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ASSESSING THE ARTIFICIAL HEART

The Clinical Moratorium Revisited

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INTRODUCTION: THE HEART, HUMAN AND MAN-MADE

Viewed in relation to the vast amount of clinical research in the United States, the number of total artificial heart (TAH) implants is so small as to be statistically invisible. And while the results of those implants to date may seem dubious in terms of the recipients' outcomes, they are in fact very similar to those of many other innovative therapies when they are first tried on desperately ill patients. Why, then, has the artificial heart been the object and subject of such extraordinary interest and controversy? It has been the subject of special federal studies, reports, and hearings for 20 years; has been perceived and portrayed as a unique chapter in the annals of human experimentation and therapeutic innovation; has attracted medically unprecedented media attention; and, in the case of permanent implants, has received unusually exhaustive and restrictive regulatory supervision.

The reasons for the intense interest and controversy generated by the artificial heart are multiple. They include the "identified life" drama of the artificial heart patients and their families, brought into our homes daily via TV and newspapers; the increasing concern and sophistication about ethical and legal aspects of med-

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ical research and care on the part of journalists, medical professionals, policy makers, and the public at large; and, perhaps most importantly, the literal and symbolic meanings of the human heart and its replacement by a man-made device. "The machines we build are highly directive," Reiser points out.

> For we build into them not only mechanical or electronic powers but our own aspirations. The artificial heart is at once a metaphor of concern about unduly sustaining an aging population, the cost of medical care, plunging into technologic creation without adequate thoughts to consequences, and of an accumulation of means as an end in itself. It stands also as a metaphor of exhilaration about the wonders of our science and technology (57,172–73).

PATTERNS, OLD AND NEW

On December 20, 1985, the Food and Drug Administration's Circulatory System Devices Panel, advisors to the agency's Division of Cardiovascular Devices, convened a special day long hearing in Washington. Responding to rising controversy about the implantation of the artificial heart, the Panel that day would hear testimony for and against the device's use during a public hearing and meet in a closed session with the Jarvik-7 heart's manufacturer and principal investigator. The Panel then would issue a recommendation to the FDA Commissioner as to whether the regulatory agency should impose a moratorium on permanent implants of the artificial heart.

The hearing and decision, a blend of regulatory process, political exercise, and media event, was a critical moment in the history of the artificial heart's development. It also embodied the medical, ethical, and social complexities involved in assessing the "success/failure" status and related aspects of the device at this early stage of its movement from laboratory development and animal testing to experimental clinical use.

Much—although by no means all—of the debate that has swirled around clinical use of the TAH, especially the series of permanent implants performed by Dr. William C. DeVries, has centered on arguments for and against the calling of a moratorium. As this debate has intensified, there already have been, in fact, two moratorium phases in the short clinical history of the permanent artificial heart. The elements and dynamics of these moratorium periods, and the more visible controversy about the device's use, involve the same contributory factors and attributes that we have found in examining other moratoria. But they also involve some newer features, primarily related to the social and institutional frameworks in which clinical research in general and work with the artificial heart in particular now take place in the United States. For these reasons, the time seemed right to revisit a phenomenon that we first named and analyzed in 1970, *the clinical moratorium* (62). This revisit is based on a study of the artificial heart that we have been conducting since 1982, involving content analyses of lay and professional literature and interviews and observations at sites including the University of Utah and Humana Heart Institute.

As we have used the term, a clinical moratorium is the suspension, rather than the permanent cessation, of the use of an experimental procedure on patients. Depending on the particular case, it is a pause that can last for months or, as

witnessed by the history of mitral valve surgery, for years. Moratoria are not isolated and idiosyncratic events. Rather, "the clinical moratorium is an event we consider generic to the process of therapeutic innovation. Its significance lies not only in the frequency with which it occurs, but also in its relationship to some fundamental conceptual, technical, social, and ethical properties of clinical investigation" (62, 315).

