideration of that. And then the next stage, I think if they've had moderate abnormalities, I think even *recommend* isn't quite good enough. I think it should be *strongly recommend*. I think if they've had severe symptoms, then all these tests should be mandated before return to diving.

Lindell Weaver: Well, I guess that's where I'm stuck here on mild/asymptomatic divers. Are we saying a person who is COVID positive, but never had symptoms now needs PFTs before they get in the water?

Kenneth LeDez: I think we need to focus on the fatigue and the shortness of breath stuff.

Bob Sanders: I think Charlotte and I have both advocated requiring PFTs. Now, I like Ken's comment about suggest; I'd be willing to tone it down to that. If the patient has experienced no pulmonary abnormality, why are we going to do it? However, it is those cases that I'm most concerned about, with the possibility of missing an abnormality and putting people at risk for potential AGE.

Bob Sanders: We know that there are people who are completely asymptomatic yet have significant changes in their PFTs. Therefore, even though it does not seem apparent that PFT could be abnormal, our experience and the data shows that they are people who are at risk." That's why I want a guideline that is stronger than consider.

Lindell Weaver: Fair enough. So then in that group, Bob, if they have abnormal PFTs and you obviously then are much more concerned, I assume you don't stop there. You now do other investigations, correct? Or do you stop there?

Bob Sanders: Correct. Once we found them, once we've identified them, yes.

Charlotte Sadler: As a caveat to our guidelines, for people who have always been completely asymptomatic, we don't require PFTs. We do require them after even mild symptoms, but for people who just had a positive test and never had even a sniffle or a symptom, we have not required PFTs or chest x-ray.

Lindell Weaver: Okay. But, Bob, you said even if they never had symptoms, you have found people with abnormal PFTs, right?

Bob Sanders: We only had one such patient with significant changes in PFTs and he did have conjunctivitis; that was it. But I have to agree with Charlotte, we don't have anybody who just tested positive without any symptoms. In our population, once they tested positive, we grilled them and they had something.

Richard Moon: So how about this? How about a guideline stating that those who had a positive test with no symptoms consistent with COVID infection, do not need any specific testing?

Bob Sanders: There needs to be some sort of comment about exercise tolerance, but not necessarily a formal test. Reduced exercise capacity counts as symptomatic.

Richard Moon: For example, your buddy or your roommate had COVID. You get tested, and you're positive, but you never have any clinical disease. You don't need any specific testing.

Bob Sanders: I'm wondering how many truly asymptomatic COVID people were just false positives.

Lindell Weaver: I think that's known. It depends on the test and when those tests were administered. But nowadays, even in the last few months, it's quite low.

Richard Moon: There are a few false positives.

Lindell Weaver: And the false negative rate is higher.

Bob Sanders: Are we still seeing as many completely asymptomatic positives though?

Richard Moon: Yes, there are tons.

Bob Sanders: Okay.

Kenneth LeDez: I think Dr. Moon's suggestion; if they tested positive and never had any symptoms, especially no symptoms even with exercise; I think that we give them a pass.

Bob Sanders: I can live with that.

Kenneth LeDez: And then we go on, if they have had respiratory symptoms, even if only with exercise, then I think that we should suggest that they have PFTs. So that way, it's a logical and rational step up of severity and a step up of the degree of recommendations for testing.

Bob Sanders: It should be a history of any symptoms, not just respiratory. It should include even mild conjunctivitis.

Kenneth LeDez: Okay, including diarrhea.

Bob Sanders: I wouldn't use 'ongoing' or we have to get into definitions of time. I would just say, history of any COVID-like symptoms.

Kenneth LeDez: In the completely asymptomatic group you're not suggesting any testing-nothing further is needed. In the next group, with some symptoms, that's when you're suggesting PFTs.

Bob Sanders: Correct.

Richard Moon: I think that the next group could be handled very simply, recognizing that there are two main issues. One is exercise performance under water, and the other is propensity to pulmonary barotrauma. There are three markers to address these issues. One is exercise capacity on dry land. If somebody gets short of breath during ordinary exercise, then the likelihood is that they're going to be impaired under water. The second is that even if their baseline exercise capacity, whatever that might be, is back to their normal, abnormalities in pulmonary function tests predict the presence of structural abnormalities in the lung, in which case imaging should be considered.

Bob Sanders: But actually, the way you started that I think is a really good introduction, that what are we concerned about, is exercise tolerance underwater and the propensity to pulmonary barotrauma. I thought that's such a great lead in, the way you said it.

Richard Moon: The two main areas of concern are exercise performance underwater due to impaired pulmonary function, and structural lung disease that may predispose to pulmonary barotrauma. With regard to the former, exercise performance on dry land and spirometry will provide some guidance. With regard to the latter, pulmonary function tests, including DLCO and exercise-induced pulse-oximeter desaturation are predictive of imaging abnormalities that should be investigated.

Tom Neuman: I think Lin's point is right on the mark. If we use the word recommend, it will become de facto a regulation for the industry, and I think we have to be very careful of that: not so much for the commercial folks, but for the recreational community in the Caribbean and so on. Also, let us not forget our combined recommendations from years and years and years ago, that no one with asthma or for that matter diabetes could ever get in the water, let alone scuba dive, and we have discovered that our concerns were to a large extent overstated.

An abnormality-absent Bayes' theorem is problematic. It is possible that there will be more false positives than true positives. Furthermore, the whole question of what a normal PFT is, is not a simple one, just as Dr. Martinez pointed out. So I think we have to be very, very careful with what we're writing here. I don't believe that one case should drive the entire process. We're on thin ice here without having data, and the implications of what we recommend are not inconsequential. So I do believe we have to be quite careful with what we're recommending.

Kenneth LeDez: The counter to that, is that the recommendation here is not that they have a PFT out of the blue, but this is in people who are having symptoms such as shortness of breath, with a reduced exercise capacity or experiencing hemoglobin-oxygen desaturation with exercise. Nobody can possibly suggest that it's safe for those people to go in the water. If you're desaturating with exercise, there is something wrong. If that's also associated with an imaging abnormality, then that tends to provide confidence that there's something wrong.

Tom Neuman: Those people shouldn't be diving, period. If someone desaturates with exercise, or is short of breath with exercise, our guidelines are not required to recommend that person shouldn't be in the water.

Kenneth LeDez: I totally agree.

Tom Neuman: We're talking about asymptomatic people.

Kenneth LeDez: No, no, no, no. The phrase we're working on right now, the clause we're working on, is addressing the person with reduced exercise capacity on land or exercise desaturation.

Kenneth LeDez: If you just image everybody, you're going to find all kinds of stuff, and they've probably been diving for 10 years with it. But if they're having symptoms with reduced capacity on land, then we have to be very suspicious of that.

Charlotte Sadler: I admit now I'm confused too, because I thought that we were talking about all asymptomatic divers right now. I thought when we were discussing symptoms, that we

were discussing symptoms of initial illness. And now assuming that everyone is back to being asymptomatic, but we're doing their workup based on their initial symptoms. Am I confused?

Richard Moon: If someone is short of breath on land it is likely that they will have some impairment underwater. However, not everybody exercises to the point where they realize that they're short of breath or not. The other issue (susceptibility to barotrauma) is related to structural abnormalities in the lung. In order to select those who may require specific imaging, plenty of data have been presented today showing that pulmonary function tests and DLCO are predictive of structural abnormalities. In order to select those for whom imaging should be performed, those tests provide a good starting point.

Charlotte Sadler: Okay. I completely agree with that. I was assuming that these are people that are presumably asymptomatic, but still might need further testing. And I think that's what you're saying.

Richard Moon: That's exactly right.

Bob Sanders: It should be asymptomatic after two weeks of return

Richard Moon: Okay, that's good. I think the lung issue is pretty straightforward. What I'd like to move on to is whether we can make some recommendations the heart.

Bob Sanders: Shall we start with the mild and asymptomatic? Do we all agree that if someone returns to normal exercise tolerance, they don't need heart evaluation? Such evaluation would only occur with lack of exercise tolerance after two weeks or moderate to severe illness.

Richard Moon: Yes.

Kenneth LeDez: Do you add in there that if cardiac testing was performed when they were mild, if they had an elevation of troponin, or an alteration of their ECG or echo, that those things should be repeated?

Richard Moon: Yes. So during their acute illness, if there was any evidence of heart abnormality, then they do need testing. Matt, could you articulate what you think needs to be here.

Matthew Martinez: The data suggest, now from 3,000 people, that if symptoms were asymptomatic or mild with no cardiorespiratory symptoms, nothing needs to be done from a cardiac imaging standpoint. That's for the initial presentation. The second part of that is if symptoms develop after returning to exercise, I think that changes everything. If chest pressure, breathlessness or there is inappropriate tachycardia, there is reason for concern, but the vast majority do not. I think it's important from a medical legal standpoint, that if we make something a recommendation and it's not done, and there's a one-off event, physicians will do whatever it takes to cover themselves legally.

Richard Moon: Yes.

Charlotte Sadler: I have a question for you. In this moderate to severe group, if someone is back to a normal and say aggressive exercise regime, and they're completely asymptomatic, would you recommend the triple screen? From my understanding, a lot of this triple screening data came from people who were wanting to return to exercise and return to play. But a lot of our divers are

not college or professional athletes. They've already returned to their aggressive exercise routine that's normal. Would you still say that those people need a triple screen?

Matthew Martinez: So, help for me define what you mean by moderate.

Charlotte Sadler: I think in this definition, we were saying anyone that had any sort of hospitalization or even an abnormal imaging, so abnormal chest x-ray or CT scan. Or in what we said in our definition is that anyone who had any evidence of cardiac involvement initially, but I think that's almost like a different category of people.

Matthew Martinez: Agreed.

Charlotte Sadler: But anyone who was hospitalized or had an abnormal chest x-ray, say, but now they're back to exercising aggressively, no symptoms.

Matthew Martinez: So in that group, if you required hospital stay, then you're at risk. I don't know if the triple screen applies, but I think a cardiac imaging study, probably just an echo would be sufficient. But troponin, as you know, goes up and goes down with exercise. You'd have to halt them from exercise for a couple of days to do the troponin, otherwise you're at risk for false positives, but you can exercise when you have a 30% ejection fraction and not know it.

Charlotte Sadler: That's exactly what we had in our guidelines. We had said an EKG and a 2D echo at minimum for those people, but we had not included a troponin, if they were back to exercising.

Matthew Martinez: I can tell you that clinically, those of us who are doing this around the country are skipping the troponin if it's been more than a couple of weeks. If it's truly related to myocarditis, it should go up and go back down again and not really present for months and months and months. And you could end up getting down a rabbit hole, wishing you had not drawn one at the beginning. I would say that if the ECG and echo are normal, you're on pretty solid ground that they're safe to participate.

Richard Moon: So, Matt, exactly who should get an echo?

Matthew Martinez: Anyone who has been hospitalized with COVID, , requiring therapy, especially if requiring mechanical ventilation, or with an abnormal chest x-ray or other imaging study, I think that group needs an echo. I would want to make sure that the echo is normal, that the PA pressures are normal before scuba diving.

Richard Moon: What about EKG? The same?

Matthew Martinez: Sure.

Richard Moon: I agree. Now, what about the person who is asymptomatic, but during hospitalization there was a concern about the heart, and there were some investigations that might have included an echo, or maybe even a cardiac MRI. Should that person also get post-COVID investigation as well?

Matthew Martinez: If there is a prior imaging study that's abnormal, elevated troponin, abnormal ECG or echo, we're going to have to recommend that they are evaluated by a cardiologist or have

their imaging repeated to make sure that abnormalities have resolved. It may be simpler to have them be seen by a cardiologist, because some would argue a cardiopulmonary exercise test would be the best answer. Some would argue that an MRI would be. I would argue that it would depend on what their presentation was.

Richard Moon: When you said imaging, did you mean abnormal chest x-ray?

Matthew Martinez: No, sorry: this is the cardiologist speaking. To me, all imaging starts with either echo, MRI, or cardiac CT, but not a chest x-ray. If you had an abnormal cardiac study, we can call it that, cardiac imaging, if you'd like, an ECG, troponin, certainly an echo because people are getting POCUS and it could certainly be just stress induced cardiomyopathy, where you have a transient change in left ventricular dysfunction related to the initial stress of the illness, which doesn't mean anything long-term. However that would be really difficult to put into an algorithm.

Jim Chimiak: This workshop primarily addressed all groups of divers that were infected by COVID-19, recovered and were now asymptomatic. For those with continued symptoms, "long haulers", the following discussion was conducted also to acknowledge a potentially large problem for those affected.

A Brief Discussion on Divers who Remain Symptomatic:

Richard Moon: What about the individual who didn't get any cardiac imaging or EKG in hospital, but now has chronic fatigue?

Matthew Martinez: I think if you've got persistent symptoms beyond four weeks, and we see tons of these, I think it has to start with an imaging study, probably an echo to make sure that there's no LV or RV dysfunction. I think we just defined the long hauler, right?

Richard Moon: Yes.

Matthew Martinez: Greater than four weeks, you need imaging studies.

Speaker 19: Can we talk about which imaging study now?

Matthew Martinez: Yes.

Speaker 19: I mean, I assume if they're complaining of fatigue, they need to have a stress evaluation. Right?

Matthew Martinez: Agreed. Most of us wouldn't put somebody on a treadmill without assurance that their LV function was normal at rest.

Speaker 19: Okay. So then they get a baseline echo. Looks okay. And then do you a treadmill test?

Speaker 18: After four weeks of persistent cardiopulmonary symptoms of any kind, recommend echocardiogram, with consideration of stress testing and/or MRI.

Speaker 19: Which stress test?

Speaker 20: You're talking about the symptomatic patient and you're already back to the symptomatic patient who we've already said is not being back in the water.

Bob Sanders: That is a good point. Does that need to go in there, that we're only talking about the asymptomatic patient getting back in the water.

Speaker 20: The whole basis of the guidelines as Dr Sadler presented. It's only for those people who have completely recovered, who are asymptomatic. The rest of the people, we're not evaluating to go back to diving because they are still symptomatic. They may have long haul symptoms, and they're going to fall out of these guidelines unless we want to make guidelines for symptomatic patients who are not doing that well.

Richard Moon: It's easy to make decisions about the person who can't go to work and has to lie on the couch all day. But I imagine there are people who report palpitations once in a while or "I can go to work, but I can only run two miles instead of four." There's a gradation between full back to normal and completely disabled that encompasses a lot of people.

Bob Sanders: For the person who could run four miles, and now can only run two, we can help guide their workup, because there's still something going on, a persistent clinical abnormality. Do we need to figure out what that something is before we say, "Go ahead and go back to diving." Because, if it's a huge anomaly in their lungs, that's very different than just some loss of conditioning, secondary to being on a couch for four weeks.

Bob Sanders: But then that's another document, in contrast to what Dr. Van Hoesen and Dr. Sadler were talking about, which is that in order to return to diving you have to be asymptomatic. So maybe we need to have yet another gradation or another category to make life simpler.

Kenneth LeDez: Unfortunately it's confused by the fact that a lot of people who are just mentally exhausted, could also have physical issues. A lot of people may say, " I've been really down from this. You know what would make me feel much better? It would be a nice, a dive trip to the Caribbean." So, there is value in giving some guidelines like this.

Jim Chimiak: I agree with Richard, you'll see the chronic fatigue. We are contacted by divers who report a chronic fatigue, but they'll go diving. They report they did not have the best of time. They report significant fatigue quickly. They had a negative workup. Cardiopulmonary issues are the center of investigation. If the workup is negative, then what? Can a person with chronic fatigue dive? We talked about brain fog today but often no objective findings. So the idea that if there's nothing there, nothing comes up in the investigations, do you keep digging? Or do you just say what many today have said, "You've got symptoms. You can't dive until your fatigue is resolved."

Matthew Martinez: Jim, when you say they were negative. I mean, did they have a formal exercise study? So we know what their capacity was?

Jim Chimiak: Yes. Investigations were normal and included a cardiac workup.

Matthew Martinez: So that we know they had 10, 12, 14 METs, pick a number.

Jim Chimiak: The one individual achieved 12. Many were young individuals in their thirties. And the issue was they had not had the same opportunities to exercise with the same intensity

over a number of months prior to their dive, but felt they were nearly back to their baseline.

Matthew Martinez: Well, like I talked about earlier, any brain symptoms here? Because if they have sleep and other things going on, that it may be their brain that is limiting their exercise capacity and not their heart.

Jim Chimiak: But how far do you dig? How many additional studies do you do? Do you start doing some studies, like the dual energy CT to go look for some of these relatively discrete findings?

Speaker 21: I think it feels a little bit like they just needed assessment and that we ought to just recommend that if you have persistent symptoms that they have to be cleared because there's so many subtleties to this, as you mentioned. The other part is that there's so much fear that I have people in the office all week long who say, "I just don't feel right. I'm scared that there's something wrong. I just need to be seen."

Peter Lindholm: So I have another, I would like to say something again. That is, I mean, we've been talking of this, it's just another hour or for the panel. And a lot of people are dropping off, but for those who are still here, is there anybody that has some issues with the current guidelines? Because it seems like as a community, we need research. We need to have data on maybe the long haulers. And we are going into discussion of these people who have residual symptoms. The guidelines have taken the symptomatic diver who's backing exercise capacity, but starting to discuss whether you have a little bit of limited exercise capacity, I have 5% fibrosis in my lung, can I dive with 5% fibrosis in my lung? I have lost my leg, can I dive with the one leg? That seems like a separate workshop? And maybe follow-ups. I don't see anything that we have discussed today that actually feels like we need to change the guidelines that are already out there.

Richard Moon: Part of this is to provide an information document. We've heard quite a bit about the heart today, that that can be encapsulated into a paragraph. Tom made the point that the asthma guidelines are probably out of date now, but at the time the asthma guidelines, which were published in 1996, provided some background information for the physician who assesses these people. This document can do exactly that for COVID. When you get down to a question as to how much fibrosis can be tolerated, at this point, it's an individual decision. Many decisions will have to be made that depend mostly on our own comfort level. The question at hand here is who needs to be investigated? We have just heard in the last five minutes, there are plenty of divers who are worried about symptoms such as fatigue or diminished exercise capacity. Their brain may be abnormal, but we're focusing mostly on acute risk due to the heart and lungs. Also, David Eckmann raised some very interesting issues related to decompression, which need to be included as well.

Kenneth LeDez: I'd be okay with that. I think one thing I think there seems to be probably support for too, is that if you've been in the moderate or severe category, really you need to be assessed by an expert in diving medicine and probably add into that cardiologist and pulmonologist. I think that needs to trigger something further.

Bob Sanders: We haven't talked about fatigue and attention span. So. Does it put you at risk for making a mistake in the recreational diver who hasn't been doing this very long, if they're just going in when they're really tired thinking, "This is going to get me out of my funk or out of my depression."?

Kenneth LeDez: PTSD is a very important component of this.

Peter Lindholm: We'll see whether we need to have another meeting. If we have some documentation, if there's more data coming out, maybe there should be a workshop meeting to discuss further. There seemed to be a lot of discussion and especially on these that are not asymptomatic, which are, I consider already covered in the guidelines that we have, but for how do we follow up the long haulers with symptoms? And that's a very interesting topic. But I think there's not enough data for that to finish it today. So I agree with Dr. Moon and Jim Chimiak that I don't think we can get any further today.

Jim Chimiak: Divers who remain symptomatic after their acute recovery should receive the necessary investigation determined by their physician team. Individual determination about the return to diving would be made based on that investigation. A specific workshop may be needed to address some of the general cardiopulmonary issues raised today.

Concluding Remarks

The full understanding of COVID-19 is ongoing. New insights into the cause, spread, prevention, treatment, and recovery are uncovered with regularity. There is little doubt that information presented today will undergo modification. COVID-19 will profoundly impact our understanding and overall management of infectious disease outbreaks going forward. The scientific community continues to focus on the entire scope of the COVID-19 pandemic with a trend away from the early, justifiably conservative advice rendered and giving way to a rational, evidence based relaxation as better data became available. The decision concerning the return to diving for those who have recovered from this infection today is based on the best evidence available to us now.

A central premise for any fitness to dive consideration: Do not dive if unwell. This statement of the seemingly obvious, is unfortunately violated with regularity even before the COVID-19 pandemic. DAN receives emergency calls from individuals who proceeded to dive despite being unwell. The acutely ill diver not only causes problems for themselves but puts others, including the crew and medical personnel at risk also. This problem is compounded when an infection occurs in remote locations with very limited medical capabilities exist. Such places are quickly overwhelmed if more than a few become ill at one time. Medical facilities and evacuation systems are stressed both internally with their own personnel becoming ill and externally with the dramatic uptick in the number of patients needing emergent evacuation. In addition, severe international flight restrictions and scarce bed availability has made evacuation to traditional referral hospitals difficult to impossible. A reasonable doubt about how one feels or a recent close contact with someone ill is always a good reason to reconsider a planned dive

trip. It is particularly important during this pandemic to play an active role to prevent spread and not worsen one's condition by traveling or diving if feeling unwell especially for those with risk factors such as advanced age or underlying medical conditions. Again, consider whether the region's medical system may be under extreme stress and can no longer manage cases adequately. Overburdened evacuation services and referral hospitals may not be available.

The presentations today focused on the return to diving after recovering from a COVID-19 infection and now feels well. Symptoms remaining after recovery were not addressed as they should be managed on an individual basis by the physician team. The diving medical physician's guidance should include the following elements:

- **Preventive measures:** optimizing underlying medical conditions, regular exercise1, weight loss2, contact management, physical barriers, and vaccination.
- **Acute infection:** isolation to avoid spread of the infection, management of the acute infection at home, hospital floor, ICU. Treatment, consultation and testing conducted per the physician team.
- **Acute recovery from infection:** that includes no longer infectious, afebrile
- Monitored rehabilitation with continued guidance from your physician team as indicated
- Released by physician team to full unrestricted, unmonitored exercise and progress until meeting or surpassing pre-infection exercise levels before Diving medical physician evaluation
- Evaluation by diving medicine physician for diving after full asymptomatic recovery and meeting/exceeding exercise capability thresholds
- Refresher training under controlled conditions
- Unrestricted diving to the level of certification

At any point in this systematic approach, if any problems/complaints arise or the inability to achieve sustained levels of rigorous exercise, then that individual should stop and seek medical attention that may possibly prompt additional evaluation and testing.

Specific considerations:

1. Pulmonary: pneumothorax, fibrotic changes, structural abnormalities discovered (cyst/bleb/bullae), pulmonary edema, diffusion abnormalities, ARDS, secondary pneumonia, pulmonary embolus.
    - Fatigue and shortness of breath are common findings after the acute infection and can be multi-factorial. Those factors can range from poor conditioning while ill, psychological issues and cardiopulmonary conditions that can also result in associated oxygen desaturation with exercise.

2. Cardiac: Can include cardiomyopathy, dysrhythmias, myocarditis, dysautonomia (includes POTS) and MI; the incidence is not as common as first reported but warrants consultation if indicated.
3. Vascular: coagulopathy, DVT, microthrombi, pulmonary embolism. Information highlighted the potential for injury to the vasculature and its recovery. Healthy vasculature is essential for the take up and elimination of nitrogen while diving. The impact by venous gas emboli on the recovering vascular endothelium in addition to dive/travel associated factors such as dehydration and prolonged seated travel is not known at this point. The impact of diving on the known formation of intravascular thrombi formation in some COVID-19 patients also raised a theoretical concern. Frequent standing and walking to disrupt prolonged periods of sitting during travel and consideration of aspirin administration during travel if no contraindication were suggested.
4. Neuro/psych: Evidence of cerebral involvement has been reported. Both neurologic and psychiatric deficits have been associated with infection. Some issues can continue to linger for months after the acute phase and should prompt a medical evaluation before returning to diving.

Additional Issues

Recovery time: There were time interval recommendations for the fully recovered (full exercise capacity and asymptomatic) before return to diving. Recommended non-diving recovery interval ranged from 2-4 weeks to 3-6 months depending on severity of infection and organization while some gave no time interval guidance. Generally, for most serious infectious disease, the longer the time between full recovery and returning to diving, the lower the level of concern. It is also rational, that the intensity of organ system illness such as lung involvement marked by the need for oxygenation or mechanical ventilation, that both recovery time and level of clinical investigation should be increased. It could be logically argued that the testing recommendations could be less rigorous as the time interval increases. Other organizations have adopted a minimum time interval to mitigate risk. The American Society of Anesthesiologist have recommended an interval before conducting elective surgery by tracking the decrease in post-op mortality that returns to the baseline around 7 weeks on average. This anesthesia recommendation is consistent with the traditional recommendation after any significant pulmonary infections to avoid post operative complications. Obvious differences exist between diving and surgical procedures requiring anesthesia, but cardiopulmonary concerns may still be relevant shared concern.

Decompression issue: Although involvement of the vascular endothelium may occur, a linkage to impaired inert gas uptake and elimination has not been reported at this time but will remain a focused concern.

Nitrogen Narcosis: No worsening of nitrogen narcosis has been reported. Worsening of "Brain Fog" could theoretically occur but any alteration of mental status including "Brain Fog" warrants continued physician consultation and no diving.

Oxygen toxicity: High levels of oxygen may have been required during the acute phase to maintain adequate oxygen saturation. The development of pulmonary oxygen toxicity may have occurred. Its occurrence needs to be followed to resolution before diving consideration. No reports of CNS oxygen toxicity have been reported. Interestingly, no such adverse event from those conducting trials of hyperbaric oxygen treatment for patients with acute COVID-19 infection have been made despite prolonged oxygen treatment exposures at or above 2.0 ATA.

Infectious disease risk: Identification of those acutely infected and then placement in quarantine until no longer infectious is an important control measure. This pandemic has sensitized all to utilize sensible hygienic measures such staying home when sick, handwashing, covering when coughing etc. and hopefully will be retained long after this pandemic resolves. Infectious disease outbreaks on both travel and dive expeditions were becoming commonplace. Perhaps these hygiene measures will remain the routine and make such these other common infectious outbreaks a rarity.

Breath-Hold Diving: Special considerations may be indicated for breath-hold divers. This may be seen as an understatement since any condition that alters the mechanisms of oxygen gas exchange such as lung infection sequelae must be rigorously evaluated to prevent known cardiopulmonary concerns such as dysrhythmias and hypoxic blackout that can lead to drowning. This risk may be lessened to a degree with this population since it is on average a younger, fitter group with fewer medical comorbidities. In addition, there may be better awareness of overall exercise fitness with the ability to quantify exercise capacity decrements especially in apneic exercises/times that if impaired would preclude return until formally investigated by the physician team and fully recovered. In addition to indicated medical testing, a return or surpassing of pre-COVID baseline measures of apnea and exercise conditioning could be a precondition before the final diving medical evaluation. Consider pulmonary function testing with DLCO in the overall evaluation. Any return to diving in this group should be down slowly, under controlled conditions and always under the close watchful eye of tenders and a buddy during the initial return phase.

Returning to diving after a COVID-19 infection should at a minimum conform to previous recommendations for returning from any serious respiratory infection in addition to consideration of the unique cardiac, vascular and neuro/psych concerns associated with this infection. The sheer numbers of those infected makes it crucial that measures to uncover asymptomatic, significant residual injury be readily available, cost effective and not result in risky follow-up testing after an unnecessary, false positive screening test. Also, incidental findings such as small PFO's or lung cysts that have existed for years and uncovered from blind incorporation of blanket sensitive testing could lead to unnecessary disqualification for some divers.

Most algorithms require classification of the original infection severity to guide the degree of subsequent evaluation. That classification ranges from those who were asymptomatic/mild and those who required oxygen, mechanical ventilation, or organ system support. Several algorithms exist and are included in this summary. As previously discussed, a conservative approach to both the ongoing evaluation and management of these patients was warranted during the early phase of this pandemic. As research on larger numbers of patients becomes available, modification of these

recommendations may continue to occur. As more is learned, these recommendations may require further modification.

A number of algorithms from a variety of diving organizations are included in the Appendix. Some common features and recommendations could be "averaged" and summarized for those diagnosed (positive test and/or symptoms) and fully recovered from a COVID-19 infection as:

- **Asymptomatic, never had symptoms:** Return no earlier than two weeks of diagnosis
- **Mild:** Return no earlier than four weeks after diagnosis
- **Moderate:** Return no earlier than 7-8 weeks after diagnosis; consider echocardiography, chest radiographs and pulmonary function tests including DLCO
- **Severe:** Return no earlier than 12 weeks after diagnosis; recommend echo, EKG, PFT, chest radiographs and possibly chest CT

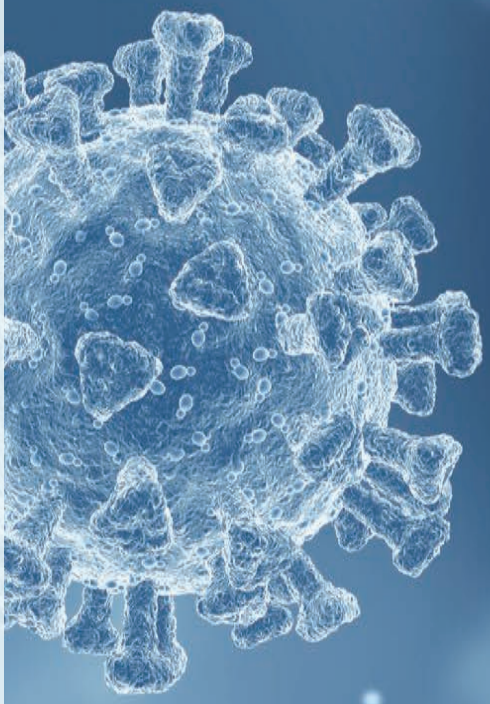
If a fully recovered diver desires to return sooner than the above recommendations for his level of acute infection, then use of a conservative algorithm should be considered that does not utilize the time interval since infection.

Common generally agreed upon recommendations made

1. Review and follow-up any abnormal test finding uncovered during the course of the illness.
2. If performed, imaging studies for routine follow-up after recovery from pneumonia are usually performed after 6–8 week intervals.

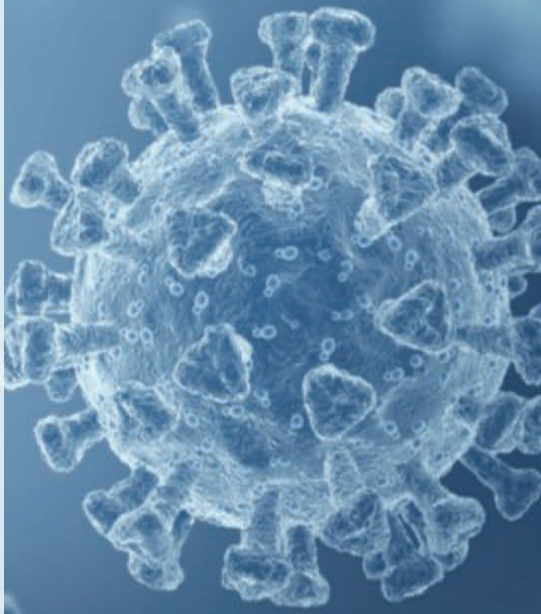
It is with great admiration that the diving community voices its appreciation to those involved in these proceedings who were also simultaneously managing the sickest of COVID-19 patients in overwhelmed hospitals yet able to create rational return to diving algorithms during this pandemic. To quote an insight from Dr. Ott, "we were building the airplane while it was in still in flight". These efforts will no doubt be essential to this pandemics end and as well as a robust return of safe diving activity worldwide. We end with an encouraging note from the Editor-in-Chief, The Lancet Infectious Diseases: Findings from South Africa, plus real-time disease surveillance by public health agencies worldwide, give a strong indication that after 2 years of COVID-19 population immunity generated by vaccination and natural infection is weakening the link between case numbers and severe outcomes.

Richard Moon: I would like to thank all of the panelists for their presentation and their efforts, and I will look forward to working with you in the near future on, on finalizing a document.



Addendum

Published algorithms from other sources



The following are procedures adopted by various diving organizations for returning to dive after a COVID-19 infection. These are included for informational purposes. They reflect many of the points detailed in these proceedings but with unique variations. As more information is obtained, these procedures will undergo revisions. Please note, some have already been revised during the editing of these proceedings and have been included. Since divers follow the fitness to dive guidelines for the organization they are affiliated with, it is important to utilize the most current version. For the most current procedures, contact that respective organization.

THE DIVING MEDICAL ADVISORY COMMITTEE 148

BUMED GUIDANCE FOR UNDERSEA MEDICINE 153

AMERICAN SOCIETY OF ANESTHESIOLOGISTS AND ANESTHESIA PATIENT SAFETY FOUNDATION JOINT STATEMENT 165

AMERICAN ACADEMY OF PEDIATRICS 172

PHYSICIANS DIVING ADVISORY COMMITTEE 174

THE BELGIAN SOCIETY FOR DIVING AND HYPERBARIC MEDICINE (SBMHS-BVOOG) 178

UK DIVING MEDICAL COMMITTEE (UKDMC) 181

IANTD — INTERNATIONAL ASSOCIATION OF NITROX AND TECHNICAL DIVERS 188

SMITHSONIAN SCIENTIFIC DIVING PROGRAM 198

UNIVERSITY OF CALIFORNIA SAN DIEGO (UCSD) 199

The Diving Medical Advisory Committee

DMAC, 66 Buckingham Gate, London SW1E 6AU, UK
Tel: +44 (0) 20 7824 5520

www.dmac-diving.org
info@dmac-diving.org

Return to Diving after COVID-19

DMAC 33 Rev. 3 – February 2022

Supersedes DMAC 33 Rev. 2, which is now withdrawn

1 Introduction and Scope

This guidance covers the return to commercial offshore surface supplied and saturation diving after confirmed or suspected COVID-19. It also contains recommendations for the assessment of fitness for diving duties of asymptomatic offshore commercial divers during the ongoing COVID-19 pandemic. The assessment of asymptomatic divers is necessary to identify potential pulmonary changes in those who contracted the disease but were symptom free. It is recognised that the guidance may be of interest to other diving sectors (e.g. inland/inshore, military etc.).

2 Short-term and Long-term Health Effects of COVID-19

The severity of COVID-19 disease is highly variable – from asymptomatic infection to death. A recent review suggests that the fraction of asymptomatic patients may be as high as 40-50% (1). Although pulmonary infection (pneumonia) with ground-glass opacities visible in chest CT scans is well recognised (2), it has been reported that, particularly in severe cases, the central nervous system and the cardiovascular system may be involved as well (3, 4). Preliminary data suggest a high incidence of pulmonary embolism in patients hospitalised for COVID-19 (5). A high proportion (44-89%) of pulmonary CT changes has been reported in studies of patients with asymptomatic or mildly symptomatic COVID-19 disease (6-8). In a study of cardiopulmonary recovery after COVID-19, the authors found significant improvement of lung abnormalities in chest CT scans 100 days after diagnosis in patients with moderate, severe and critical disease (9). In this study radiological changes for non-hospitalised patients were minor. Overall, the findings suggest that there may be structural pulmonary changes in the absence of symptoms, but these changes are likely to improve over the course of a few months

3 Effects of COVID-19 on Fitness for Diving

In the acute phase of disease, symptoms like fatigue, malaise, dyspnoea and coughing will often preclude diving and will not be further discussed. The question arises as to the consequence for diving safety and infectivity once the diver is asymptomatic. Advice on these questions will be based on extrapolation of data and expectations based on the effects of similar infectious diseases. An example of such an assessment is the one published by the Belgian Hyperbaric Medicine Society (10). This statement discusses the potential consequences for fitness for diving after COVID-19 based on infectivity to other divers, pulmonary barotrauma, cardiac events, pulmonary oxygen toxicity and decompression sickness. The statement does not specify whether it is applicable to diving in general or whether it specifically addresses recreational or occupational diving.

It is the opinion of DMAC that the data on cardiac events, pulmonary oxygen toxicity and decompression sickness after COVID-19 is too scarce to support any guidance. If the chest CT is normal, the likelihood of contracting pulmonary barotrauma is probably very low in the occupational diving industry. The most significant effects of COVID-19 on divers' fitness are probably fatigue, impaired exercise capacity and infectivity. Our recommendations in section 5 below reflect this opinion.

4 Existing Guidelines on Fitness for Diving after COVID-19

The Belgian Hyperbaric Medicine Society calls for a minimum of two, preferably three months, of abstention from diving after COVID-19 (10). The Society recommends extensive pulmonary function testing, high resolution CT scans and cardiac evaluation before diving is resumed for divers who have been hospitalised for COVID-19. The University of California, San Diego, has issued guidelines for examination of recreational, scientific and commercial divers after COVID-19 (11). The guidelines detail requirements for clinical examination, exercise testing (with and without oximetry), chest X-ray, ECG, and echocardiogram. Similar guidelines have been issued by the US Physicians Diving Advisory Committee. The UK Diving Medical Committee (UKDMC) has published guidance on its webpage including a valuable scorecard. It should be noted that UKDMC primarily supports recreational diving.

5 Recommendations for Assessment of Fitness for Commercial Diving during the ongoing COVID-19 Pandemic

DMAC advice is based upon the precautionary principle. We recommend caution and vigilance with respect to the as yet unknown consequences for diving health and safety that previous COVID-19 infection amongst divers may cause. The diving industry is international, and divers are recruited from areas where the proportions of people affected by COVID-19 in populations may be vastly different. As previously mentioned, a significant proportion of persons infected with COVID-19 remain asymptomatic but can still have pulmonary changes on CT scans. Asymptomatic carriers present virus RNA in the same order as symptomatic patients, but data suggest that asymptomatic carriers are less contagious than symptomatic patients (12, 13).

The risk of virus transmission from an infected person is generally considered low from 14 days after debut of symptoms AND at least 48 hours with no fever. PCR testing should not be used to assess infectivity once COVID-19 has been confirmed, as shedding of non-viable virus can continue for many weeks after cessation of infectivity (14). Therefore, the interpretation of a positive PCR result (and subsequent actions) must be discussed with the diving contractor's medical adviser, taking into account medical history, previous results, and other relevant factors.

All divers should be tested for the presence of SARS-CoV-2, as discussed in IMCA Information Note 1563 (15). The timing of such testing should be as recommended by the company diving medical adviser. If applicable, the test method and test equipment should be recognised by the appropriate national regulatory authorities.

The diving contractor is advised to establish a screening procedure to identify divers potentially affected by COVID-19. The screening procedure suggested below would be in addition to any virus-testing (PCR or antigen) conducted. The screening procedure should be applied to all divers – saturation as well as surface oriented – independently of whether they have experienced COVID-19 infection. The reason for this is the high proportion of asymptomatic cases of COVID-19 observed. The contractor's diving medical adviser should supervise the screening, assess the screening results and establish requirements for medical contingency related to the screening. It is advised that screening should take place during mobilisation before each diving project. For surface-oriented diving, the need for repeated tests should be assessed individually by the contractor's diving medical adviser.

The further extent of screening and required medical examinations will depend on the likelihood of COVID-19 short term health effects. For this purpose, we have divided divers into three groups:

1. Asymptomatic divers with no evidence of SARS-CoV-2 infection.
2. Asymptomatic divers with positive SARS-CoV-2 virus test and divers who have suffered COVID-19 with mild symptoms only. Chest x-rays or CT scans in this group are normal or not taken.
3. Divers with moderate or severe symptoms of COVID-19. This includes (but is not limited to) all divers who have been hospitalised with COVID-19, divers who have received supplemental oxygen treatment, divers who have shown signs or symptoms of hypoxemia, any cardiac or neurological symptom, and divers with changes in chest x-rays or CT scans secondary to COVID-19.

For all divers (Group 1, 2 and 3) we recommend:

- Testing of physical fitness capacity should be considered before each mobilisation for surface supplied divers in group 1 based on a risk assessment including factors such as COVID-19 vaccine status and national disease incidence. The test should be mandatory for group 2 and 3 surface supplied divers. For saturation divers whose access to medical review is limited once mobilised, we suggest that the test is performed pre

deployment/mobilisation for each of the groups 1, 2, and 3. The purpose of the test is to identify health effects of asymptomatic and symptomatic COVID-19 disease. IMCA D 061 (16) provides details of such tests, e.g. the Chester Step Test (CST), however it is expected that a maximal exercise test would have a higher sensitivity of detection of symptoms and hypoxemia.

- The diver should be monitored for SpO_2 during the test, if possible. Exercise testing should not take place if resting SpO2<95%. In this case medical guidance on further examination is required.
- The test should be supervised by a trained medic, respiratory technician, nurse or physician and the results should be assessed by the diving contractor's medical adviser.
- The diving contractor's medical adviser should consider referral to a specialist in pulmonary medicine if a decrement of >4% in SpO2 is observed (17) or if there is a significant decrease in physical capacity compared to previous tests.

For divers in group 2 we recommend:

- Divers who have suffered COVID-19 with no or mild symptoms only should observe a seven days absence from diving after the cessation of fever and respiratory symptoms.
- Divers in group 2 may return to diving after the seven day period of absence provided they have two negative antigen test results 24 hours apart and provided they pass the physical fitness pre-deployment/mobilisation test discussed above.
- The diver should be reviewed by a Medical Examiner of Divers (MED) before resumption of diving. The extent and nature of the review is left to the discretion of the MED, but clinical examination is recommended for those who have exhibited mild symptoms.
- When a diver in group 2 has been reviewed as described above and considered fit to dive, later screening should be done as per group 1 guidance.

For divers in group 3 we recommend:

- All divers should be assessed by specialists in pulmonary medicine and cardiology. This should be done in close cooperation with the diving medical examiner or the diving medical adviser.
- The diver's medical fitness for diving should be reassessed by a Medical Examiner of Divers. The examination should comply with the appropriate standard for medical examination and assessment of working divers, and a new certificate of medical fitness should be issued.
- A chest X-ray or CT should be completed in all cases when previous imaging has identified structural changes secondary to the infection, or the diver wants to return to diving earlier than 3 months after being asymptomatic. Abnormal findings on the CXR should be followed up with a chest CT.
- A pulmonary function test, as a minimum including conventional dynamic spirometry, should be completed. Any clinically relevant deterioration from previous measurements should be reviewed by a specialist in pulmonary medicine.
- When a diver in group 3 has been examined as described above and considered fit to dive, later screening should be done as per group 1 guidance.

6 Participation in Commercial Offshore Diving Operations after Vaccination for COVID-19

Several vaccines have been developed and have been proven to prevent COVID-19 effectively. As of 1 December 2021, the World Health Organization (WHO) has validated 8 COVID-19 vaccines for emergency use listing. Data from phase 3 studies of the vaccines (18-20) indicate that they are effective and generally well tolerated. However, mild to moderate local side effects are common, specifically local reactions at the injection site and systemic effects like fatigue, headaches and chills. Systemic side effects are more common after dose 2 of the vaccine. The median onset of systemic side effects was 1-2 days after injection and duration generally 1-2 days. More serious side effects have been reported, but these are very rare. As with all other vaccines, there is a small risk of serious allergic reactions immediately after vaccination. There have also been reports of blood clotting and inflammatory heart conditions that may be linked to vaccinations. In the Norwegian Medicines Agency report on suspected adverse

reactions to COVID-19 vaccines published on September 2021, the frequency of serious side effects is 3.7 cases per 10,000 vaccinations (20). This is probably a high estimate, as it is based on reports of possible, not confirmed, side effects.

Side effects after vaccination may temporarily reduce the work ability of the diver and may also be confused with symptoms of decompression illness. The risk of side effects should therefore be considered carefully for divers participating in offshore diving operations shortly after vaccination. In the Position of the Belgian Society for Diving and Hyperbaric Medicine on Diving and COVID-19 Vaccination (21), the authors recommend divers to consider a waiting period of 7-14 days after vaccination before engaging in diving activities. We have found no evidence to support this as a general recommendation. Based on the available safety data for the vaccines, we consider an abstention period of 2-3 days after vaccination to be sufficient for offshore diving. A similar abstention period has been suggested by the Italian Diving and Hyperbaric Medical Society (22).

Vaccination will significantly reduce the risk of severe COVID-19 infection and may also reduce human to human transmission of the SARS-CoV-2 virus. DMAC has issued a Position Statement on COVID-19 Vaccination and the Offshore Energy Diving Community recommending strongly that offshore divers and diving personnel follow national guidelines for vaccination.