The simplest form a moratorium that can take is represented by Dr. Elliot Cutler's decision to suspend mitral valve surgery. In this case, the surgeon who pioneered a risky innovative procedure decided personally to call a halt to further clinical trials, after he experienced a mortality rate of 90% in 10 operations. Cutler, who was "just devastated" by his results, quietly signalled the moratorium in the subtitle of his 1929 paper: "Final Report of all Surgical Cases" (16). Mitral valve surgery was not tried again until 1945.

The artificial heart involves a far more complex set of factors and patterns in the possible calling of a moratorium. From the start of our research, we have been struck by the ways that the patterns involved in the device's development and clinical introduction are historically and sociologically "the same, but different" from those that we have analyzed before (28). Some of the differences will be presented in this paper. But to recognize and appreciate them, and understand the artificial heart controversy, one first needs to see what the familiar patterns are (29).

These patterned phenomena and issues include, first, how the decision is made that the time has come for the inherently premature move from laboratory to human testing of a new drug, device, or procedure—the decision that man is now "the animal of necessity" in the effort to develop new therapies. A second pattern involves the experiment–therapy dilemma. It includes medical, ethical, and psychosocial problems, decisions, and often enormous strains and tensions for physicians who are also investigators and patients who are also research subjects. For example, how does one decide what it is "justifiable" to do or try on humans in the name of biomedical research and therapeutic gain? What criteria, medically and ethically, should be used in selecting patient-subjects? What does informed, voluntary consent mean in this context, and how can it be realized most adequately? How should the success or failure of the new intervention be judged?

How the decision to move from the laboratory to the clinic is viewed in light of the first outcomes with human subjects, and how success and failure and other experiment–therapy issues are dealt with, are critical to whether a therapeutic innovation is abandoned or, over time and with ongoing evaluation, moves along the spectrum that runs from early clinical testing to conventional therapy.

THE ARTIFICIAL HEART: FROM THE LABORATORY TO THE CLINIC

A full assessment of the artificial heart's clinical introduction, which is beyond the scope of this paper, needs to be set in the context of the extensive research and development efforts that have taken place over three decades. That history involves early efforts to develop prototype hearts by investigators like Kantrowitz, DeBakey, and Kolff in the 1950s, and the biomedical, bioengineering, and

political history of the National Institutes of Heath artificial heart program, which began in 1963 (61;63).

The history of the artificial heart prior to the permanent implant series with the Jarvik-7 model also includes two earlier efforts to move the artificial heart from the laboratory to the clinic. The two bridge-to-transplant implants were performed by Dr. Denton Cooley, in 1969 and 1981 (13;14;29;69). As Cooley acknowledged, "the length of the patients' survival [was] unimpressive." But, he argued in justifying the implants, "this experience demonstrates the feasibility of the concept [of staged cardiac transplantation] and encourages the further development of cardiac prostheses" (13, 145). Both implants received dramatic and extensive media coverage that helped to focus public attention and interest on the effort to replace a failing human heart with a mechanical substitute. But in discussions about current implants, there seems to have been a "structured forgetting" about many of the medically, ethically, and in the first case legally controversial aspects of Cooley's procedures.

Cooley's two implants were essentially one-shot and, to many, highly premature attempts at the clinical use of inadequately tested experimental devices. The major locus of the artificial heart's move from the laboratory to the clinic was in Salt Lake City, Utah. The work Dr. Willem Kolff had begun at Cleveland Clinic in the 1950s had moved with him to the the University of Utah where he began the Institute for Biomedical Engineering and Division of Artificial Organs in 1967. One of his first research associates that year was a freshman medical student, William DeVries. Another young researcher, Robert Jarvik, joined the group in 1971. In 1976 Kolff Medical Associates (now Symbion) was formed as an independent company with close ties to the University of Utah. As Kolff has detailed, the device implanted in Dr. Barney Clark in 1982, which bears the name of Dr. Robert Jarvik, represented a quarter century of work on artificial hearts by Kolff and 247 co-workers (44).