It should be noted that although COVID-19 vaccination significantly reduces the risk of infection, it does not eliminate it. The SARS-CoV-2 Omicron variant identified Nov 2021 is associated with higher transmissibility than previous variants. It should be noted that persons who have been vaccinated, or have had COVID-19 with previous variants, are still capable of contracting and transmitting the virus. All divers and diving contractors are therefore urged to maintain compliance with preventative measures, and to continually monitor for symptoms of COVID-19 disease.

7 References

1. Ma Q, Liu J, Liu Q, Kang L, Liu R, Jing W, et al. Global Percentage of Asymptomatic SARS-CoV-2 Infections Among the Tested Population and Individuals With Confirmed COVID-19 Diagnosis: A Systematic Review and Meta-analysis. JAMA Network Open. 2021;4(12):e2137257-e.
2. Lai CC, Liu YH, Wang CY, Wang YH, Hsueh SC, Yen MY, et al. Asymptomatic carrier state, acute respiratory disease, and pneumonia due to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2): Facts and myths. J Microbiol Immunol Infect. 2020.
3. Asadi-Pooya AA, Simani L. Central nervous system manifestations of COVID-19: A systematic review. J Neurol Sci. 2020;413:116832.
4. Guzik TJ, Mohiddin SA, Dimarco A, Patel V, Savvatis K, Marelli-Berg FM, et al. COVID-19 and the cardiovascular system: implications for risk assessment, diagnosis, and treatment options. Cardiovascular Research. 2020.
5. Grillet F, Behr J, Calame P, Aubry S, Delabrousse E. Acute Pulmonary Embolism Associated with COVID-19 Pneumonia Detected by Pulmonary CT Angiography. Radiology. 2020:201544.
6. Bandirali M, Sconfienza LM, Serra R, Brembilla R, Albano D, Pregliasco FE, et al. Chest Radiograph Findings in Asymptomatic and Minimally Symptomatic Quarantined Patients in Codogno, Italy during COVID-19 Pandemic. Radiology. 2020;295(3):E7-E.
7. Parry AH, Wani AH, Yaseen M, Shah NN, Dar KA. Clinicoradiological course in coronavirus disease-19 (COVID-19) patients who are asymptomatic at admission. BJR|Open. 2020;2(1):20200033.
8. Uysal E, Kilinçer A, Cebeci H, Özer H, Demir NA, Öztürk M, et al. Chest CT findings in RT-PCR positive asymptomatic COVID-19 patients. Clinical imaging. 2021;77:37-42.
9. Sonnweber T, Sahanic S, Pizzini A, Luger A, Schwabl C, Sonnweber B, et al. Cardiopulmonary recovery after COVID-19: an observational prospective multicentre trial. Eur Respir J. 2021;57(4).
10. Société Belge de Médicine Hyperbare et Subaquatique. Position of the Belgian Society for Diving and Hyperbaric Medicine (SBMHS-BVOOG) on Diving after COVID-19 pulmonary infection [18.10.2021]. Available from: http://www.sbmhs.be/2020%200412%20Position%20of%20the%20BVOOG.pdf.
11. Sadler C, Alvarez Villela M, Van Hoesen K, Grover I, Lang M, Neuman T, et al. Diving after SARS-CoV-2 (COVID-19) infection: Fitness to dive assessment and medical guidance. Diving Hyperb Med. 2020;50(3):278-87.
12. Buitrago-Garcia D, Egli-Gany D, Counotte MJ, Hossmann S, Imeri H, Ipekci AM, et al. Occurrence and transmission potential of asymptomatic and presymptomatic SARS-CoV-2 infections: A living systematic review and meta-analysis. PLoS Med. 2020;17(9):e1003346.

13. Lee S, Kim T, Lee E, Lee C, Kim H, Rhee H, et al. Clinical Course and Molecular Viral Shedding Among Asymptomatic and Symptomatic Patients With SARS-CoV-2 Infection in a Community Treatment Center in the Republic of Korea. JAMA Intern Med. 2020.
14. Cevik M, Tate M, Lloyd O, Maraolo AE, Schafers J, Ho A. SARS-CoV-2, SARS-CoV, and MERS-CoV viral load dynamics, duration of viral shedding, and infectiousness: a systematic review and meta-analysis. The Lancet Microbe. 2020.
15. International Marine Contractors Association. Novel Coronavirus (COVID-19) - Guidance for Diving Contractors IMCA; 2021. Report No.: IMCA Information Note No 1563 - May 2021. Accessed:17.10.2021 from: https://imcaweb.blob.core.windows.net/wp-uploads/2021/06/1563.pdf.
16. International Marine Contractors Association. Guidance on Health, Fitness and Medical Issues in Diving Operations. IMCA; 2018. Report No.: IMCA D 061.
17. Forman DE, Myers J, Lavie CJ, Guazzi M, Celli B, Arena R. Cardiopulmonary exercise testing: relevant but underused. Postgrad Med. 2010;122(6):68-86.
18. US Food and Drug Administration. Vaccines and Related Biological Products Advisory Committee Meeting December 10, 2020. FDA Briefing Document. Pfizer-BioNTech COVID-19 Vaccine 2020 [18.10.2021]. Available from: https://www.fda.gov/media/144245/download.
19. US Food and Drug Administration. Vaccines and Related Biological Products Advisory Committee Meeting December 17, 2020. FDA Briefing Document. Moderna COVID-19 Vaccine 2020 [18.10.2021]. Available from: https://www.fda.gov/media/144434/download.
20. Norwegian Medicines Agency. Reported suspected adverse reactions to COVID- 19 vaccines as of 14.09.2021. 2021. Accessed:18.10.2021 from: https://legemiddelverket.no/Documents/English/COVID-19/20210917%20Reported%20suspected%20adverse%20reactions%20coronavirus%20vaccines.pdf.
21. Société Belge de Médicine Hyperbare et Subaquatique. Position of the Belgian Society for Diving and Hyperbaric Medicine on Diving and COVID-19 Vaccination 2021 [updated 18.10.2021. Available from: http://www.sbmhs.be/2021%200326%20SBMHS%20-%20Vaccination%20COVID%20ENG%20final.pdf.
22. Società Italiana di Medicina Subacquea ed Iperbarica SIMSI [The Italian Diving and Hyperbaric Society]. Raccomandazioni sulle ripresa delle attivita' iberbariche in soggetti sottoposti a vaccinaziona anti COVID19 [Recommendations on the resumption of hyperbaric activities in subjects vaccinated for COVID-19] [26.1.2022]. Available from: https://simsi.it/wp-content/uploads/2019/03/Vaccini_COVID_e_immersioni.pdf.

UNCLASSIFIED

Undersea Medicine Sub-Community
–
COVID-19 Return to Dive/ Special Operations Duty Status
BUMED Guidance for Undersea Medicine

20 May 2021 at 2100 EDT

POC: CAPT Mike Tripp,
michael.s.tripp.mil@mail.mil

UNCLASSIFIED

Reference: Medical Evaluation and ECG

Current Screening Strategies in Athletes After COVID-19:

Currently, there are very limited available data on the prevalence of COVID-19 cardiac involvement in athletes, and on the diagnostic performance of the recommended testing modalities included in consensus screening guidelines. Given that the efficacy of a screening program hinges on these factors, it is expected that screening recommendations will continue to evolve in parallel with available data on COVID-19 illness in athletes. Until such data are available, general principles from the implementation of the pre-pandemic pre-participation physical evaluation serve a foundation for current recommendations.

First, a focused medical history and examination are a commonsense launching point. Many athletes may be asymptomatic or experience nonspecific symptoms that they do not recognize as being associated with COVID-19 and will remain entirely asymptomatic at the time of RTP evaluation. Other athletes may have nonspecific malaise, reduced exercise tolerance, recurrent chest pain, dyspnea, or palpitations at the time of illness, which may persist into convalescence. The evaluation of athletes with persistent symptoms after recovery from acute COVID-19 will be guided by the nature of the symptoms, whereas the evaluation of the asymptomatic athlete will be oriented around screening for subclinical pathology.
Second, data from the pre-pandemic pre-participation physical evaluation suggest the inclusion of additional testing above the most basic tests will invariably improve the sensitivity of screening. However, the addition of more layers to screening in athletes post–COVID-19, specifically the widespread use of more advanced imaging, may come at the cost of reduced specificity for identification of clinically meaningful pathology, particularly if there is a paucity of experience in identifying what constitutes normal, adaptive cardiac remodeling in an athlete. A more comprehensive strategy inclusive of advanced imaging modalities, such as cardiac magnetic resonance (CMR) imaging, also calls into question the practical issues of health care expenditures, qualified technical expertise, and unproven clinical efficacy. Although there have been some variations and updates in the published RTP CV screening recommendations, a moderately conservative approach that accounts for these practical issues has generally been recommended (1–3,20,21) with the combination of an electrocardiogram (ECG), cardiac biomarker assessment, and imaging with transthoracic echocardiography (TTE) generally accepted as a reasonable risk stratification RTP strategy in certain athletes depending on their perceived risk (1,20). This testing strategy also aligns with published recommendations for testing in the evaluation of suspected myocarditis (22). Because available health care resources and expenditures must also be appreciated, RTP without CV risk stratification in clearly identified, low-risk cases of COVID-19 may be reasonable, so long as clinical observation is easily accessible and physical training resumes in a progressive and deliberate manner.[1]

[1] Journal of the American College of Cardiology: Screening of Potential Cardiac Involvement in Competitive Athletes Recovering from COVID-19. 2020 Dec. https://doi.org/10.1016/j.jcmg.2020.10.005.

UNCLASSIFIED

Reference: PFT and Exercise Screening Test

Pulmonary Function Tests (PFT):

COVID-19 patients can show diffuse alveolar damage on postmortem histopathology in patients with radiographic bilateral ground-glass opacities.[1] PFT is the gold standard in evaluating alveolar injury compared to spirometry because spirometry can be normal with early or mild disease while PFT will still show low DLCO.[2,3]

In remote locations or for operational expediency, physicians may use spirometry when PFT is not available in conjunction with an **exercise screening test**. Spirometry FVC will be considered abnormal below 80% of predicted instead of 70% considering this is the normal cut off for 18 years of age and Divers require optimal pulmonary performance.[2] If spirometry FVC is below 80% of predicted, pulmonary consult and imaging is required to evaluate sequelae from COVID-19.

[1] American College of Physicians: COVID-19: An ACP Physician's Guide + Resources. 20 May 2020.
[2] Johnson JD, Theurer WM. A stepwise approach to the interpretation of pulmonary function tests. *Am Fam Physician.* 2014;89(5):359-3
[3] European Respiratory Journal: Interpretative strategies for lung function tests. 05 April 2005. https://www.thoracic.org/statements/resources/pft/pft5.pdf

UNCLASSIFIED

Reference: Exercise Screening Test

Exercise Screening Test with Monitored SpO_2 and Heart Rate:
SpO_2 alone is unable to measure ventilation but is a noninvasive method of assessing oxygenation. SpO_2 monitored while Divers are moderately exercising for 10 minutes will screen for functional decline in respiratory function.

Exercise Screening Test Protocol

1. Initially screen SpO_2 and heart rate (HR) at rest (sitting for five minutes). If resting SpO_2 less than or equal to 96%, then do not proceed, evaluate patient for pulmonary pathology/abnormalities. Consult pulmonary for evaluation to include PFT (DLCO) and chest CT.
2. Have SM start exercise on a treadmill or elliptical or exercise bike. Once at a moderate exercise heart rate (HR 120-130), monitor SpO_2 and HR for 10 minutes of moderate exercise. An exertional SpO_2 less than or equal to 88% or a decrease of 5% or more from resting baseline is a positive test needing pulmonary or cardiology evaluation.

Note: SpO_2 and HR should be back to baseline 30 minutes after test

UNCLASSIFIED

Sub-Community Contributors

The following individuals are subject matter experts from across the Enterprise that contributed to the development of return to diving duty guidance. These individuals represent a variety of clinical backgrounds and military experiences relevant to the delivery of undersea, diving, and radiation medicine.

Undersea Medicine Sub-Community Team Members	
CAPT Mike Tripp, Chair, BUMED Undersea Sub-Community	CDR Joy Dierks – Deputy Chair, BUMED Undersea Sub-Community
CAPT Jonathan Lieske - Force Surgeon, Marine Corps Special Operations Command	CAPT (sel) Thomas Baldwin – Force Medical Officer, COMSUBLANT
CAPT Lanny Littlejohn – Force Medical Officer, Naval Special Warfare	
CAPT James (Jim) Mucciarone – Force Medical Officer, COMSUBPAC, Undersea Medicine Specialty Leader (SL)	CDR Brian Keuski – Senior Medical Officer, Naval Diving and Salvage Training Center (NDSTC)
CAPT David Regis – Naval Sea Systems Command (NAVSEA)	
CAPT Thomas Robinson – Department Head, Biomedical Research (N32), Navy Experimental Diving Unit	LT Eugen Goeser – Undersea Medical Officer, SUBASE Kings Bay GA
CAPT Anthony Tucker – Force Surgeon, Naval Expeditionary Combat Command	
CAPT Edward (Ted) Waters – Undersea Medical Officer (UMO), Undersea Rescue Command	LT Nathan Lorei – UMO, NHC Charleston

Disclaimer:

The **Operational Medicine Clinical Community** (OpMed CC) mission is to foster collaboration and knowledge sharing across Naval Medicine to implement leading practices that improve medical readiness, while also supporting operational clinicians and staff in delivering the highest quality care to all Active Duty Sailors and Marines.

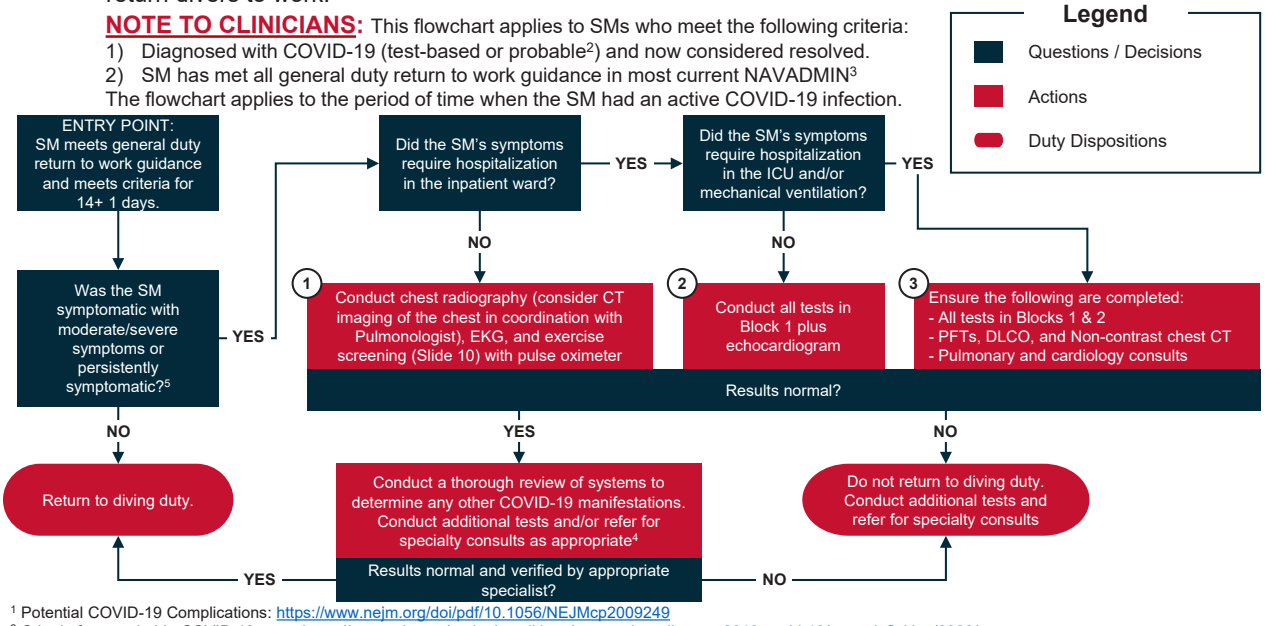
The **Undersea Medicine Sub-Community** (SC), under the Navy's OpMed CC, has the goal of "supporting undersea and radiation health medical clinicians and staff through the promotion of best practices" and an objective to "decrease variation and increase standardization in the delivery of patient care in operational environments." The Undersea Medicine SC responded to the COVID-19 pandemic by generating the protocols contained in this document. **These protocols reflect official Navy Medicine guidelines** in this format and are the best recommendations as of this time from BUMED for returning service members to diving duty status.

UNCLASSIFIED

Return to Dive/ Special Operations Duty Status Protocol

The Undersea Medicine Sub-Community (SC) is recommending Undersea Medical Officers use the following protocol to determine whether service members (SMs) who are divers can return to diving duty after recovering from COVID-19. Return to Work (Diving) evaluations should consider all potential COVID-19 complications.[1] These complications can be elicited in a thorough review of systems and focused examination. This flowchart provides a basic framework and should not substitute for sound clinical judgement. Additional work-up, testing and specialty consult may be required on a case by case basis to return divers to work.

NOTE TO CLINICIANS: This flowchart applies to SMs who meet the following criteria:
1) Diagnosed with COVID-19 (test-based or probable[2]) and now considered resolved.
2) SM has met all general duty return to work guidance in most current NAVADMIN[3]
The flowchart applies to the period of time when the SM had an active COVID-19 infection.



[1] Potential COVID-19 Complications: https://www.nejm.org/doi/pdf/10.1056/NEJMcp2009249
[2] Criteria for a probable COVID-19 case: https://www.cdc.gov/nndss/conditions/coronavirus-disease-2019-covid-19/case-definition/2020/
[3] Current NAVADMIN on COVID-19 Standardized Operational Guidance: https://www.public.navy.mil/bupers-npc/reference/messages/NAVADMINS/Pages/NAVADMIN2020.aspx
[4] See Slide 4 for additional testing/consult implications based on a thorough review of systems.
[5] Persistent symptoms may include fatigue, exercise intolerance, or other cardiopulmonary symptoms, as defined by DOD PMG 03/01/21 appendix K, page 180

UNCLASSIFIED

Suggestions on Testing & Specialty Consults

If the SM tested positive for COVID-19 and was symptomatic, the below table outlines suggestions on appropriate testing and specialty consults, based on a thorough review of systems.

COVID-19 Manifestation by System	Suggested Test(s)	Suggested Consult(s)
Pulmonary / Respiratory	Office-based pulmonary function testing including plethysmography and diffusing capacity for carbon monoxide (DLCO) Exercise Stress Test with Pulse Oximeter HR Computerized Tomography (CT) of chest	Pulmonologist
Cardiac	Electrocardiogram (ECG/EKG) Echocardiogram (Echo)	Cardiologist
Neurologic	Diver Neurological Exam CT or Magnetic Resonance Imaging (MRI) of head	Neurologist
Hematologic	Complete Blood Count (CBC)	Hematologist
Renal	Urinalysis Comprehensive Metabolic Panel (CMP)	Nephrologist
Hepatic	Liver Function Tests	Hepatologist or Gastroenterologist
Gastrointestinal	As directed by specialist	Gastroenterologist
Endocrine	As directed by specialist	Endocrinologist

UNCLASSIFIED

Undersea Medicine References

UNCLASSIFIED

Reference: Clinical Criteria for Case Definition

"A surveillance case definition is a set of uniform criteria used to define a disease for public health surveillance. Surveillance case definitions enable public health officials to classify and count cases consistently across reporting jurisdictions. Surveillance case definitions are not intended to be used by healthcare providers for making a clinical diagnosis or determining how to meet an individual patient's health needs."[1]

Use the Clinical Criteria for guidance, not as an alternative to clinical judgement

Clinical Criteria:

At least **two** of the following symptoms: fever (**measured or subjective**), chills, rigors, myalgia, headache, sore throat, **new** olfactory and taste disorder(s).

OR

At least **one** of the following symptoms: cough, shortness of breath, or difficulty breathing.

OR

Severe respiratory illness with at least one of the following:
Clinical or radiographic evidence of pneumonia.

OR

Acute respiratory distress syndrome (ARDS).

AND

No alternative more likely diagnosis.[1, 2]

Note: Anosmia, hyposmia, and dysgeusia are unique to SARS-CoV-2 and infection should be strongly considered in patients without other respiratory disease, even without other symptoms.[3]

[1] THE COUNCIL OF STATE AND TERRITORIAL EPIDEMIOLOGIST(CSTE) CRITERIA FOR A PROBABLE COVID-19 CASE: https://www.cdc.gov/nndss/conditions/coronavirus-disease-2019-covid-19/case-definition/2020/
[2] Infectious Diseases Society of America Guidelines on the Diagnosis of COVID-19 https://www.idsociety.org/practice-guideline/covid-19-guideline-diagnostics/
[3] American Academy of Otolaryngology – Head and Neck Surgery. Coronavirus Disease 2019: Resources, Anosmia, Hyposmia, and Dysgeusia Symptoms of Coronavirus Disease. Mar 2020.

UNCLASSIFIED

Reference: DOD PMG 03/01/21 (Appendix K, page 180)

COVID-19 Infection:

Mild COVID-19 infection - Defined as symptoms of nausea, vomiting, diarrhea, anosmia or ageusia, nasal congestion, or self-limiting fatigue.

Moderate COVID-19 infection - Defined as symptoms of persistent fever (at least 100.4), persistent myalgias, persistent fatigue (persistent defined as at least 7 days in duration), hypoxia or pneumonia, and /or cardiopulmonary symptoms (chest pain not associated with cough, activity limiting dyspnea, orthopnea, palpitations, syncope).

Severe COVID-19 infection - Defined as symptoms of persistent fever (at least 100.4), persistent myalgias, persistent fatigue (persistent defined as at least 7 days in duration), hypoxia or pneumonia, and /or cardiopulmonary symptoms (chest pain not associated with cough, activity limiting dyspnea, orthopnea, palpitations, syncope) requiring hospitalization for medical treatment and respiratory support (supplemental oxygen or above).

UNCLASSIFIED

Reference: Laboratory Criteria

Laboratory evidence should be obtained by using a method approved or authorized by the U.S. Food and Drug Administration or designated authority.[1] Available test types will vary location to location and therefore so will the sensitivity and specificity.

Confirmatory Laboratory Evidence:
Detection of severe acute respiratory syndrome coronavirus 2 ribonucleic acid (SARS-CoV-2 RNA) in a clinical specimen using a molecular amplification detection test.

Common test type available is the real time reverse transcription Polymerase Chain Reaction (RT-PCR) and specimens are obtained either by nasopharyngeal or oropharyngeal swab.
Nasopharyngeal is preferred as it is more sensitive[2]

Negative tests cannot rule out COVID-19 with clinical suspicion. Meta-analysis of testing false negative rate shows decreases from 100% on day 1 post-exposure to low of 20% on day 8 (on average symptom day 3) followed by an increase to 66% on day 21. The best day to obtain the lowest chance of a false negative test is day three of fever/symptoms or alternatively day eight in close contact SMs. Therefore, RT-PCR testing has limited ability to rule out COVID-19 on the basis of a single point-in-time upper respiratory tract sample.[2] Overall false negative rate for COVID testing is thought to be around 30%. This may vary from lab to lab and depends on technique with nasopharyngeal swabs. High pre-test probability patients based on clinical presentation should be in isolation and have repeat testing even if testing is initially negative.[3]

Testing for Fleet screening or host country protocol will be determined by those agents

[1] THE COUNCIL OF STATE AND TERRITORIAL EPIDEMIOLOGIST(CSTE) CRITERIA FOR A PROBABLE COVID-19 CASE: https://www.cdc.gov/nndss/conditions/coronavirus-disease-2019-covid-19/case-definition/2020/
[2] American College of Physicians: COVID-19: An ACP Physician's Guide + Resources. 8 June 2020.
[3] Evergreen Health Lessons Learned: COVID-19 https://www.evergreenhealth.com/covid-19-lessons

UNCLASSIFIED

Reference: Medical Evaluation and ECG

Medical Evaluation:

Complete medical evaluation to include at a minimum, assessment of fatigue, anorexia, headaches, anosmia, and cardiac, ENT, neurologic, and respiratory exams.[1] Address all medications and prior waivers granted. ECG changes or any cardiac symptoms (arrhythmia, angina, prolonged QT interval, limited exercise tolerance) will require cardiology consult. PFT changes or any respiratory symptoms (SpO_2 ≤95%, shortness of breath, limited exercise tolerance, etc.) will require pulmonology consult.

Evaluations must be done face-to-face and may not be done via telehealth

Electrocardiogram (ECG):

ECGs to be performed based on recommendations from the American College of Cardiology in physically active populations with symptomatic COVID-19 due to a 22x increase in significant cardiac morbidity in hospitalized COVID-19 patients. ECG findings that may indicate myocardial injury include pathological Q waves, ST segment depressions, (new) diffuse ST segment elevation, and T wave inversions that are outside of the normal parameters.[2] If treatment included hydroxychloroquine, a **manually** calculated QT interval is required. Automated QT intervals are based on the Bazett formula and can overestimate the QT interval, especially at elevated heart rates.[3,4] Recommend using Hodges formula for manual calculation.[4] On-line calculator is located here: https://www.mdcalc.com/corrected-qt-interval-qtc

[1] JAMA Cardiology: Coronavirus Disease 2019 and the Athletic Heart: Emerging Perspectives on Pathology, Risks, and Return to Play. 2021 Feb. jamacardiology_kim_2020_sc_200003_1612387652.26945%20(1).pdf
[2] A Game Plan for the Resumption of Sport and Exercise After COVID-19 Infection. https://jamanetwork.com/journals/jamacardiology/fullarticle/2766124
[3, 4] Journal of the American College of Cardiology: International Recommendations for Electrocardiographic Interpretation in Athletes. 2017 Feb. http://dx.doi.org/10.1016/j.jacc.2017.01.015.

American Society of Anesthesiologists and Anesthesia Patient Safety Foundation Joint Statement on Elective Surgery/Procedures and Anesthesia for Patients after COVID-19 Infection

Published: March 9, 2021
Last updated: February 22, 2022

Since hospitals are able to continue to perform elective surgeries while the COVID-19 pandemic continues, determining the optimal timing of procedures for patients who have recovered from COVID-19 infection and the appropriate level of preoperative evaluation are challenging given the current lack of evidence or precedent. The following guidance is intended to aid hospitals, surgeons, anesthesiologists, and proceduralists in evaluating and scheduling these patients. The updated recommendations detailed in this document are based upon new evidence that has come to light over the past year. The recommendations will be subject to continued evolution as new evidence emerges.

Elective surgeries should be performed for patients who have recovered from COVID-19 infection only when the anesthesiologist and surgeon or proceduralist agree jointly to proceed. The decision for surgery/procedure is centered on two factors: 1. Is the patient still infectious? and 2. For patients that are no longer infectious what is the appropriate length of time to wait between recovery from COVID and surgery/procedure in terms of risk to the patient.

What determines when a patient confirmed to have COVID-19 is no longer infectious?

The Centers for Disease Control and Prevention (CDC) provides guidance for physicians to decide when transmission-based precautions (e.g., isolation, use of personal protective equipment and engineering controls) may be discontinued for hospitalized patients, or home isolation may be discontinued for outpatients.[1]

Patients infected with SARS-CoV-2, as confirmed by reverse transcriptase-polymerase chain reaction (RT-PCR) testing of respiratory secretions, may be asymptomatic or symptomatic. The National Institutes of Health has recently updated the categories of SARS-CoV-2 infection into the following phenotypic expressions of COVID severity.[2] (see Appendix I for full description).

- *Asymptomatic or Presymptomatic Infection*
- *Mild Illness.*
- *Moderate Illness*
- *Severe Illness*
- *Critical Illness*

Severely immunocompromised patients, whether suffering from asymptomatic or symptomatic COVID-19, are considered separately.

Current data indicate that, in patients with mild to moderate COVID-19, repeat RT-PCR testing may detect SARS-CoV-2 RNA for a prolonged period after symptoms first appear. According to the Centers for Disease Control and Prevention (CDC), it is rare to recover replication-competent virus after **10 days**

from onset of symptoms, except in people who have severe COVID-19 or who are moderately or severely immunocompromised.

Considering this information, the CDC recommends that physicians use a time- and symptom-based strategy to decide when patients with COVID-19 are no longer infectious.

For patients with confirmed COVID-19 infection the CDC recommends discontinuing isolation and other transmission-based precautions per the following:[1]

- ***Children and adults with mild, symptomatic COVID-19:*** *Isolation can end at least 5 days after symptom onset and after fever ends for 24 hours (without the use of fever-reducing medication) and symptoms are improving, if these people can continue to properly wear a well-fitted mask around others for 5 more days after the 5-day isolation period. Day 0 is the first day of symptoms.*
- ***People who are infected but asymptomatic (never develop symptoms):*** *Isolation can end at least 5 days after the first positive test (with day 0 being the date their specimen was collected for the positive test), if these people can continue to wear a properly well-fitted mask around others for 5 more days after the 5-day isolation period. However, if symptoms develop after a positive test, their 5-day isolation period should start over (day 0 changes to the first day of symptoms)**
- ***People who have moderate COVID-19 illness:*** *Isolate for 10 days.*
- ***People who are severely ill (i.e., requiring hospitalization, intensive care, or ventilation support):*** *Extending the duration of isolation and precautions to at least 10 days and up to 20 days after symptom onset, and after fever ends (without the use of fever-reducing medication) and symptoms are improving, may be warranted.*
- ***People who are moderately or severely immunocompromised might have a longer infectious period:*** *Extend isolation to 20 or more days (day 0 is the first day of symptoms or a positive viral test). Use a test-based strategy and consult with an infectious disease specialist to determine the appropriate duration of isolation and precautions.*

*The additional 5-day isolation period with masking for asymptomatic and mildly symptomatic patients has no practical implication in anesthesia care. Patients in these categories should be considered infectious for anesthesia care purposes for the full 10 days.

Consultation with infection control experts is strongly advised prior to discontinuing precautions for patients with severe to critical illness or who are severely immunocompromised. Clinical judgment ultimately prevails when deciding whether a patient remains infectious. Maintaining transmission-based precautions and repeat RT-PCR testing may be appropriate if clinical suspicion of ongoing infection exists.

If a patient suspected of having SARS-CoV-2 infection is never tested, the decision to discontinue transmission-based precautions can be made using the symptom-based strategy described above.

Other factors, such as advanced age, diabetes mellitus, or end-stage renal disease, may pose a much lower degree of immunocompromise; their effect upon the duration of infectivity for a given patient is not known.

Ultimately, the degree of immunocompromise for the patient is determined by the treating provider, and preventive actions are tailored to each individual and situation.

What is the appropriate length of time between recovery from COVID-19 and surgery/procedure with respect to minimizing postoperative complications?

Currently there is a backlog of surgical procedures that have been delayed but are necessary to improve the health and quality of life of our patients. Although there is increasing information to address the timing of surgery after COVID-19 infection, studies continue to lag behind the emerging variants and the likelihood that vaccinated patients have a lower a risk of postoperative complications as compared to unvaccinated patients.[3] Almost all available data come from study periods with zero to low prevalence of vaccination.

The preoperative preparation of a surgical patient who is recovering from COVID-19 involves evaluation and optimization of the patient's medical conditions and physiologic status. Since COVID-19 can impact virtually all major organ systems, the timing of surgery after a COVID-19 diagnosis is important when considering the risk of postoperative complications. Heretofore, protocols have been based on limited data specific to SARS-CoV-2, expert opinion, and previous data from other post-viral syndromes.

An early limited study of 122 patients found a significantly higher risk of pulmonary complications within the first four weeks after SARS-CoV-2 diagnosis.[4] A Brazilian study of 49 patients who underwent surgery with a median delay of 25 days after asymptomatic COVID-19 did not have increased complications when compared to a cohort of patients with a negative SARS-CoV-2 test.[5]

Subsequently, a multi-country (116 countries), multi-center (1674 hospitals) study, in a mixture of high income and low/middle income countries, followed more than 140,000 patients with 3,127 having COVID-19 infections before surgery. Data were collected from surgery **in October 2020**, meaning that none of these patients had received even one vaccination. They reported increased risks of mortality and morbidity—especially with pulmonary complications--up to 7 weeks post COVID diagnosis, although the confidence interval for patients in the 5-6 week cohort suggests that there may not be a true difference in this group.[6] This data found increased risks to be present at 5-6 weeks regardless of being asymptomatic or symptomatic, older or younger than 70, having major or minor surgery, or undergoing elective or emergency surgery. Mortality data is summarized in the table below. Finally, patients with ongoing symptoms at ≥7 weeks were at increased risk for complications versus patients without symptoms.

Interval Between COVID Diagnosis and Surgery	30-day Mortality Rate for Elective Patients (%, CI)**
No COVID Diagnosis	0.62 (0.57-0.67)
0-2 weeks	3.09 (1.64-4.54)
3-4 weeks	2.29 (1.06-3.53)
5-6 weeks	2.39 (0.87-3.91)
≥7 weeks	0.64 (0.20-1.07)

**With a sensitivity analysis.

A second U.S. study covering a timeline of patients with a COVID-19 diagnosis and surgery up to May 31, 2021 reviewed 5479 surgical patients following COVID-19 infection. Immunization status was not given but the study period ranged from a time of zero vaccination until a period when about 30% of the US adult population had received at least one vaccination. The results corroborate the above findings and report higher postop complications of pneumonia and respiratory failure at 0-4 weeks and continued higher postoperative pneumonia complications 4-8 weeks post PCR diagnosis.[7]

Of note, a consensus-based statement from the United Kingdom recommends "delaying surgery, whenever feasible for a minimum of 7 weeks after known SARS-CoV-2 infection."[8]

To date, there are no robust data on patients recovering from more recent Delta and Omicron variants. According to the CDC, the Omicron variant causes less severe disease,[9] and is more likely to reside in the oro- and nasopharynx without infiltration and damage to the lungs. It should also be noted that severity likely varies by vaccination status. Some have extrapolated these facts to a conclusion that risk in patients who are vaccinated and are recovering from Omicron should be less. However plausible, such a conclusion remains unproven. SARS-CoV-2 affects other organ systems beyond the pulmonary system (e.g., thromboembolic events including stroke, myocarditis, renal failure).

RECOMMENDATIONS

1. Elective surgery should be delayed for 7 weeks after a SARS-CoV-2 infection in unvaccinated patients that are asymptomatic at the time of surgery.

2. The evidence is insufficient to make recommendations for those who become infected after COVID vaccination. Although there is evidence that, in general, vaccination reduces post-infection morbidity, the effect of vaccination on the appropriate length of time between infection and surgery/procedure is unknown.

3. Any delay in surgery needs to be weighed against the time-sensitive needs of the individual patient.

4. If surgery is deemed necessary during a period of likely increased risk, those potential risks should be included in the informed consent and shared decision-making with the patient.

5. Extending the above delay should be considered if the patient has continued symptomatology not exclusive of pulmonary symptoms.

6. Any decision to proceed with surgery should consider:
    - The severity of the initial infection
    - The potential risk of ongoing symptoms
    - Comorbidities and frailty status
    - Complexity of surgery

Residual symptoms such as fatigue, shortness of breath, and chest pain are common in patients who have had COVID-19 [10,11]. These symptoms can be present more than 60 days after diagnosis [11]. In addition, COVID-19 may have long term deleterious effects on myocardial anatomy and function [12]. A more thorough preoperative evaluation, scheduled further in advance of surgery with special attention given to the cardiopulmonary systems, should be considered in patients who have recovered from COVID-19 and especially those with residual symptoms.

Is repeat SARS-CoV-2 testing needed?

At present, the CDC does not recommend re-testing for COVID-19 within 90 days of symptom onset [13]. Repeat PCR testing in asymptomatic patients is strongly discouraged since persistent or recurrent positive PCR tests are common after recovery. However, if a patient presents within 90 days and has recurrence of symptoms, re-testing and consultation with an infectious disease expert should be considered. Once the 90-day recovery period has ended, the patient should undergo one pre-operative nasopharyngeal PCR test ideally ≤ three days prior to the procedure.

These recommendations are under continuous review and will be updated as additional evidence becomes available.

References:

1. https://www.cdc.gov/coronavirus/2019-ncov/hcp/duration-isolation.html. Accessed February 15, 2022.

2. https://www.covid19treatmentguidelines.nih.gov/overview/clinical-spectrum. Accessed February 15, 2022.

3. Prasad NK, Lake R, Englum BR, Turner DJ, Siddiqui T, Mayorga-Carlin M, Sorkin JD, Lal BK. COVID-19 vaccination associated with reduced postoperative SARS-CoV-2 infection and morbidity. Ann Surg. 2022 Jan 1;275(1):31-36. doi: 10.1097/SLA.0000000000005176. PMID: 34417362; PMCID: PMC8678152.

4. COVIDSurg Collaborative. Delaying surgery for patients with a previous SARS-CoV-2 infection. British Journal of Surgery 2020;107:e601–2. https://doi.org/10.1002/bjs.12050

5. Baiocchi G, Aguiar S Jr, Duprat JP, Coimbra FJF, Makdissi FB, Vartanian JG, Zequi SC, Gross JL, Nakagawa SA, Yazbek G, Diniz TP, Gonçalves BT, Zurstrassen CE, Campos HGDA, Joaquim EHG, França E Silva IA, Kowalski LP. Early postoperative outcomes among patients with delayed surgeries after preoperative positive test for SARS-CoV-2: A case-control study from a single institution. J Surg Oncol. 2021 Mar;123(4):823-833. doi: 10.1002/jso.26377. Epub 2021 Jan 11. PMID: 33428790; PMCID: PMC8014861.

6. COVIDSurg Collaborative, GlobalSurg Collaborative. Timing of surgery following SARS-CoV-2 infection: an international prospective cohort study. Anaesthesia 2021;76:748–758. doi: 10.1111/anae.15458. Epub 2021 Mar 9. PMID: 33690889; PMCID: PMC8206995.

7. Deng JZ, Chan JS, Potter AL, Chen Y-W, Sandhu HS, Panda N, Chang DC, Yang, CF J. The risk of postoperative complications after major elective surgery in active or resolved COVID-19 in the United States. Ann Surg 2022;275:242-246. doi: 10.1097/SLA.0000000000005308. PMID: 34793348; PMCID: PMC8745943.

8. El-Boghdadly K, Cook TM, Goodacre T, Kua J, Blake L, Denmark S, McNally S, Mercer N, Moonesinghe SR, Summerton DJ. SARS-CoV-2 infection, COVID-19 and timing of elective surgery: A multidisciplinary consensus statement on behalf of the Association of Anaesthetists, the Centre for Peri-operative Care, the Federation of Surgical Specialty Associations, the Royal College of Anaesthetists and the Royal College of Surgeons of England. Anaesthesia 2021;76:940-946. doi: 10.1111/anae.15464. Epub 2021 Mar 18. PMID: 33735942; PMCID: PMC8250763.

9. https://www.cdc.gov/coronavirus/2019-ncov/variants/omicron-variant.html. Accessed February 21, 2022

10. Tenforde MW, Kim SS, Lindsell CJ., et al. Symptom Duration and Risk Factors for Delayed Return to Usual Health Among Outpatients with COVID-19 in a Multistate Health Care Systems Network – United States, March-June 2020. MMWR 2020 Jul 31;69(30):993-998. https://dx.doi.org/10.15585%2Fmmwr.mm6930e1.

11. Carfì A, Bernabei R, Landi F, for the Gemelli Against COVID-19 Post-Acute Care Study Group. Persistent Symptoms in Patients After Acute COVID-19. *JAMA*. 2020;324(6):603–605. doi:10.1001/jama.2020.12603

12. Puntmann VO, Carerj ML, Wieters I, et al. Outcomes of Cardiovascular Magnetic Resonance Imaging in Patients Recently Recovered From Coronavirus Disease 2019 (COVID-19). JAMA Cardiol. 2020;5(11):1265-1273. doi:10.1001/jamacardio.2020.3557

13. https://www.cdc.gov/coronavirus/2019-ncov/hcp/testing-overview.html. Accessed February 15, 2022.

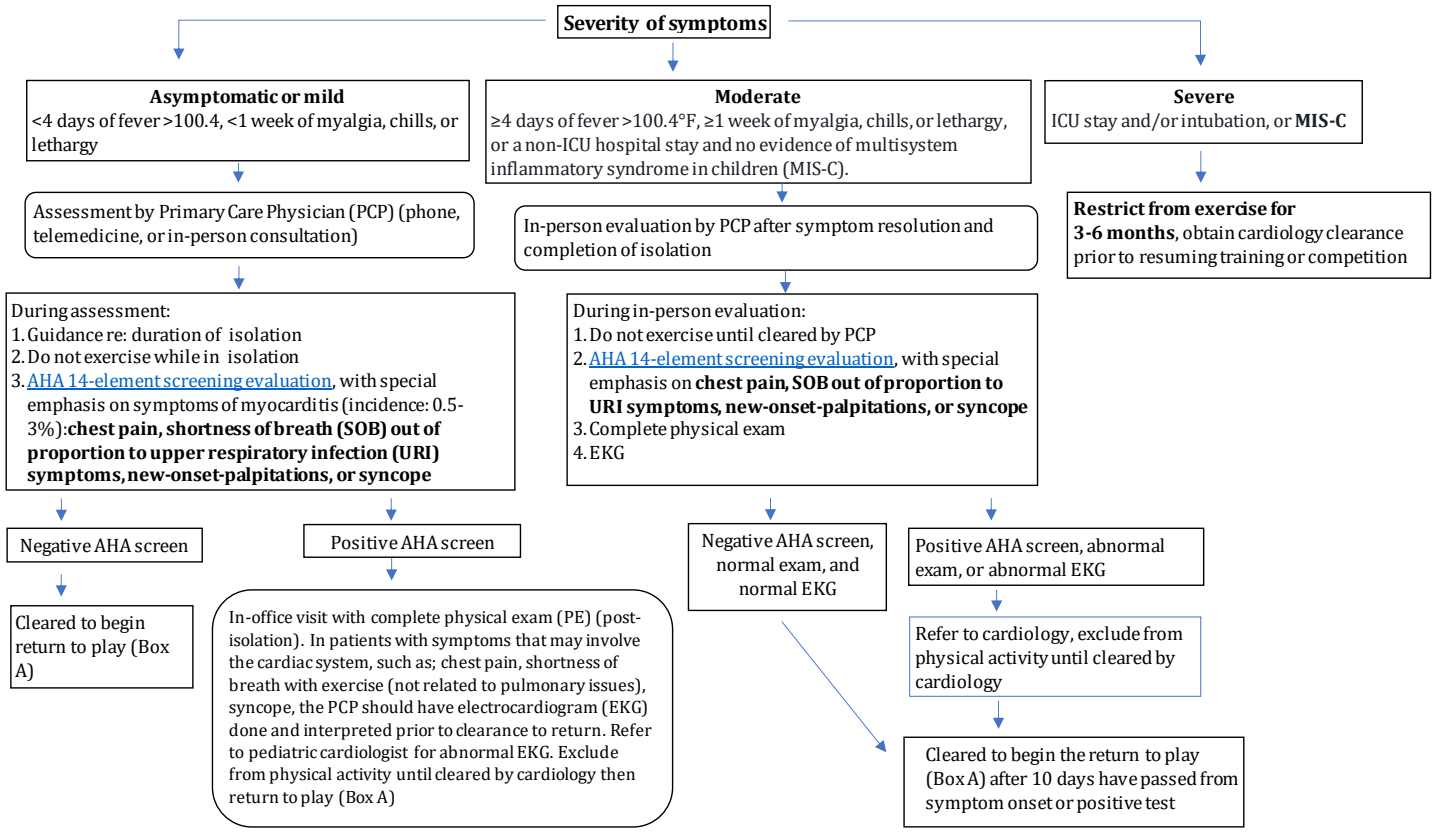
Appendix I

- *Asymptomatic or Presymptomatic Infection: Individuals who test positive for SARS-CoV-2 using a virologic test (i.e., a nucleic acid amplification test [NAAT] or an antigen test) but who have no symptoms that are consistent with COVID-19.*
- *Mild Illness: Individuals who have any of the various signs and symptoms of COVID-19 (e.g., fever, cough, sore throat, malaise, headache, muscle pain, nausea, vomiting, diarrhea, loss of taste and smell) but who do not have shortness of breath, dyspnea, or abnormal chest imaging.*
- *Moderate Illness: Individuals who show evidence of lower respiratory disease during clinical assessment or imaging and who have an oxygen saturation (SpO_2) ≥94% on room air at sea level.*
- *Severe Illness: Individuals who have SpO_2 <94% on room air at sea level, a ratio of arterial partial pressure of oxygen to fraction of inspired oxygen (PaO_2/FiO_2) <300 mm Hg, a respiratory rate >30 breaths/min, or lung infiltrates >50%.*
- *Critical Illness: Individuals who have respiratory failure, septic shock, and/or multiple organ dysfunction.*

AMERICAN ACADEMY OF PEDIATRICS
COVID-19 Interim Guidance: Return to Sports and Physical Activity

Return to play after COVID-19 infection

Adapted from the *AAP COVID-19 Interim Guidance: Return to Sports and Physical Activity* by Anna Zuckerman, MD, FAAP and Jonathan Flyer, MD, FAAP, FACC.
For detailed guidance, please refer to the AAP COVID-19 Interim Guidance: Return to Sports and Physical Activity. (Last updated 1/20/2022)



Return to play after COVID-19 infection

Adapted from the *AAP COVID-19 Interim Guidance: Return to Sports and Physical Activity* by Anna Zuckerman, MD, FAAP and Jonathan Flyer, MD, FAAP, FACC.
For detailed guidance, please refer to the AAP COVID-19 Interim Guidance: Return to Sports and Physical Activity. (Last updated 1/20/2022)

BOX A: Additional Guidance on Returning to Play *(Note: if the patient has already advanced back to physical activity on their own and is without abnormal cardiovascular signs/symptoms, then no further evaluation is necessary. COVID19 disease history should be documented.)*

When should children and adolescents return to play?