The Jarvik Heart. Both at the time that it is made and in retrospect, the decision that "the time is right" to move a new drug, device, or procedure from the laboratory to tests with human subjects is seldom unambiguous or certain. This is true both for investigators and their immediate colleagues, as well as those involved in the regulatory context in which most clinical research in the U.S. now takes place.

In the United States, clinical use of the artificial heart is regulated under the Food and Drug Administration's Medical Device Amendments (1976), specifically its investigational device exemption (IDE) regulations, which took effect in 1980. Under the IDE regulations, the artificial heart is classified as a significant risk investigational device: it "presents a potential for serious risk to the health, safety or welfare of a subject" and is of "unproven safety and efficacy." Under this classification, an investigator must obtain permission for "experimental use" from the FDA's Bureau of Medical Devices and his or her institutional review board for research with human subjects (24).

Complying with these regulatory requirements—which not all artificial heart researchers have done—Kolff Associates made their first applications to the University of Utah IRB and the FDA in 1980–81, seeking permission to begin testing the Jarvik-7 device on patients at University Hospital in Salt Lake City, with Dr. William DeVries as principal investigator.

How clearly the decision to initiate human testing was warranted by results with animals has been a matter of debate. In a January 1981 *Scientific American* article, Jarvik declared that "neither the Jarvik-7 nor any of the several other total artificial hearts being developed is yet ready to permanently replace a human heart, even on a trial basis, but the pace of improvement in the technology suggests that the day may not be long in coming" (37, 74). Over the years, morbidity problems had been reduced and survival rates improved, but the level of success with animals that researchers felt was a prerequisite for human use had not been consistently achieved.

"The current goal in artificial heart research," researchers from the Cleveland Clinic wrote in 1983,

> is to develop a device which remains functional and reliable for a minnimum of 2 yrs in a clinical setting. The problem, however, is that to date, not a single animal experiment has achieved this 2 yr status for a variety of reasons, such as overgrowth of animals, calcification, thrombosis, inflow/outflow obstruction or sepsis (26, 535).

Compared to the clinical goal of a total artificial heart (TAH) that functions for at least two years, "long-term" survival in the Utah sheep and calf recipients was defined at more than 30 days (49). By 1981, Kolff's group had achieved a survival record of five months or longer in 9 calves with the J-5 and J-7 heart models; the longest survival was 268 days (34). A chief source of morbidity and mortality, in part inherent to chronic animal experimentation, was the "dreaded complication" of infection (26, 532). Utah data from 35 animals implanted during 1980–82 showed the artificial heart to be a "particularly susceptible device for the establishment of an infection" from a "wide spectrum of microorganisms" (49, 541–42). The relationship between the device and infection was unclear; in retrospect it may have foreshadowed the pronounced suppression of the immune system found in the first human recipients of a permanent artificial heart. Other reported causes of death in this series included broken or malfunctioning mechanical valves, malfunctions in connections between parts of the device, pneumothorax, respiratory failure, and brain death from hypotension and acidosis.

Judging the degree of success in animal trials of the Jarvik heart was partly a matter of deciding whether the proverbial glass is half empty or half full; such is often the case, too, in evaluating early clinical use. In part, those involved in the device's development assessed their work in relation to the fact that in the early 1970s, after more than 15 years of laboratory work, the longest animal survival with a TAH was only one week. Thus, in terms of durability, functional reliability, and the length of animal survival, the Jarvik-7 had set a "record performance." In the eyes of its developers, this "level of experimental success rekindled the dream of application . . . in man" (50, 5).

Implementing that dream involved two major rationales. First, based on "the success of the animal research at the University of Utah predictions were made that patients with end-stage heart disease could benefit from the clinical application of artificial heart technology" (50, 11). Second, following another common pattern of reasoning, the Utah group argued that man now had become the animal of necessity in terms of the ability to study physiological parameters and the

responses of a "sick organism" (an end-stage cardiac patient rather than a healthy animal) to the device, including such aspects as quality of life (41;50).