1) Completed isolation and minimum amount of symptom free time has passed
2) Can perform all activities of daily living
3) No concerning signs/symptoms
4) Physician clearance has been given, if indicated

At what pace should children and adolescents return to play?

5) <12yo: progress according to own tolerance
6) 12+: gradual return to physical activity
    - Asymptomatic / Mild symptoms: Minimum 1 day symptom free (excluding loss of taste / smell), 2 days of increase in physical activity (i.e. one light practice, one normal practice), no games before day 3. A mask is required for ALL physical activity, including games or scrimmages, until 10 full days from + test or symptom onset have passed.
    - Moderate symptoms: Minimum 1 day symptom free (excluding loss of taste / smell), and a minimum of 4 days of gradual increase in physical activity (one light cardio workout on own, two light practices, one full practice), no games before day 5. A mask is required for ALL physical activity, including games or scrimmages, until 10 full days from + test or symptom onset have passed.

When should children and adolescents pause return to play?

- If patient develops any chest pain, SOB out of proportion to URI infection, new-onset palpitations, or syncope when returning to exercise, immediately stop and go to PCP for in-person exam and consider referral to Pediatric Cardiology

Physicians Diving Advisory Committee

Coronavirus Related Items

Introduction

As the world deals with SARS-CoV-2, the novel coronavirus that causes COVID-19, the Physicians Diving Advisory Committee (PDAC) is issuing a new statement regarding physicals that should be performed on commercial divers or candidates. The purpose of this guidance is to give diving medical examiners advice about parts of medical examinations that may expose their staff and other patients to the virus, and guidance on return to diving on people that have recovered from the virus. Medical examiners will be faced with local or federal laws that must be adhered to and may supersede some of these recommendations. PDAC mandates the use of a questionnaire, and one is provided for those providers who do not currently have one developed. It is expected that divers currently on extension should have their annual examinations as required by the Consensus Standards 6.3 by November 1, 2020.

The prevalence of COVID-19 can be expected to rise until an effective vaccine is developed and given to a majority of the population. Until then, we must assess risk and determine procedures to minimize spread of the virus. The most concerning tests to be considered that may expose staff or other patients are spirometry and exercise stress testing. The following recommendations have been discussed by PDAC regarding these tests.

Recommendations on Initial and Annual Diver Physical Exams during the COVID-19 Pandemic

** The following recommendations assume the diver has not experienced a case of COVID-19 nor symptoms consistent with COVID-19. Divers who have missed multiple consecutive days of work due to a respiratory illness since 1/1/20 should be medically evaluated in consultation with a diving medical examiner prior to return to diving. If the diver does have a history suggestive of COVID infection, please follow the “return to diving” flowsheet addressed in the UCSD Guidelines with a link below.

Initial Examination:

For a new diver presenting for their first evaluation for diving, or a diver who has not been seen for the last 2-3 years it is the recommendation of the PDAC that the candidate completes the entire medical protocol as written in the Consensus Standards 6.3, including spirometry. If your clinic is not able to provide PFT’s in a safe manner, it is recommended that the remainder of the exam be completed and the patient referred to an outside facility for completion of the PFT’s. The American College of Occupational and Environmental Medicine (ACOEM) has information on occupational spirometry and fit testing at:

https://acoem.org/acoem/media/PDF-Library/Publications/Spirometry-and-Fit-Testing-Recommendations-During-COVID-19-7-10-2020.pdf

Rationale: Stable, healthy lung function is critical to reducing the risk of a life-threatening diving injury from arterial gas embolism or pulmonary barotrauma. While imaging (x-ray and CT) can provide essential information about the architecture and structure of the lungs, it does not give us insight into the function of the airways. Pulmonary function studies close the gap and give the physical performance of the airways, and insight into risk.

Annual Examination:

For a returning diver that has a history of stable spirometry (see definition below) and normal interval chest x-rays over the last few years, and no interval history of lung injury or significant irritant exposure,

it is the recommendation of the PDAC that spirometry be waived for the upcoming year. For divers that have had progressively worsening or variable spirometry (see definition below), interval history of significant irritant exposure or pathology on the most recent CXR, it is the recommendation of the PDAC that the candidate completes the entire medical protocol as written, including spirometry. If the physician feels that there is another clinical indication to perform spirometry, then PDAC would support spirometry or full pulmonary function testing. If your clinic is not able to provide spirometry in a safe manner, it is recommended that the remainder of the exam be completed and the patient referred to an outside facility for completion of the spirometry.

Rationale: Lung function and health is primarily a result of lifestyle choices, external exposures, and illness. A detailed interval history and questionnaire can give valuable insight into the likelihood of pulmonary injury. This insight coupled with historical spirometry data and imaging results should be enough to allow the examiner to estimate the likelihood of significant change in lung function. For those divers at low risk of deficit, the risk of spirometry testing during the pandemic outweighs the benefit. For those at intermediate or high likelihood of changes in their spirometry, then such studies would be recommended.

*Acceptable clinic based spirometry are results performed by trained technicians using ATS/ERS standards[1,2,3]. Spirometry results that are greater than 5% decline of prior numbers [FEV1 and/or FVC] over the last 2-3 tests or with a downward trend may indicate the need for ordering formal pulmonary function tests; or at the discretion of the examining physician.

Re-examination After Illness

Divers who have missed multiple consecutive days of work due to a respiratory illness since 1/1/20 should be medically evaluated in consultation with a diving medical examiner prior to return to diving using the UCSD Guidelines for Evaluation of Divers during COVID-19 Pandemic.

https://health.ucsd.edu/coronavirus/Documents/UC%20San%20Diego%20Guidelines%20for%20Evaluation%20of%20Divers%20during%20COVID-19%20pandemic.pdf

Rationale: We are learning more each day about the impact of the COVID 19 virus on the body. The most recent patient reports demonstrate significant injury to the cardiopulmonary system of varying severity and permanence. As such, thorough provocative testing is required to ensure fitness for diving and acceptable recovery from the illness. Detailed imaging and provocative testing (exercise stress, stress echo, etc.) is recommended to ensure cardiac fitness to dive.

Face Coverings in the Offshore Environment

Regarding the uses of masks offshore, the ADCI has published COVID-19 Guidance for Surface Diving Operations. PDAC supports the following that is covered in the document:

Commercial divers and support personnel should use face coverings for the entire duration of a project. Neck gaiters are acceptable. Personnel who remain offshore in excess of 14 days should be required to wear a face covering for the first 14 days while they are offshore. Any “Day Workers” to these locations must wear a face covering for the duration of their stay. Any dive operation that has medical personnel should have N-95 respirators for use in case of suspected positive COVID-19 personnel. Refer to the ADCI COVID-19 Guidance for Surface Diving Operations and the CDC for more information. If the CDC changes recommendations for face coverings that would contradict any part of the ADCI COVID-19 Guidance for Surface Diving Operations then the CDC recommendation should supersede.

[1]Graham BL, et. al., Standardization of Spirometry 2019 Update, Am J Resp & Crit Care Med, Vol 200, No.8, 2019
[2]https://www.cdc.gov/niosh/topics/spirometry/training.html
[3]https://www.atsjournals.org/doi/full/10.1164/rccm.201908-1590ST

Classification of divers based on severity of COVID-19 suspected illness

Category 0 ***NO*** *history of COVID-19 suspected illness*	**Category 1** ***MILD*** *COVID-19-suspected illness*	**Category 2** ***MODERATE*** *COVID-19-suspected illness*	**Category 3** ***SEVERE*** *COVID-19-suspected illness*
Definition: Divers who have no history of COVID-19 suspected illness should proceed with normal evaluations. Additionally, we would use these criteria in those who may have had a positive screening PCR or antibody test, but without any history of illness or symptoms consistent with COVID-19.	Definition: ● Did not seek health care or received outpatient treatment only without evidence of hypoxaemia. ● Did not require supplemental oxygen ● Imaging was normal or not required	Definition: ● Required supplemental oxygen or was hypoxic ● Had abnormal chest imaging (chest radiograph or CT scan) ● Admitted to the hospital but did NOT require mechanical (intubation) or assisted ventilation (BIPAP, CPAP) or ICU level of care. ● If admitted, had documentation of a normal cardiac work up including normal ECG and cardiac biomarkers e.g. troponin or CK-MB and BNP	Definition: ● Required mechanical (intubation) or assisted ventilation (BIPAP, CPAP) or ICU level of care. ● Cardiac involvement defined as abnormal ECG or echocardiogram, or elevated cardiac biomarkers; e.g. troponin or CK-MB and BNP (or absence of documented work up) ● Thromboembolic complications (such as PE, DVT, or other coagulopathy)

Recommendations for evaluations of divers or diving candidates

Category 0 ***NO*** *history of COVID-19 suspected illness*	**Category 1** ***MILD*** *COVID-19-suspected illness*	**Category 2** ***MODERATE*** *COVID-19-suspected illness*	**Category 3** ***SEVERE*** *COVID-19-suspected illness*
● Initial/periodic exam per ADCI guidelines ● Chest radiograph only if required per professional group ● No additional testing required	● Initial/periodic exam per ADCI guidelines ● Spirometry ● Chest radiograph (PA & lateral); if abnormal, obtain chest CT ● If unknown (or unsatisfactory) exercise tolerance*, perform exercise tolerance test with oxygen saturation	● Initial/periodic exam per ADCI guidelines ● Spirometry ● Chest radiograph (PA & lateral); if abnormal, obtain chest CT ● ECG ● Echocardiogram (if no work up was done as an inpatient. Can forgo if had negative work up) ● If unknown (or unsatisfactory) exercise tolerance*, perform exercise tolerance test with oxygen saturation ● Investigation and management of any other complications or symptoms per provider and professional group or RSTC guidelines	● Initial/periodic exam per ADCI guidelines ● Spirometry ● Chest radiograph (PA & lateral); if abnormal, obtain chest CT ● ECG ● Repeat cardiac troponin or CK-MB and BNP to ensure normalization ● Echocardiogram ● Exercise Echocardiogram with oxygen saturation ● Investigation and management of any other complications or symptoms per provider and professional group or RSTC guidelines

** If the physician is not assured the diver's self-reported exercise level meets appropriate criteria or is concerned it would not reveal underlying cardiac or pulmonary disease, further testing is warranted.*

Adapted from : Charlotte Sadler, Miguel Alvarez Villela, Karen Van Hoesen, Ian Grover, Michael Lang, Tom Neuman, Peter Lindholm. Diving after SARS-CoV-2 (COVID-19) infection: Fitness to dive assessment and medical guidance. Diving and Hyperbaric Medicine. 2020 30 September;50(3). doi: 10.28920/dhm50.3

ADCI COVID-19 DIVER QUESTIONNAIRE

NAME: _____ DOB: _____ DATE: _____

COVID-19 SYMPTOMS: **Please circle**

Since January 2020:

1. Have you had a positive swab (PCR) or blood (antibody test) for COVID-19? If YES, date of test(s): _____ No Yes

2. Have you had any of the following symptoms? (circle all that apply) cough, shortness of breath, difficulty breathing, fever, chills, shivering, muscle aches, headache, sore throat, loss of taste or smell, diarrhea No Yes

3. Did you miss any days of work due to the above symptoms? No Yes

4. Have you had severe respiratory illness with clinical or x-ray evidence of pneumonia, or acute respiratory distress syndrome? No Yes

5. If YES to question 2-4, were you diagnosed with any respiratory illness other than COVID-19? If YES, what illness: _____ No Yes

6. Are you having any symptoms currently? No Yes

7. Do you feel anxious or depressed about the COVID-19 pandemic or working? No Yes

EXERCISE TOLERANCE:

1 What is your normal exercise routine? -_____

_____

2. Any change in your ability to do your normal exercise or exertion? No Yes

3. If YES to question 2, why can't you do your normal exercise? _____

_____

Stop here if you answered no to all above questions.

HEALTHCARE:		
1. Did you seek healthcare related to the symptoms you experienced above?	NO	YES, what level of healthcare?
		☐ Outpatient
		☐ Hospital admission
		☐ Intensive Care Unit
2. Did you have a low blood oxygen level or require supplemental oxygen?	NO	YES
3. Was a chest x-ray or CT scan done?	NO	YES, it was:
		☐ Normal
		☐ Abnormal
4. Did you require assisted ventilation (BiPAP, CPAP, ventilator)?	NO	YES
5. Was an evaluation of your heart done (EKG, echocardiogram, blood tests)?	NO	YES, it was:
		☐ Normal
		☐ Abnormal
6. Did you have any blood clots or blood clotting problems?	NO	YES

Société Belge de Médecine Hyperbare et Subaquatique asbl
Belgische Vereniging voor Overdruk- en OnderwaterGeneeskunde vzw

Position of the Belgian Society for Diving and Hyperbaric Medicine (SBMHS-BVOOG) on Diving after COVID-19 pulmonary infection

April 12th, 2020

The COVID-19 pandemic has had a major impact on recreational and professional diving activities, with an almost complete cessation of this activity during many weeks/months. These measures were a logical consequence of Government and Public Health Care recommendations to limit unnecessary commuting but also because it is virtually impossible to observe the regulations of "social distancing" and avoiding the possible sharing of divers' breathing equipment. Lastly, there is a real possibility that emergency first aid teams may be overwhelmed by cases related to COVID-19 or the logistics involved (decontamination procedures), and not be able to respond in a timely and efficient manner.

When the precautionary measures to combat the pandemic will be relaxed, it is important to resume normal recreational and professional diving activities as soon as reasonably possible, both for the social, physical and mental welfare of the diving population. The question has been raised, whether having suffered and recovered from COVID-19 has any influence on the medical fitness to dive or the risk of diving accidents.

Novel Corona Virus (SARS-CoV-2) infection (COVID-19) can manifest itself with various clinical syndromes, ranging from no symptoms, over a flu-like syndrome, to severe pulmonary compromise (ARDS – Acute Respiratory Distress Syndrome) and cardiac symptoms (cardiomyopathy). Factors that determine the severity of COVID-19 symptoms are but incompletely known: older persons, suffering from other medical conditions, are an obvious group at risk; also, heavy smokers and obese persons seem to have more risk of complications; however, there are numerous cases reported of young, previously healthy persons in whom the disease has had a sudden and dramatic evolution. In general, if the symptoms were mild and improve within a week to complete resolution, the risk for permanent damage to heart or lungs is very low.

The Board of the SBMHS-BVOOG, after examining the relevant and available literature and discussion with several experts, recommends:

1. Risk of spreading COVID-19: a person who has had symptomatic COVID-19 can, just as someone who was infected but did not have symptoms, spread viral particles in nasal or oral secretions for a certain period after recovery, and thus, still be contagious to others. The exact period during which this is possible is not known and probably variable, but has been reported to be up to 37 days or longer. This is an important consideration for the possible sharing of breathing regulators (buddy-breathing) but also for rescue actions in case of a diving accident.

Secretaria(a)t: Sigrid Theunissen – Weygenstraat, 26 - 3060 Bertem
Tel: 0476/44.10.44 – E-mail: secretary@sbmhs-bvoog.be
Website: www.sbmhs-bvoog.be – N° Enterprise: 428.739.109

Therefore, it is recommended:

a. *That divers who have had symptomatic COVID-19, wait a minimum of TWO months, preferable three, before resuming their diving activity.*
b. *That divers who have tested positive for COVID-19 but have remained completely asymptomatic, wait ONE month before resuming diving.*
c. *Divers who have never had symptoms and have not been tested (who either have not been infected or have had the infection completely asymptomatic) may not have developed immunity against the disease (currently, serological tests are not widely available and do not confirm with 100% certainty a sufficient level of immunity). Therefore, they may still be infected by other divers and would need to observe a waiting period after the release of the confinement period. The duration of this waiting period may be variable depending on the local situation (type of diving, location and local organisation).*
d. *Divers and dive centres should observe strictly the guidelines for disinfection of diving gear (as issued by the diving Federations and DAN Europe).*

2. Risk for pulmonary overpressure syndrome (lung barotrauma): a person who has had COVID-19 infection with severe pulmonary symptoms may suffer from prolonged or even permanent pulmonary damage, even if the lung function seems to have returned to (near) normal. This damage may give a higher risk for lung barotrauma, even after dives without a rapid or uncontrolled ascent.
   Therefore, it is recommended that a diver who has been hospitalised with or because of pulmonary symptoms in relation to COVID-19, should, after the three-month waiting period (as indicated above), undergo complete pulmonary function testing as well as a high-resolution CT scanning of the lungs.
   Pulmonary function testing should include FVC, FEV1, PEF25-50-75, RV and FEV1/FVC), and the CT scan should show a return to normal, before resuming diving. It is important that these tests should be interpreted and validated by a medical officer with specific knowledge of diving medicine.
   If major pulmonary symptoms have been present, even if not requiring hospitalisation, pulmonary damage may have occurred and a pulmonary function testing and CT-scan are useful tests.

3. Risk for cardiac events: in the context of general illness and severe pulmonary infection, a COVID-19 cardiomyopathy may not a prominent symptom and may even go unnoticed during the acute phase of the disease. This however may be the cause of heart muscle damage and subsequent scarring. Cardiomyopathy or cardiac scar tissue may be an important factor in the occurrence of sudden cardiac failure and sudden death during diving immersion.
   Therefore, it is recommended that a diver who has been hospitalised with or because of cardiac or pulmonary symptoms in relation to COVID-19, should, after the three-month waiting period (as indicated above), undergo cardiac evaluation with echocardiography and exercise test (exercise electrocardiography) to ascertain normal cardiac function.
   If major pulmonary symptoms or extreme fatigue/exhaustion have been present, even if not requiring hospitalisation, this may indicate a possible cardiomyopathy and cardiac testing is useful.

4. Pulmonary oxygen toxicity: at this time, there is very little known as to a possible increased sensitivity of the pulmonary tissue to the toxic effects of oxygen; *therefore, a prudent attitude would be that technical diving (with prolonged breathing of hyperoxic gas, with a pO_2 of 1.3 ATA or higher) should be avoided.* Simple "nitrox" diving (whereby a maximum pO_2 of 1.4 ATA is only breathed for short periods, at the deepest part of the dive) should not present any problem.

5. Decompression sickness: even less is known about the possible alteration of the "bubble filter" function of the lung after COVID-19 pulmonary infection. This may imply that the risk for decompression sickness could increase significantly. It has been shown that after deeper recreational dives (close to the No-Decompression-Limit – NDL – of the dive computer, or with mandatory decompression stops), in 70-90% of cases, inert gas bubbles can be detected. These bubbles circulate in the venous blood, and are filtered out by the pulmonary capillary circulation and thus usually do not cause decompression sickness. If the lung "bubble filter" would become less efficient, these bubbles could pass into the arterial circulation ("arterialise"), comparably to divers with a Patent Foramen Ovale, and cause cerebral, vestibular or other types of decompression sickness. *Therefore, a prudent attitude would be that divers who have suffered from pulmonary symptoms of COVID-19, limit their dives temporarily (or definitively) to well within the NDL of their computer (so that at no moment during the dive, the computer indicates mandatory decompression stops).*

These recommendations are made on the basis of scientific data available on April 12th, 2020. It is likely that these will evolve if and when new data or insights become available.

For the Board of SBMHS-BVOOG:

(signed)	*(signed)*	*(signed)*
Dr Guy Vandenhoven President	Dr Peter Germonpre Board member	Dr Jean-Pierre Rezette Board member

Secretaria(a)t: Sigrid Theunissen – Weygenstraat, 26 - 3060 Bertem
Tel: 0476/44.10.44 – E-mail: secretary@sbmhs-bvoog.be
Website: www.sbmhs-bvoog.be – N° Enterprise: 428.739.109

COVID-19 Guidance for Referees

This guidance uses the very limited evidence currently available to minimise risk while avoiding restrictions and medical investigations that would deter divers from declaring issues that require assessment.

A score card has been devised and approved by the UK Diving Medical Committee for divers to assess their own risk and the need for appropriate follow-up. It is endorsed by the British Diving Safety Group. All divers other than those with very low risk are prompted to have a conversation / consultation with a Medical Referee.

Summary

Likely risk	Score	Recommendation
Very Low	Less than 0	No requirement for review, note unknown risks
Low	0	Advise of unknown risks of asymptomatic COVID-19 lung damage
Moderate	1-7	Delay assessment for 3 months from illness or exposure to infection Complete resolution of COVID-19-related symptoms Assessment as below
High	8-47	Delay assessment for 3 months from illness Complete resolution of COVID-19-related symptoms Assessment as below
Very High	>=48	Delay assessment for one year Diver likely to have had Respiratory Medicine follow-up Obtain medical records and undertake a full risk assessment

Guidance notes

1. Divers who have no known exposure to SARS-CoV2 and had no symptoms of COVID-19 (score zero on the score card) may still have suffered asymptomatic disease which can be associated with damage to the lungs[1], heart and other organs which could lead to injury or death whilst diving. This risk however is deemed to be low.[2] Undertaking medicals and / or invasive testing on all divers would be impractical. These low risk individuals can return to diving as they would have done previously, providing they accept this potential risk.