These arguments involved another pattern of reasoning that we have seen recurrently in decisions to move from the laboratory to the clinic and in assessments of new modalities during their first human trials. It is a pattern that we term *ritualized optimism*, in which hopes for success rest on more than scientifically based assumptions. It blends scientific and medical knowledge and judgment with a degree of optimism in the face of uncertainty that often seems to involve magico-religious dimensions. In this case, one hope was that the human body would prove to be as "tolerant" of the device, if not more so, than the bodies of calves and sheep, and that complications thus would be less severe (41). With similar optimism, transplanters once hoped that the human heart would be a "privileged organ" with respect to rejection, and that cyclosporine would be a uniquely selective, effective, and safe immunosuppressive "weapon" (29;30).

The norms of writing for modern scientific and clinical journals include a conciseness that truncates and simplifies the complex nature of research. There is a form of reductionism at work that contributes to an inadvertant retrospective falsification of the nature of research and related decision making (7). As described in 1983 to Swazey and Fox by members of the Utah artificial heart program during personal interviews, for example, there was more ambivalence and uncertainty about the "success" of animal tests as a basis for embarking on clinical trials than is reflected in published accounts. Not surprisingly then, the final decision that the "glass was half full" was influenced by more than the animal data alone. One such influence was the fact that federal support for artificial heart research, at Utah and elsewhere, was waning. The prospect of diminishing research funds, a key member of the Utah program recalled, figured strongly in the decision to "go now with a human experiment, because if successful it would be a great moral and financial stimulus to the artificial heart program."

Another pivotal factor, which is also a recurrent one in the process of therapeutic innovation, was the conviction and drive of a key factor in the decision-making process. In this case it was surgeon William DeVries, who in the words of one of his colleagues "championed the research data and had the courage to take it to humans."

DeVries formally initiated his quest to perform the first permanent artificial heart implant in June 1980, when he submitted a protocol to the Utah IRB. After a series of submissions, revisions, and resubmissions to the IRB and to the FDA, the approval process was completed in May 1982. DeVries was authorized to do a series of seven implants. Rather than granting the usuual type of permission to conduct the full series, however, the FDA stipulated a case-by-case approval from the IRB. Two groups of candidates could be considered for artificial hearts: patients who could not be weaned from the heart–lung machine following cardiac surgery, and patients with class IV (end-stage) congestive heart failure (18;23;68).

The stage was now set to move the Jarvik-7 heart from the laboratory to the clinic. The candidate who emerged was a dentist, Dr. Barney Clark, suffering from end-stage heart failure. His artificial heart beat 12,912,499 times before he died, 112 days after his implant on December 2, 1982.

THE FIRST PATIENT-SUBJECTS: USES AND CLINICAL RESULTS

From April 1969 to February 1986, total artificial hearts have been implanted in fifteen patients: five as permanent replacements, and twelve as a bridge-to-transplant (with one patient receiving two implants). The accompanying chart chronologically summarizes these implants, including reported complications and the recipients' status as of February 1986. For the purposes of our analysis, we will exclude Cooley's two implants.

As the chart shows (pp. 394–397), two of the permanent TAH recipients were alive in February 1986, and all experienced serious morbidity problems postimplant (see Note b, p. 396). Eight patients received nine temporary implants between March 1985 and February 1986. Six of these patients were alive: four with cardiac transplants and two awaiting a transplant. One of the latter patients had suffered an acute rejection of her transplant and had undergone a second emergency implant of a Jarvik-70 model. Only two of the eight patients had no reported complications during their tenure with an artificial heart. In one of these cases, involving the controversial use of the "Phoenix" heart which kept Thomas Creighton biologically alive for eleven hours, the patient was so compromised preimplant that it is impossible to assess the effects of the artificial heart on his condition (4).