2. Divers may seek reassurance by having an antibody test at their own expense. The test must be CE marked, comply with the MHRA's Target Product Profile for antibody tests[3] and be used in the way that it has been validated and for which the CE mark has been awarded.[4] If a low risk diver phones for advice or requests a medical the potential risks of asymptomatic disease should be explained to them so they can make their own informed decision (based on the best available evidence at the time) as to whether they return to diving. It is worth asking a diver who has not had the case identification symptoms (new

persistent cough, fever, anosmia) about any other illnesses since 1 January 2020 to rule out an atypical presentation.[5]

3. Those with a known contact with SARS-CoV2 but who remained asymptomatic score 1. They should discuss this with a referee. They can choose to have a validated antibody test which would adjust the score to -1 if negative but they must be made aware that a positive result would move them to a higher level of risk with a score of 6.

4. Those with a positive test who have been asymptomatic score 5, so will need more detailed assessment due to the higher risk of lung changes.[6]

5. Those with mild to moderate symptoms but not requiring admission to hospital (scoring between 10 and 47 on the score card) will include some 'false positives' who had one or more of the case identification symptoms without being infected. There is not yet, however, a highly reliable method to rule out past infection – one series (admittedly from a pre-print paper) estimates that up to 8.5% of patients do not have detectable IgG antibodies up to 60 days post infection, and that the rate of seroconversion is lower in those who have had milder symptoms, are younger, have no co-morbidities and lower BMI.[7] As a result, for the time being, it is safest to assume that they had COVID-19 and their risk of lung changes exceeds the 54% found in asymptomatic patients with proven infection. These divers are advised to wait three months from when they have recovered. This is more conservative than some organisations, but has been selected because the time course for resolution of lung changes is not yet known with any accuracy and case series have shown abnormalities persisting for at least 14 days after onset of symptoms in patients who did not have severe respiratory distress or require oxygen at any time.[8] The diver can then be assessed provided they are back to their previous level of aerobic fitness.

6. For the time being, those with severe COVID-19 will not, in general, be assessed for one year. It is likely, however, that these patients will undergo a structured programme of follow up [9] and, if there is objective evidence that lung lesions have resolved, then an earlier return to diving can be considered on a case-by-case basis. Further guidance on decision-making for these individuals will be issued as relevant evidence becomes available.

Referee Consultation Guidance

Assessment of divers scoring 1-47 (Moderate and High Risk): A careful history should be taken. Where the history is highly suggestive of ongoing respiratory symptoms or unresolved issues, the diver is unfit to dive. If the diver has returned to their previous level of fitness, a medical examination should be carried out per existing guidelines with the following additional tests recommended:

a) Pulse assessment for 15 to 60 seconds [10] and at least long enough to determine if there are frequent ectopic beats. If frequent ectopic beats are detected or if the history indicates concerns such as palpitations, an ECG should be performed. If the ECG shows frequent ventricular ectopic beats or evidence of repolarisation changes (ST segment or T wave changes) or LBBB, the diver should be referred to a cardiologist for further investigation which should include an echocardiogram.

b) An exercise test (such as the Chester step test) with oxygen saturation monitoring. Do not proceed if the resting saturation is lower than 96%.[11] Comparison with previous exercise test results is useful (if available). A drop in O_2 saturation of more than 3% on exercise or an unexpected deterioration in exercise capacity (estimated VO_2 max) compared to previous values would preclude certification of fitness to dive. The test should be conducted and terminated as normal, but the result can only be accepted if the diver reaches and can maintain at least 7 METS (VO_2 24.5 ml/kg/min) for 2 minutes before reaching any criteria for termination. Using the Chester Step Test this would require completion of Stage V with a 15 cm step or Stage III with a 30 cm step.[12]

Very high risk: Those who required admission to hospital with COVID-19 (scoring more than 48 on the score card) are at very high risk of lung changes and, in general, should wait 12 months from recovery before seeking assessment for fitness to dive. The diver will need to have returned to their previous level of fitness. There is, of course, no information specific to long-term pulmonary outcome in COVID-19 but, if the lesions behave similarly to those seen in SARS and MERS, of those patients who had abnormal chest x-rays at discharge some 35% will still have abnormalities 12 weeks later and 30% at 6 months[13]with some changes persisting for at least 230 days.[14] In addition to the testing mentioned above, they will require more comprehensive chest imaging and possibly laboratory-based lung function testing, including assessment of residual volume. This is expensive and currently not available due to capacity issues within the NHS. It is however possible that these patients will have such tests undertaken as part of their post COVID-19 follow up from their hospital team.

Referee Notes

It is anticipated that a Referee's clinical judgement and shared decision making with the diver will form a large part of the fitness to dive assessment, especially with regard to the known and unknown potential risks of diving post COVID-19. The rate and persistence of lung changes in both symptomatic and asymptomatic individuals is not yet well understood. The relationship of such lung changes to pulmonary barotrauma and consequent decompression illness is not known. The role and interpretation of extended investigations in assessing fitness to dive is currently uncertain.

Where a diver has been found unfit to dive, it is expected that appropriate explanation is given and follow up advised through the diver's primary or secondary care teams as appropriate. It is unlikely that a Referee would be best placed to arrange further investigations themselves as interpretation and follow up of results along with the current logistical issues of arranging such tests is complex.

Divers in both very low to high risk groups may seek additional reassurance of dive fitness through chest imaging or pulmonary function testing. It is important to note that while this may be feasible and a normal result reassuring, there are likely to be a proportion where abnormalities are found. Translating such abnormalities into barotrauma risk or knowing if further investigation is then appropriate (especially if large radiation doses or significant

cost is involved) is very complex and this should be discussed with the diver in advance. The sensitivity and specificity of identifying those at risk of pulmonary barotrauma or other complications such as immersion pulmonary oedema using investigations such as desktop spirometry, peak flow measurements, chest plain films or CT imaging is currently unknown but these tests may be considered based on clinical judgement.

The Association for Respiratory Technology and Physiology (ARTP) anticipates that spirometry will be useful for routine clinical follow up.[15] Simple desktop spirometry will, however, be difficult to interpret in the absence of results prior to exposure to, or infection with, SARS-CoV2. In one series FVC, FEV1, FEV1/FVC and mid-expiratory flows were in the expected range in the large majority of 110 patients at discharge. The only spirometry measurement that reached statistical significance in this series was $FEF_{75\%}$ in the 19 patients who had severe pneumonia, of whom 5 had values lower than 65% of predicted.[16] Spirometry is, however, simple, widely available and non-invasive so, although the information above suggests that an abnormal result is unlikely to be due to COVID-19, it would be a prompt for further assessment in any diver regardless of the underlying abnormality. It might also be useful as a baseline for follow-up of a candidate who has not yet fully recovered since objective evidence of further deterioration, instead of an improvement, would be a valuable prompt for the diver to seek advice from their general practitioner. When considering spirometry, ARTP guidance or other appropriate procedures for infection control should be taken into account.

According to the British Thoracic Society Guidance, follow-up chest x-rays are likely to be offered routinely to all patients who had abnormalities on imaging whether they were admitted to hospital or were assessed in hospital but then cared for in the community. Some of these patients will be discharged with a normal chest x-ray and others will proceed to more detailed investigation which will be useful when eventually reviewing fitness to dive. There will be some divers who lack objective evidence of resolution, such as those who are discharged from secondary care with “minor insignificant changes”, others who had symptoms but no imaging and asymptomatic divers with evidence of past infection. Although the radiation risk associated with a chest x-ray is low, there is currently no evidence regarding the significance of some of the lung abnormalities seen in COVID-19 on which to base clear advice for or against further imaging and its optimal timing, especially if abnormalities persist and repeat imaging needs to be considered. It is also worth bearing in mind that a chest x-ray might miss lesions related to COVID-19 that would have been identified by a CT scan.[17] Where guidance already exists for an abnormality, such as pneumothorax, this should be followed. In other circumstances, the medical referee will either need to seek specialist advice or to make a decision on the requirement for further imaging based on an overall assessment of risk, taking into account factors such as the likelihood of infection with SARS-CoV2, the nature and severity of symptoms and the type, distribution and number of lesions last shown on imaging.

Review of Guidelines

This guidance is based on current understanding at the time of writing, but all Medical Referees should continue to remain up to date with latest data on COVID-19.

The attached references have been used in the development of these guidelines and may form a useful adjunct for clinical decision making and discussions with divers.

The committee will review this document at least every 3 months or earlier if important new evidence becomes available. If you find any new information that you think is relevant, please let the committee know via http://www.ukdmc.org/contact-us/.

[1] Inui S, Fujikawa A, Jitsu M, Kunishima N, Watanabe S, Suzuki Y, Umeda S, Uwabe Y. Chest CT Findings in Cases from the Cruise Ship "Diamond Princess" with Coronavirus Disease 2019 (COVID-19). Radiology Cardiothoracic Imaging 2020 Mar 17. doi: 10.1148/ryct.2020200110
[2]https://www.gov.uk/government/publications/national-COVID-19-surveillance-reports/sero-surveillance-of-COVID-19
[3]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/883897/Target_Product_Profile_antibody_tests_to_help_determine_if_people_have_immunity_to_SARS-CoV-2_Version_2.pdf
[4]https://www.gov.uk/drug-device-alerts/results-from-laboratory-based-tests-for-COVID-19-antibodies-using-capillary-blood-sample-collection-kits-may-not-be-reliable-mda-2020-015
[5]https://www.cebm.net/COVID-19/in-patients-of-COVID-19-what-are-the-symptoms-and-clinical-features-of-mild-and-moderate-case/
[6]Hu, Z., Song, C., Xu, C. et al. Clinical characteristics of 24 asymptomatic infections with COVID-19 screened among close contacts in Nanjing, China. Sci. China Life Sci. 63, 706–711 (2020). https://doi.org/10.1007/s11427-020-1661-4
[7] Staines HM, Daniela E Kirwan DE, David J Clark DJ et al Dynamics of IgG seroconversion and pathophysiology of COVID-19 infections. medRxiv 2020.06.07.20124636; doi: https://doi.org/10.1101/2020.06.07.20124636
[8]Pan F, Ye T, Sun P, et al. Time Course of Lung Changes at Chest CT during Recovery from Coronavirus Disease 2019 (COVID-19). Radiology. 2020;295(3):715-721. doi:10.1148/radiol.2020200370
[9]British Thoracic Society Guidance on Respiratory Follow Up of Patients with a Clinico-Radiological Diagnosis of COVID-19 Pneumonia. https://www.brit-thoracic.org.uk/document-library/quality-improvement/COVID-19/resp-follow-up-guidance-post-COVID-19-pneumonia/ (accessed 27 June 2020)
[10] Oxford Handbook of Clinical Examination and Practical Skills (2 ed.) Editors Thomas J and Monaghan T. Oxford University Press. Jul 2014 DOI: 10.1093/med/9780199593972.001.0001
[11]https://www.cebm.net/COVID-19/what-is-the-efficacy-and-safety-of-rapid-exercise-tests-for-exertional-desaturation-in-COVID-19/
[12]Buckley JP, Sim J, Eston RG, Hession R, Fox R. Reliability and validity of measures taken during the Chester step test to predict aerobic power and to prescribe aerobic exercise. Br J Sports Med 2004;38:197–205. doi: 10.1136/bjsm.2003.005389
[13]Hui DS, Joynt GM, Wong KT, et al. Impact of severe acute respiratory syndrome (SARS) on pulmonary function, functional capacity and quality of life in a cohort of survivors. Thorax. 2005;60(5):401-409.
[14]2. Das KM, Lee EY, Singh R, et al. Follow-up chest radiographic findings in patients with MERS-CoV after recovery. Indian J Radiol Imaging. 2017;27(3):342-349.
[15]COVID 19 Informationhttps://www.artp.org.uk/COVID19 (accessed 28 June 2020)
[16] Mo X, Jian W, Su Z, et al. Abnormal pulmonary function in COVID-19 patients at time of hospital discharge. Eur Respir J 2020; 55: 2001217 [https://doi.org/10.1183/13993003.01217-2020].
[17]Wong HYF, Lam HYS, Fong AH, et al. Frequency and Distribution of Chest Radiographic Findings in COVID-19 Positive Patients. Radiology. 2019 Mar:201160. DOI: 10.1148/radiol.2020201160.

Add together the individual scores for each item that applies to you in the Medical History table. This will give a Total Score. Use this score in the second table to find the current advice for you.

Medical history	Score
Negative COVID-19 antibody test (sample taken more than 3 weeks after any contact)	-2
An episode of new persistent cough at some time since 1 January 2020	10
An episode of fever at some time since 1 January 2020	10
An episode of increased shortness of breath at some time since 1 January 2020	10
An episode of loss of taste or smell at some time since January 2020	10
Known contact with proven or suspected COVID-19 (e.g. household isolation) without appropriate Personal Protective Equipment	1
Positive COVID-19 antibody test or throat swab	5
Symptoms of COVID-19 severe enough to require admission to hospital	50

Total score	Estimated risk of lung changes	Recommended action	Testing
Less than 0	Low	No review required prior to diving	No review required prior to diving - diver should understand that there are still unknown risks. Consider validated antibody testing to aid risk assessment.
0	Probably low (about 5% chance of lung changes)	No review required prior to diving if prepared to accept risk	Consider validated antibody test to adjust score if not already done.
1-7	Moderate (up to about 50% chance of lung changes)	Discuss with medical referee no earlier than 3 months after most recent illness and when returned to normal exercise capacity	If score is 1, consider validated antibody test to adjust score if not already done. Other tests might be required
8-47	High	Discuss with medical referee no earlier than 3 months after you were ill, when fully recovered and returned to normal exercise capacity	Other tests are likely to be required
48 or greater	Very high (almost 100% chance of lung changes)	Refer to medical referee 1 year after you were discharged from hospital, when fully recovered and returned to normal exercise capacity Refer earlier if returned to normal exercise capacity and there is evidence that the lungs (normal CT chest and gas transfer factor) and heart (normal ECG and echocardiogram) were not affected	Will require review of any testing undertaken as part of usual clinical care. Other tests are likely to be required

UKDMC 14th June 2020

NB - The NHS gives the following advice about symptoms:

- high temperature – this means you feel hot to touch on your chest or back (you do not need to measure your temperature)
- new, continuous cough – this means coughing a lot for more than an hour, or 3 or more coughing episodes in 24 hours (if you usually have a cough, it may be worse than usual)
- loss or change to your sense of smell or taste – this means you've noticed you cannot smell or taste anything, or things smell or taste different to normal.

Currently the only validated antibody tests that have been approved by Government are those produced by Abbott and by Roche.

Any diver requiring assessment for fitness to dive or further tests as above or has any queries with regard to the medical implications of COVID-19 on diving please contact a UK Diving Medical Referee listed at www.ukdmc.org/medical-referees/

The evidence base re COVID-19 is currently limited, hence this advice and chart may be edited as more evidence becomes available.

Return to Diving and Hyperbarics Post-COVID-19

by Dituri, J., Carpenter, E., Ebersole, D., Ebersole, C., Siddiqi, F., Radtke, R., Ardon, A., Schwaiger Kemp, E., Sriaroon, C., Taylor, S.

Abstract

COVID-19 is a virus which impacts many individuals including divers and those seeking HBOT. Currently little to no guidance exists for selection criteria and tests / examinations to establish a safe return to dive status or HBOT following all variants of symptoms of COVID-19. A multi-specialty group of researchers, all of whom are subspecialty trained in hyperbaric medicine, was selected to establish a decision matrix to assist practitioners not trained in hyperbarics and aide in returning patients to diving or HBOT. An easy-to-understand algorithm was established with tests which should be administered and wait times following hospitalized and non-hospitalized COVID-19 symptoms. Safe return to dive status and HBOT can be obtained with great care for the patient and some simple diagnostic examinations.

Introduction

SARS-CoV-2, the novel coronavirus responsible for COVID-19, is impacting patients' ability to remain active and engaged in sports such as SCUBA diving, or to participate in activities involving exposure to Hyperbaric Oxygen Therapy (HBOT). While most COVID-19 patients recover from their illness and return to activities of daily living, physicians will be required to determine if and when it is safe for them to return to their underwater activities. Underseas and hyperbaric physicians, in particular, will be faced with the challenging task of determining when patients can safely return to commercial and recreational underwater activities. There are currently no consensus recommendations regarding post-COVID return to diving, or clearance for HBOT. In hopes of recommending a path forward, an Emergency Room physician, Critical Care / Pulmonologist, Cardiologist, Radiologist, Surgeon, and a Ph.D., who are all subspecialty trained in hyperbaric medicine, worked together to form a plan for return to diving activities. They further consulted with peers, including Cardiothoracic Surgeons, Pulmonologists, Sleep and Infectious Disease Doctors to safely recommend a path forward. The overriding goal is to provide guidance to physicians regarding clearance for return to diving activities as well as clearance for HBOT.

Background

COVID-19 has a myriad of clinical manifestations, ranging from completely asymptomatic, to multiorgan failure and death. As months progress, the medical community has developed a better understanding of the symptomatology and natural progression of COVID-19. Patients initially display a wide range of symptoms including: fever, chills, cough, shortness of breath, fatigue, muscle or body aches, headache, loss of taste or smell, sore throat, congestion or runny nose, nausea, vomiting, and/or diarrhea (1-7). Some patients progress to severe symptomatology including hypoxia and acute respiratory failure. Complications such as pneumothorax, venous thromboembolism, and strokes are commonplace among the more severely afflicted. Additionally, pulmonologists and cardiothoracic surgeons have witnessed an approximately 4-fold increase in mediastinal emphysema in COVID-19 patients.

The COVID-19 virus initially attacks the lungs, where it purportedly attaches to type II pneumocytes, which are responsible for surfactant production. Type II pneumocytes ultimately

infarct. This, compounded by a significant inflammatory response, hastens the production of reactive oxygen species leading to damage of the type I pneumocytes, which are responsible for gas exchange. As inflammation progresses, alveolar gas diffusion worsens and cellular debris accumulates. This triggers an overwhelming inflammatory response known as the "cytokine storm," which can lead to significant and long-term damage to the lungs and other organ systems. Chest X rays (CXR) often show bilateral infiltrates and CT scans show bilateral ground glass opacities, dense consolidations, and rarely cavitary lung disease. CXR are often normal in the asymptomatic or mildly symptomatic COVID-19 patient.(8) CXR findings in the more symptomatic patients involve areas of patchy infiltrate and consolidation (pneumonia), are often bilateral, multifocal, and involve the lower lobes. Pleural and pericardial effusions are less common, as are pneumothoraces, blebs, and bullae, but they do occur. CT scans are much more sensitive exams, but should only be performed if a complication is suspected and not readily evident on the CXR, or if additional CT findings will impact future management. CT imaging can be done with low dose radiation protocols and is usually done without IV contrast, unless a pulmonary embolism is suspected. CXR and CT findings can be suggestive of COVID, but are not pathognomonic. Other disease entities can have similar radiographic, so close clinical correlation of these imaging findings is imperative.(9)

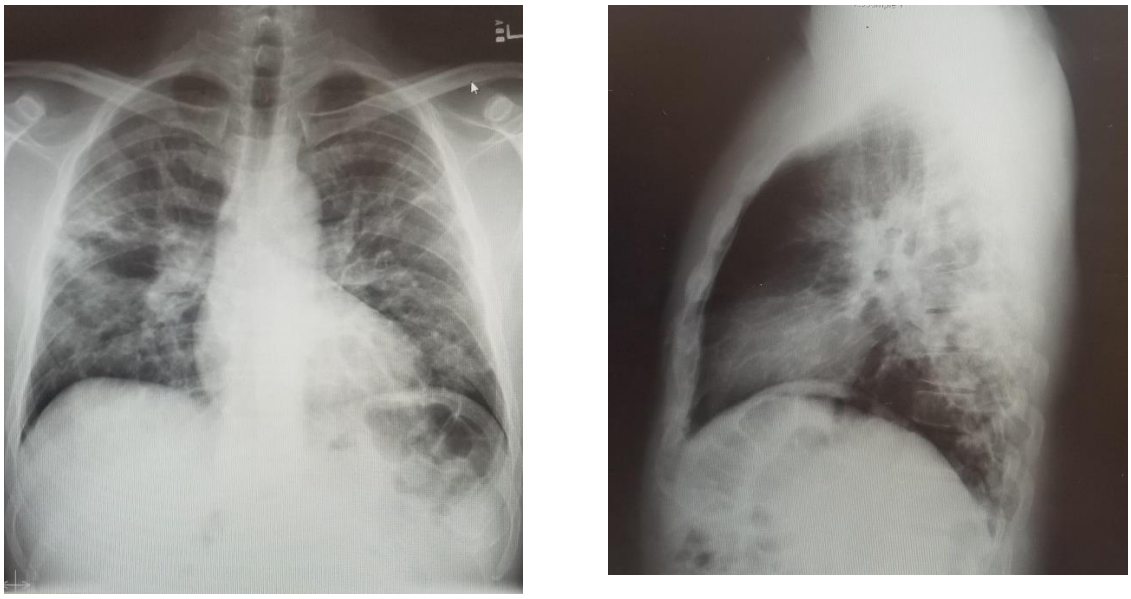


Figure 1: Chest X Ray showing patchy diffuse airspace disease in this COVID patient.

A number of cardiac issues have been noted with COVID-19 infection. Myocardial injury, indicated by elevated troponin levels, is described in patients hospitalized with COVID-19 and seems to be associated with adverse outcomes.(10,11) The origin of myocardial injury can result from myocarditis (related to direct viral infection of the tissue), ischemia due to thrombotic coronary obstruction, or other causes such as heart failure, pulmonary embolism, increased cardiac output states, and sepsis. (12)

Although myocarditis is a surprisingly common complication of many viral infections, more severe manifestations appear to be associated with COVID-19, and this can result in both acute and chronic issues. During the acute phase of myocarditis, the patient may develop ventricular tachycardia and/or severe left ventricular systolic dysfunction, which could result in congestive heart failure, cardiogenic shock, and even death. While most patients will have recovery of heart muscle function after the acute myocarditis, some will not and will be left with a dilated cardiomyopathy. This may result in long-term issues of exercise intolerance, congestive heart failure symptoms, and the risk of dangerous ventricular arrhythmias. Additional complications involving the heart may develop from the cytokine storm, which frequently occurs in hospitalized patients with COVID-19. This inflammatory process can produce a prothrombotic state, which can lead to coronary artery thrombosis and resultant myocardial infarction, even in patients without prior underlying coronary artery disease.

Among patients ill enough to require hospitalization, cardiac involvement appears to be particularly common. Nearly one-fourth of those hospitalized with COVID-19 have been diagnosed with cardiovascular complications, which have been shown to contribute to roughly 40% of all COVID-19 deaths. In one study, elevated biomarkers consistent with cardiac injury and myocardial dysfunction noted on echocardiography were reported in up to 70% of hospitalized patients. (13) Hospitalization alone, however, is not the only risk factor in the potential for developing myocardial involvement. In another study of 100 patients who recovered from COVID-19 infection, 78% had cardiovascular involvement detected by standardized cardiac MRI, irrespective of preexisting conditions, the severity and overall course of the patient's COVID-19 infection, the time from the original diagnosis, or the presence of cardiac symptoms. The most prevalent abnormality was myocardial inflammation (defined as abnormal native T1 and T2 measures), detected in 60% patients recently recovered from COVID-19, followed by regional scar and pericardial enhancement. (14) Unfortunately, the prevalence of cardiac manifestations in non-hospitalized, or even asymptomatic individuals is not entirely clear. The possibility of these complications, however, will require ongoing vigilance of providers tasked with clearing them for return to activities that demand significant levels of physical activity.

The medical community is still learning the true long-term impact of COVID-19 on the body's organ systems. Even amongst patients who do not develop severe disease, individuals may still develop sequelae such as persistent hypoxia, post viral obstructive lung disease (characterized by a decrease in FEV-1 and FVC), pneumothorax, mediastinal / subcutaneous emphysema, and in rare occasions, persistent cavitary lung disease. All of these conditions are considered exclusionary to dive clearance, creating a significant challenge to the Undersea and HBOT community. As a community, we must identify these patients and rule out these potentially life-threatening conditions, before returning a diver to underwater activity or clearing a patient to initiate or resume HBOT.

Diver and HBOT Clearance Discussion

Underwater and hyperbaric environments place divers under significant physiologic stressors. Divers are frequently required to tolerate strenuous underwater exertion, cold temperatures, pressure changes, and dry air. Even the healthiest of divers can develop decompression illness, pulmonary barotrauma, arterial gas embolism, and other dive-related

medical emergencies, which can lead to drowning and death. Conditions such as asthma, obstructive lung disease, restrictive lung disease, interstitial lung disease, lung lesions (solid, cystic, or cavitary), exercise induced bronchospasm, and previous pneumothoraces, all increase the risk of adverse underwater events and are therefore relative or absolute contraindications to dive clearance. The goal of medical clearance is to assess each patient's medical history, pre-existing medical conditions, and current physical capabilities to determine the relative risk of developing an underwater or post-dive medical emergency. It is also our duty to avoid unnecessarily preventing a patient from pursuing their current underwater diving career or the enjoyment of recreational scuba diving.

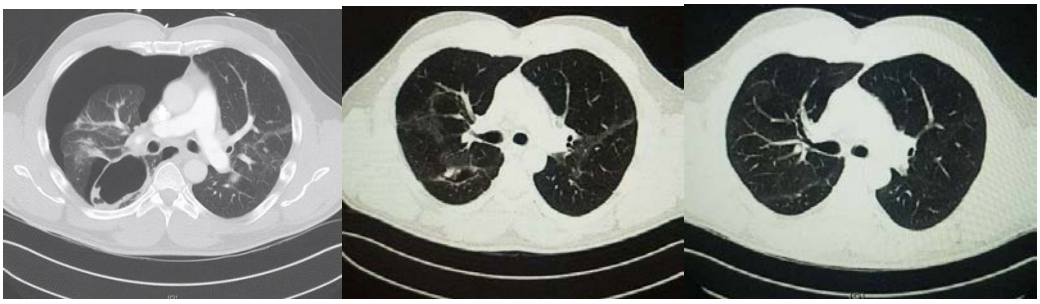


Figure 2: First axial CT image reveals a moderate right pneumothorax with early shift of the mediastinum, large cavitary lesion in the posterior right lung, and scattered areas of patchy infiltrate in both lungs. Middle CT image 4 weeks later shows resolution of the right pneumothorax, much smaller cavitary right lung lesion, and improving infiltrates. Last CT image almost 7 weeks later demonstrates complete resolution of the previous abnormalities without sequelae.

Clearance requirements to dive and undergo hyperbaric conditions vary depending on the certifying organization and complexity of the diving activity. Commercial divers are under the most stringent regulations, while those for HBOT and recreational divers are more permissive. Clearance guidelines for scientific divers, and public safety / rescue divers fall between the prior categories.

For the sake of diving and HBOT clearance, we split patients into two groups: those who did not require hospitalization (who presumably developed no or mild symptoms), and those who required hospitalization. Hospitalized patients most likely developed moderate to severe symptoms and complications such as hypoxia, pneumothorax (or other pulmonary overinflation syndrome), acute respiratory distress or failure, or other organ failure requiring interventions -- such as oxygen, chest tubes, trial medications, or mechanical ventilatory support.

Commercial divers have a well-documented and generally agreed upon set of criteria for underwater clearance and this clearance is renewed on a yearly or bi-yearly basis. The Association of Diving Contractors International (ADCI) publishes the International Consensus Standards for Commercial Diving and Underwater Operations, with a clear and well-thought-out list of exclusionary diagnosis, as well as the required testing to rule out these conditions before clearance is completed. The ADCI guidance likely needs to be updated for present day conditions, with respect to conditions found in this article. CXR and spirometry are standard

requirements of these yearly clearance exams. Exams must be performed by a physician certified in Undersea and Hyperbaric medicine. Exclusionary conditions include cystic, bullous, or cavitary lung disease, significant obstructive or restrictive lung disease, and spontaneous pneumothorax. All of these conditions have been observed in COVID-19 patients and therefore must be thoroughly investigated before return to hyperbaric conditions. Furthermore, ADCI recommends a 'medical evaluation following any non-diving injury or illness that requires any prescription medication, any surgical procedure, or any hospitalization, thus committing commercial divers to a fitness to dive examination post COVID-19 infection, specifically if the patient required hospitalization.

Regulations for recreational dive clearance are provided by the Recreational Scuba Training Council (RSTC), which publishes a medical statement and dive clearance form for physicians detailing the physical stressors a diver may encounter while underwater and the conditions that are considered relative or absolute contraindications to underwater activity. Divers are expected to tolerate 13 METS of exertion and be free of high-risk conditions, as detailed on the clearance form. Final clearance is at the discretion of the performing physician and Undersea and Hyperbaric certification of the examining physician is not required.

COVID-19 patients commonly develop many of the exclusionary lung related conditions such as hypoxia, interstitial lung disease in the form of ground glass infiltrates, decreased exercise tolerance, and, less commonly, pneumothorax and cavitary lung disease. As these patients recover and attempt to return to pre-COVID activities, it may be challenging for physicians to determine the optimal time frame to safely return to hyperbaric conditions and underwater activity.

Recommendation / Conclusion

There is some confusion and concern surrounding post-COVID return to diving. We have designed a return to diving diagnostic matrix, to assist physicians in determining the most appropriate testing. This testing is meant to assist in the risk stratification process when evaluating a diver for return to underwater activity or HBOT.

Asymptomatic and non-hospitalized patients should have a minimum of one-month from the time of diagnosis until consideration for return to diving. The one-month convalescence prior to exam increases the likelihood of resolution of subclinical conditions. Patients should have a negative PCR and be fully asymptomatic at the time of clearance evaluation. They should all have a negative CXR, be able to demonstrate tolerance of a six-minute brisk walk, and have normal spirometry. The specifics of these evaluations will be detailed below.

Hospitalized patients require a higher degree of scrutiny prior to returning to diving, due to the increased probability of concomitant pulmonary and cardiac involvement. They will require a minimum of three months from time of diagnosis until consideration for return to diving. They should also have a negative PCR and be asymptomatic and the time of clearance evaluation. CT scan should be used for screening these patients, due to an increased risk of underlying lung damage. They should also have an ECHO to evaluate for normal ventricular function and lack of dilated cardiomyopathy. They should also be able to demonstrate tolerance of a six-minute brisk walk, and have normal spirometry.

Hospitalized patients who developed known significant elevations in troponin, suggesting myocarditis or myocardial infarction, or who had known significant left ventricular dysfunction

during their illness, should be evaluated by a cardiologist -- preferably, one knowledgeable in diving medicine. After a recovery period of three months after the resolution of symptoms, these patients should undergo exercise treadmill testing to assess their exercise capacity and to confirm there is no evidence of myocardial ischemia, no oxygen desaturation with exercise, or significant exercise-induced arrhythmias. Ideally this would have been performed prior to presentation for medical clearance evaluation.

The six-minute walk test described in the decision matrix below is accomplished by placing a pulse oximeter on the patient's finger and having them walk briskly around the office for a period of six-minutes. If there is a decrease in the oxygen level past than 94% the patient should be considered not fit for the strenuous nature of diving and reevaluated within four weeks. Patients whose oxygen saturations drop below 90% should be referred for evaluation by a pulmonologist and if below 88% consideration should be given to placing them on supplemental home oxygen.

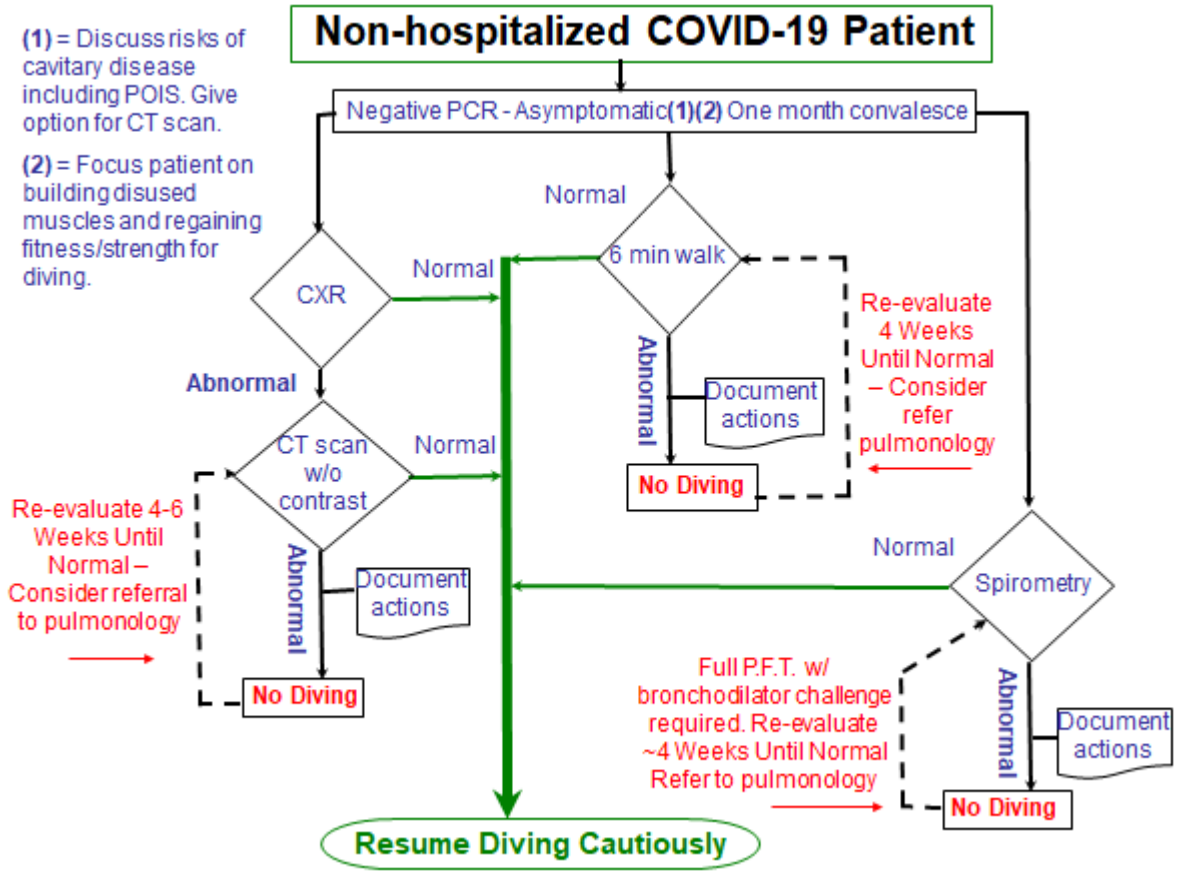
In the case of spirometry, any result outside the range of normal must be further evaluated. Ensure the result is in the context of a patient's height, weight, sex and age. Further evaluation should include full pulmonary function testing (spirometry, lung volumes, and DLCO). Referral to a pulmonologist is recommended for any patient with abnormalities.

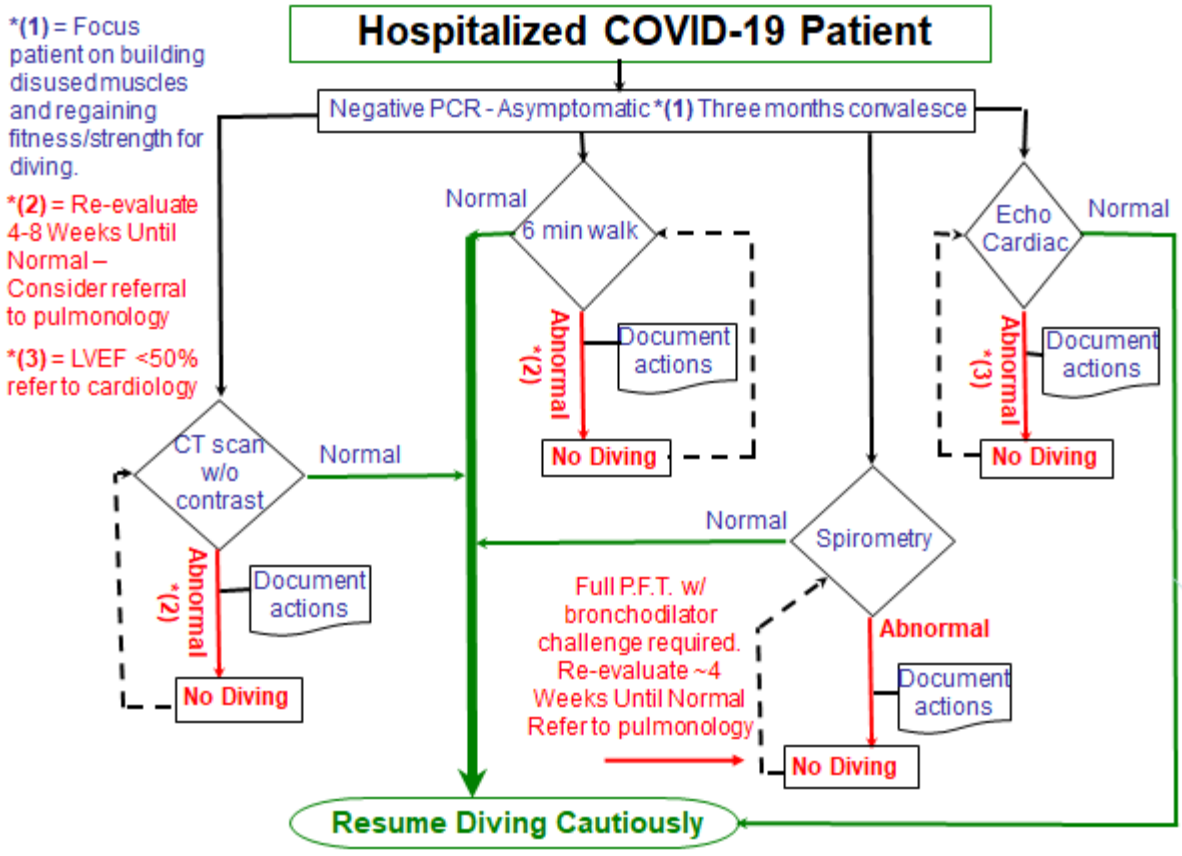
The CXR should be completely unremarkable, as read by a board-certified radiologist. Even minor abnormalities, or observations requiring clinical correlation, must be further evaluated with a non-contrast CT of the chest. CT scan provides a far more detailed diagnostic image than a CXR. If a patient was hospitalized for COVID-19, a CT scan would be required for evaluation of the lungs before clearance. Should any abnormalities be found the patient should be referred to a pulmonologist and placed in a non-diving status.

Should there be any issues whatsoever with the echocardiogram, the patient should be placed in a non-diving status. Particular attention should be paid to even a slight abnormality in ventricular function. These patients should be referred to a cardiologist for further testing and evaluation and cleared by them prior to return to diving.

There are two methods divers may use during their period of convalescence to expedite their return to normal lung function. During COVID recovery some patients improved lung function by using Inspiration Spirometry. This device can be used as much as 10 times per hour and has no negligible impact on the patient. It should be noted that COVID-19 positive patients should be cleaning the machine and performing it in a fully ventilated area. Additionally, if indicated and with the approval of a pulmonologist, an Oscillating Positive Expiratory Pressure Therapy System can prove useful to assist patients in removal of mucus secretions from the lungs. Great care should be taken to not use one of these devices in the case of cavitary disease as the pressure fluctuation may exacerbate the cavity and cause further damage.

All of these examinations should take place during the convalescence period (either one or three months as described above) with the ultimate goal of completing the examinations towards the nearer the end unless medically indicated. A negative finding on all tests is required for clearance to dive or HBOT. The following decision matrices are provided as a visual representation of the aforementioned information should be used for ease and convenience:


Non-hospitalized COVID-19 Patient
(1) = Discuss risks of cavitary disease including POIS. Give option for CT scan.
(2) = Focus patient on building disused muscles and regaining fitness/strength for diving.
Negative PCR - Asymptomatic(1)(2) One month convalesce
Normal
6 min walk
CXR
Normal
Abnormal
Document actions
Re-evaluate 4 Weeks Until Normal – Consider refer pulmonology
No Diving
CT scan w/o contrast
Normal
Abnormal
Document actions
Re-evaluate 4-6 Weeks Until Normal – Consider referral to pulmonology
No Diving
Normal
Spirometry
Full P.F.T. w/ bronchodilator challenge required. Re-evaluate ~4 Weeks Until Normal Refer to pulmonology
Abnormal
Document actions
No Diving
Resume Diving Cautiously


*(1) = Focus patient on building disused muscles and regaining fitness/strength for diving.
*(2) = Re-evaluate 4-8 Weeks Until Normal – Consider referral to pulmonology
*(3) = LVEF <50% refer to cardiology
Hospitalized COVID-19 Patient
Negative PCR - Asymptomatic *(1) Three months convalesce
6 min walk
Normal
Abnormal *(2)
Document actions
No Diving
Echo Cardiac
Normal
Abnormal *(3)
Document actions
No Diving
CT scan w/o contrast
Normal
Abnormal *(2)
Document actions
No Diving
Spirometry
Normal
Abnormal
Document actions
No Diving
Full P.F.T. w/ bronchodilator challenge required. Re-evaluate ~4 Weeks Until Normal Refer to pulmonology
Resume Diving Cautiously

References

1. Guan WJ, Ni ZY, Hu Y, et al. Clinical Characteristics of Coronavirus Disease 2019 in China. *N Engl J Med*. 2020 Apr 30;382:1708– doi:10.1056/NEJMoa2002032
2. Chen N, Zhou M, Dong X, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. *Lancet*. 2020 Feb;395:507–13. doi:10.1016/S0140-6736(20)30211-7
3. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet*. 2020 Feb;395:497–506. doi:10.1016/S0140-6736(20)30183-5
4. Wang D, Hu B, Hu C, et al. Clinical Characteristics of 138 Hospitalized Patients With 2019 Novel Coronavirus-Infected Pneumonia in Wuhan, China. *JAMA*. 2020 Feb 7.;323(11):1061–9. doi:10.1001/jama.2020.1585
5. Xu XW, Wu XX, Jiang XG, et al. Clinical findings in a group of patients infected with the 2019 novel coronavirus (SARS-Cov-2) outside of Wuhan, China: retrospective case series. *BMJ*. 2020 Feb 19;368:m606. doi:10.1136/bmj.m606
6. Wu C, Chen X, Cai Y, et al. Risk Factors Associated With Acute Respiratory Distress Syndrome and Death in Patients With Coronavirus Disease 2019 Pneumonia in Wuhan, China. *JAMA Intern Med*. 2020 Mar 13;180(7):934–43. doi:10.1001/jamainternmed.2020.0994
7. Pan L, Mu M, Yang P, et al. Clinical Characteristics of COVID-19 Patients With Digestive Symptoms in Hubei, China: A Descriptive, Cross-Sectional, Multicenter Study. *Am J Gastroenterol*. 2020 May;115(5):766–73. doi:10.14309/ajg.0000000000000620
8. Rubin GD, Ryerson CJ, Haramati LB, et al. The role of chest imaging in patient management during the Covid-19 pandemic: a multinational consensus statement from the Fleischner Society. Chest 2020;158(1):106-116
9. Kwee T, Kwee R. Chest CT in Covid-19: What the Radiologist Needs to Know. RadioGraphics 2020;40:1848-1865
10. Guo T, Fan Y, Chen M, et al. Cardiovascular implications of fatal outcomes of patients with coronavirus disease 2019 (COVID-19). *JAMA Cardiol*. Published online March 27, 2020. doi:10.1001/jamacardio.2020.1017
11. Lala A, Johnson KW, Januzzi JL, et al; Mount Sinai Covid Informatics Center. Prevalence and impact of myocardial injury in patients hospitalized with COVID-19 infection. *J Am Coll Cardiol*. Published online June 8, 2020
12. Hartikainen TS, Sörensen NA, Haller PM, et al. Clinical application of the 4th Universal Definition of Myocardial Infarction. *Eur Heart J*. 2020;41(23):2209-2216. doi:10.1093/eurheartj/ehaa035
13. Szekely Y, Lichter Y, Taieb P, et al. The spectrum of cardiac manifestations in coronavirus disease 2019 (covid-19): a systematic echocardiographic study. *Circulation*. Published online May 29, 2020. doi:10.1161/CIRCULATIONAHA.120.047971
14. Puntmann, VO, Carerj, ML, Weiters, I, et al. Outcomes of cardiovascular magnetic resonance imaging in patients recently recovered from coronavirus disease (COVID-19).JAMA Cardiol 2020;5(11):1265-1273
15. Whelan, HT., Kindwall, EP.. *Hyperbaric Medicine Practice*. Best Pub. Co., 2017.

1) Joseph Dituri, Ph.D. CDR, U.S. Navy (ret)
International Board of Undersea Medicine
701 N. Westshore Blvd
Tampa, Florida 33609
joe@gallantaquatic.com
1-202-642-3483

Corresponding Authors

2) Elizabeth Carpenter, MD
Pulmonary, Critical Care,
Undersea, and Hyperbaric Medicine
701 N. Westshore Blvd
Tampa, Florida 33609

3) Carol J. Ebersole, MD
Interventional Radiologist
Watson Clinic, LLP
1600 Lakeland Hills Blvd.
Lakeland, Florida 33805

4) Douglas Ebersole, MD
Interventional Cardiology
Watson Clinic LLP
1600 Lakeland Hills Blvd.
Lakeland, Florida 33805

5) Russell D. Radtke, MD, FACEP
Pediatric Emergency Medicine
St. Joseph's Children's Hospital
3001 W Dr Martin Luther King Jr Blvd
Tampa, Florida 3360

6) Alberto Ardon, MD MPH
Senior Associate Professor of Anesthesiology
Mayo Clinic, Department of Anesthesiology
4500 San Pablo Rd S
Jacksonville, Florida 32224

7) Erica Schwaiger Kemp, DO
Pulmonary, Critical Care, and Sleep Medicine
James A Haley Veterans Hospital
13000 Bruce B Downs Blvd
Tampa, Florida 33612

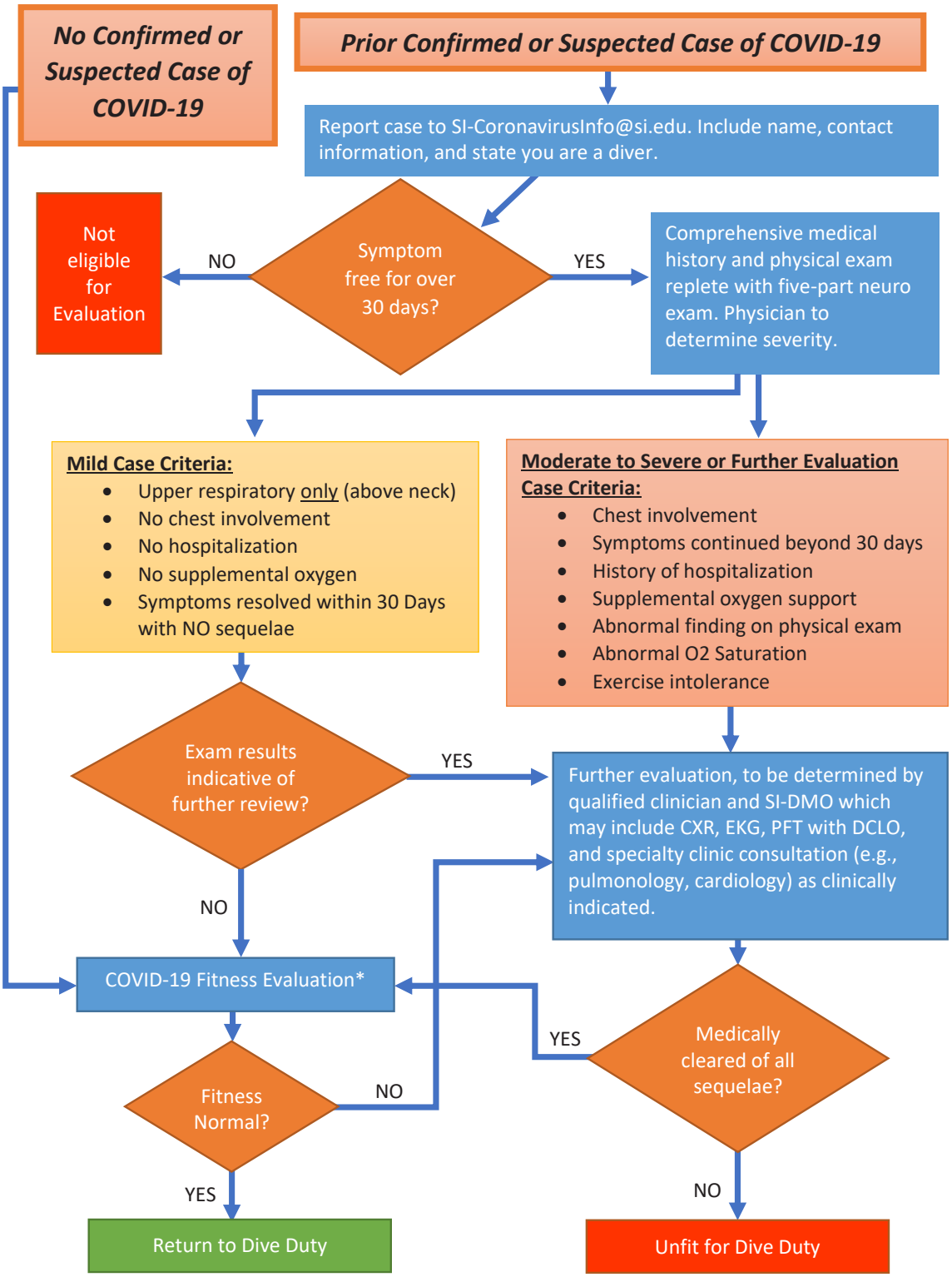
8) Chak Sriaroon, MD
Pulmonary, Critical Care,
and Infectious Disease Medicine
University of South Florida,
Department of Pulmonary
Critical Care Medicine 1
2901 Bruce B Downs Blvd
Tampa, Florida 33612

9) Sierra Taylor, IHT
Undersea Oxygen Clinic
701 N. West Shore Blvd
Tampa, Florida 33609

Smithsonian
Scientific Diving Program

ALGORITHM FOR DIVING MEDICAL CLEARANCE DURING SARS-COV-2 PANDEMIC

01Sep21



***COVID-19 Fitness Evaluation**:

1. Initial SpO2 and heart rate (PR) at rest (sitting for five minutes). If resting SpO2 less than 95%, then do not proceed.
2. Complete SDP Swim Test.
3. Final SpO2 and pulse rate (PR) (minimum rate of 130-140 BPM) after completion of swim test.

Updated-UC San Diego Guidelines for Evaluation of Divers during COVID-19 pandemic

Charlotte Sadler, MD, Miguel Alvarez Villela, MD, Karen Van Hoesen, MD, Ian Grover, MD, Tom Neuman, MD, and Peter Lindholm, MD, PhD

Updated February 4, 2022

***Background**:*

Coronavirus Disease 2019 (COVID-19) has become a global pandemic with SARS-CoV2 infecting millions of people and resulting in thousands of hospitalizations and deaths worldwide. Research examining the origins and structure of the virus, its pathogenesis, and the clinical features of its acute presentation is growing at a fast pace. However, as a nascent pandemic, the long-term sequelae to be expected in those who have survived the acute disease are largely unknown. SARS-CoV2 infection manifests primarily as atypical pneumonia, but in severe disease other complications are common, including cardiac and thromboembolic disease.

Scuba diving is a passion for many recreational divers, but, more importantly, it also represents a critical component of the commercial diving industry and scientific research. UCSD runs a diving medicine clinic that sees approximately 250 divers per year, most of whom are employed as commercial and scientific divers. As society begins to re-open after quarantines, many of these divers are presenting to our (and others') clinic requesting guidance and clearance on returning to dive after the pandemic.

COVID-19 and Diving:

We are presented with the challenge of performing fitness to dive evaluations in the context of a disease in which the natural history is still unknown, though more information is becoming available. In what we know of the pathophysiology of the disease, the pulmonary, cardiac, and thromboembolic/hypercoagulable disease seems to be relevant to divers. Potential long-term sequelae include decreased exercise tolerance, increased susceptibility to cardiac events such as heart failure, pulmonary edema, and arrhythmia, structural changes of the lung leading to increased risk for barotrauma, and increasedrisk of decompression sickness from underlying hypercoagulability.

We originally developed these guidelines in May of 2020 and the current landscape of the pandemic has significantly changed since that time. We have seen the development of vaccines that protect divers/people from infection, severe disease, and death. We have also witnessed the evolution of a virus into various strains, including some variants that are more contagious and some that seem to cause both more and less severe disease.

The situation has also changed significantly with the massive surge in cases due to the Omicron variant resulting in many divers who require rapid clearance to return to work. In addition, many only report symptoms like the common cold, which appear to be much milder than the original infection. In light of these developments, we recognized an amendment of our guidelines is needed.

The modifications to our guidelines were developed in a response to the challenges noted above and what we have observed clinically. In our experience, as well as information gathered from very limited publications, it appears that in cases where the disease causes only upper respiratory symptoms, there are limited long term sequelae or complications. We have also noted the publication of multiple recent reports suggesting that a percentage of young and otherwise

healthy patients who recover from mild or asymptomatic COVID-19 illness, may have surrogate findings of myocardial inflammation or damage on cardiac MRI. These findings are, however, of unclear clinical and prognostic significance. Our recommendations remain centered around the presence of cardiac symptoms or exercise limitations to guide further testing. Consequently, we have adjusted to treating such cases in a similar nature as we would other uncomplicated seasonal, upper respiratory viruses.

A few things should be noted-first, recommendations for those with moderate or severe disease have not changed. Second, as with our original guidelines, we strongly emphasize that these amendments are only applicable to those who have recovered from their acute illness, are completely asymptomatic, and back to their baseline exercise capacity.

Our goal has been to categorize divers based on the history and severity of their illness and base their return to dive evaluation accordingly. As with any illness, ultimately the work up is left to the discretion of the evaluating physician. Our plan is to continue to update them f= as we gain more experience and more evidence becomes available. The following guidelines are referring to divers who are ***completely asymptomatic*** after their illness, including exercise tolerance (see below). Before using the guidelines below, a few terms warrant definition:

Definitions of terms used in guidelines:

COVID-19-suspected Illness

We define a COVID-19-suspected illness as a diver who had symptoms consistent with COVID-19 with or without a positive PCR or rapid antigen, given that testing is still not universally available or reliable. We are currently using the CDC case definition (updated Aug 24, 2021) of COVID-19 for those patients who did not have PCR or rapid antigen confirmed illness:

In the absence of a more likely diagnosis:

- Acute onset or worsening of at least two of the following symptoms or signs:
- fever (measured or subjective),
- chills,
- rigors,
- myalgia,
- headache,
- sore throat,
- nausea or vomiting,
- diarrhea,
- fatigue,
- congestion or runny nose.

OR

- Acute onset or worsening of any one of the following symptoms or signs:
- cough,
- shortness of breath,
- difficulty breathing,
- olfactory disorder,
- taste disorder,
- confusion or change in mental status,
- persistent pain or pressure in the chest,
- pale, gray, or blue-colored skin, lips, or nail beds, depending on skin tone,
- inability to wake or stay awake.

OR

- Severe respiratory illness with at least one of the following:
- Clinical or radiographic evidence of pneumonia,
- Acute respiratory distress syndrome (ARDS).

Exercise Tolerance

This is likely the most important definition used in our guidelines and it is vital that physicians evaluate it carefully. It is our belief that a diver with significant cardiac or pulmonary pathophysiology would not have a normal exercise tolerance. However, the definition of the word normal is critical. First, the diver must have returned to his or her baseline level of exercise and tolerance. Even minor deviations from their baseline ("getting more winded," longer recovery times, etc) warrants further testing and investigation. Second, the physician must be satisfied that the diver's exercise regimen warrants an appropriate exertional test for diving. There are no universally agreed upon recommendations on an exercise tolerance level needed for all divers, but the ADCI guidelines for commercial divers require a minimum level of 10 METS. If the physician is not convinced that the diver's self-reported exercise level meets appropriate criteria or concerned that it would not reveal underlying cardiac or pulmonary disease, further testing is warranted.

UC San Diego Guidelines for Evaluation of Divers during COVID-19 pandemic

Charlotte Sadler, MD, Miguel Alvarez Villela, MD, Karen Van Hoesen, MD, Ian Grover, MD, Tom Neuman, MD, and Peter Lindholm, MD, PhD

Updated GUIDELINES FOR DIVER EVALUATION:

Category 0 ***NO*** *history of COVID-19 suspected illness*	*Category 0.5* ***VERY MILD*** *COVID-19-suspected illness*	*Category 1* ***MILD*** *COVID-19-suspected illness*	*Category 2* ***MODERATE*** *COVID-19-suspected illness*	*Category 3* ***SEVERE*** *COVID-19-suspected illness*
Definition: No history of COVID-19 or asymptomatic positive screening test	Definition: ● **isolated upper respiratory or systemic symptoms (rhinorrhea/ congestion/ pharyngitis/ loss of taste or smell), fevers, fatigue, or myalgias but WITHOUT lower respiratory or cardiac symptoms.** ● Returned to baseline exercise tolerance.	Definition: ● **Symptomatic COVID-19 including any of the following: Any lower respiratory or cardiac symptoms, including chest pain, palpitations, significant* cough, shortness of breath with exertion or at rest.** ● outpatient treatment only without evidence of hypoxemia. ● Did not require supplemental oxygen ● Imaging was normal or not required ● Returned to baseline exercise tolerance.	Definition: ● Required supplemental oxygen or was hypoxic ● had abnormal chest imaging (chest radiograph or CT scan) ● admitted to the hospital but did NOT require assisted ventilation (BIPAP, CPAP, or ventilator) or ICU level of care. ● If admitted, had documentation of a normal cardiac work up including normal ECG and cardiac biomarkers e.g. troponin or CK-MB and BNP ● Returned to baseline exercise tolerance.	Definition: ● Required mechanical or assisted (CPAP, BIPAP) ventilation, or ICU admission ● Cardiac involvement defined as abnormal ECG, abnormal echocardiogram, or elevated cardiac biomarkers; e.g. troponin or CK-MB and BNP (or absence of documented work up) ● Thromboembolic complications (such as PE, DVT, or other coagulopathy) ● Returned to baseline exercise tolerance.

*for example, cough that is productive, prevents from sleeping, or requires medication, ultimately defined at the discretion of the evaluating physician

Other factors may be taken into consideration including vaccination status, as there is evidence that breakthrough infections in those vaccinated against COVID-19 results in milder disease, and regional prevalence of variants (omicron vs delta, etc).

UC San Diego Guidelines for Evaluation of Divers during COVID-19 pandemic

Charlotte Sadler, MD, Miguel Alvarez Villela, MD, Karen Van Hoesen, MD, Ian Grover, MD· Tom Neuman, MD, and Peter Lindholm, MD, PhD

Category 0 ***NO*** *history of COVID-19 suspected illness*	*Category 0.5* ***VERY MILD*** *COVID-19-suspected illness*	*Category 1* ***MILD*** *COVID-19-suspected illness*	*Category 2* ***MODERATE*** *COVID-19-suspected illness*	*Category 3* ***SEVERE*** *COVID-19-suspected illness*
● Initial/annual exam per ADCI/AAUS /NOAA /RSTC guidelines ● Chest radiograph only if required per ADCI/AAUS /NOAA/ RSTC guidelines No additional testing required	● Initial/annual exam per ADCI/AAUS /NOAA /RSTC guidelines ● Chest radiograph only if required per ADCI/AAUS /NOAA/ RSTC guidelines No additional testing required	●Initial/annual exam per ADCI/AAUS/ NOAA /RSTC guidelines ● Spirometry ● Chest radiograph (PA & Lateral) if abnormal, obtain Chest CT ● If unknown (or unsatisfactory) exercise tolerance, perform exercise tolerance test with oxygen saturation	● Initial/annual exam per ADCI/AAUS/ NOAA /RSTC guidelines ● Spirometry ● Chest radiograph (PA & Lateral) if abnormal, obtain Chest CT ● ECG ● Echocardiogram (if no work up was done as an inpatient. Can forgo if had negative work up) ● If unknown (or unsatisfactory) exercise tolerance, perform exercise tolerance test with oxygen saturation ● Investigation and management of any other complications or symptoms per provider and ADCI/AAUS/NOAA/ RSTC guidelines	● Initial/annual exam per ADCI/AAUS/ NOAA /RSTC guidelines ● Spirometry ● Chest radiograph (PA & Lateral) (if abnormal, obtain Chest CT) ● ECG ● Repeat Cardiac troponin or CK-MB and BNP to ensure normalization ● Echocardiogram ● Exercise Echocardiogram with oxygen saturation ● Investigation and management of any other complications or symptoms per provider and ADCI/AAUS/NOAA/ RSTC guidelines

UC San Diego Guidelines for Evaluation of Divers during COVID-19 pandemic

Charlotte Sadler, MD, Miguel Alvarez Villela, MD, Karen Van Hoesen, MD, Ian Grover, MD, Tom Neuman, MD, and Peter Lindholm, MD, PhD

Symptomatic divers or those with abnormal test results

It is not currently our plan to allow divers who are symptomatic or have abnormal testing per the guidelines above to dive (though each will need to be evaluated on a case by case basis and exceptions are to be expected). However, we do not feel this necessarily represents a lifetime ban on diving as many of the sequelae which are currently disqualifying (such as abnormal CT scans) may resolve over the next 3-6 months and re-testing may be indicated. It is currently unknown whether or not potential sequelae of COVID-19 will become chronic and therefore re-evaluation will likely be indicated until more evidence becomes available.

Screening of diving employees prior to diving

We currently recommend following CDC guidelines for screening of an employee prior to diving and do not feel that measuring vital signs or oxygen saturation routinely before diving are warranted.

November 17, 2019 Earliest known SARS CoV-2 case in Wuhan, China

December 31, 2019 Wuhan reports Coronavirus pneumonia cluster

January 9, 2020 WHO announces new Coronavirus pneumonia in Wuhan

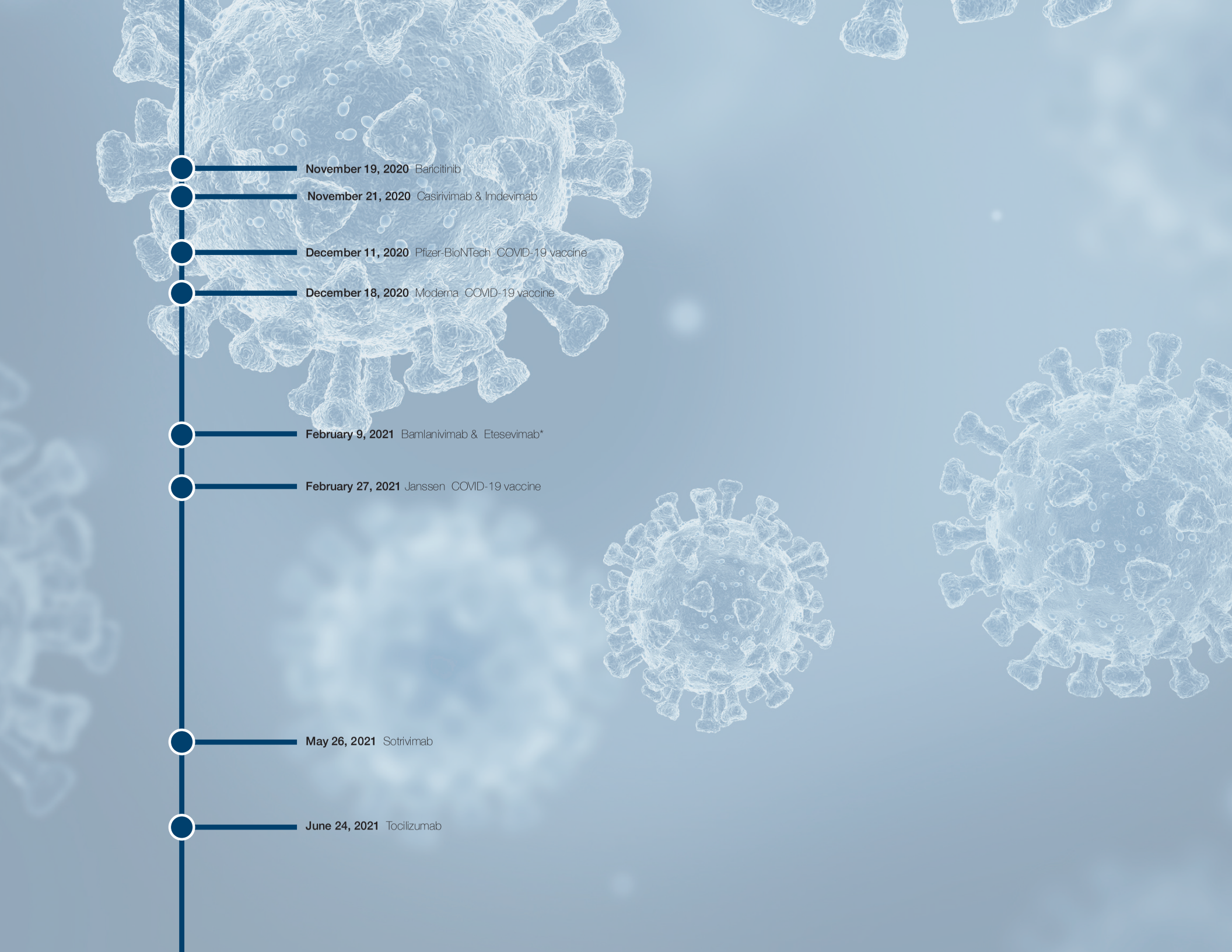
January 21, 2020 First COVID-19 case reported in U.S.

March 11, 2020 WHO declares COVID-19 a global pandemic

May 1, 2020 Remdesivir

July, 2020 Dexamethasone

August 23, 2020 Convalescent Plasma


November 19, 2020 Baricitinib
November 21, 2020 Casirivimab & Imdevimab
December 11, 2020 Pfizer-BioNTech COVID-19 vaccine
December 18, 2020 Moderna COVID-19 vaccine
February 9, 2021 Bamlanivimab & Etesevimab*
February 27, 2021 Janssen COVID-19 vaccine
May 26, 2021 Sotrivimab
June 24, 2021 Tocilizumab

UNDERSEA & HYPERBARIC MEDICAL SOCIETY

DAN
DIVERS ALERT NETWORK