Since permanent artificial heart use has been the primary focus of controversy and regulatory review, for a mix of reasons, let us turn in more detail to its recipients. The patients' numerous and often grave complications postimplant have had three possible sources: 1) the serious preexisting illnesses, related to their end-stage cardiac status and other conditions, which made them candidates for an implant; 2) the iatrogenic effects of the device; and 3) the problems of uncertainty concerning their proper clinical management. Determining which factor or combination of factors has been responsible for the major complications, especially neurological and renal problems, has been a major task and matter of concern for the artificial heart teams and the FDA's Advisory Panel (17;20;46).

With these patients, as with the test animals, some of the complications were anticipated, others not, from animal data; some problems have been more severe, others less, than those encountered in the animal barn. Overall, the hope that the human body would tolerate the device as well or better than calves or sheep has not yet been realized. As DeVries acknowledges, "at present, the use of the artificial heart means giving the patient another disease in place of his original problem" (17).

The major complications, which in various ways seem to be at least partly device-related, include: 1) a mysterious initial severe suppression of the immune system, which increases susceptibility to 2) infections; 3) hemolytic anemia; 4) renal insufficiency and in one patient renal failure due to acute tubular necrosis; 5) respiratory insufficiency; 6) bleeding; and 7) blood clotting.

The most devastating problems, and the ones that have created the greatest concern about the safety of the device, have been strokes. DeVries and his colleagues, as Swazey and Fox learned in a 1986 interview, have "learned painful lessons from our patients" as they have sought ways to manage the twin threats of bleeding and clotting by improved surgical techniques and safer and more

Artificial Heart Recipients: Summary through 2/28/86

	Patient	*Age*	*Date of implant*	*Purpose*[a]	*Surgeon and institution*	*Type of device*
1.	Haskell Karp	47	4/4/69	B	Cooley St. Lukes Hosp. Baylor Coll. of Med.	Baylor Art. Heart Prog.
2.	Willebrordus Meuffels	36	7/23/81	B	Cooley Texas Heart Inst.	Akutsu-3
3.	Barney Clark	61	12/2/82	P	DeVries Univ. Utah	Jarvik-7
4.	William Schroeder	52	11/25/84	P	DeVries Humana Audubon	Jarvik-7
5.	Murray Haydon	58	2/17/85	P	DeVries Humana Audubon	Jarvik-7
6.	Thomas Creighton	33	3/6/85	B	Copeland Univ. Arizona	Phoenix
7.	Leif Stenberg	52	4/7/85	P	Semb Karolinska, Sweden	Jarvik-7
8.	Jack Burcham	62	4/14/85	P	DeVries Humana Audubon	Jarvik-7
9.	Michael Drummond	25	8/29/85	B	Copeland Univ. Arizona	Jarvik-7
10.	Anthony Mandia	44	10/18/85	B	Pierce Hershey Medical Center	Penn State
11.	Thomas Gaidosh	47	10/24/85	B	Griffith Presbyterian Hosp. Pittsburgh	Jarvik-7

Primary indications	*Reported complications*	*Length of survival/status*
coronary artery occlusive disease; left ventricular aneurysm	hemolysis, oliguria, anuria, infections	64 hrs. on device; died 32 hrs. after transplant
coronary artery occlusive disease	diffuse bleeding, oliguria, anuria, infection multiple organ infection	54 hrs. on device; died 7½ days after transplant
CHF chronic myocarditis COPD cardiac cachexia	day 3, surgery for ruptured pulmonary blebs day 4, acute tubular necrosis day 6, generalized seizures day 13, sudden left heart failure; surgery to replace left pump subsequent GI tract bleeding, renal failure, aspiration pneumonia, recurrent epistaxsis, sepsis, pseudomembranous enterocolitis, circulatory collapse	112 days
CHF advanced atherosclerotic HD (post CABG 3/83)	day 1, repeat surgery for bleeding day 3, acute tubular necrosis day 18, stroke (CVA) (12/13) subsequent seizures, residual short term memory impairment, expressive aphasia, fever of unknown, origin cerebral hemorrhage 5/6, 11/10	alive; receiving physical, speech, & occupational therapy[b]
CHF (idiopathic cardiomyopathy) cardiac cachexia	day 5, acute tubular necrosis day 13, repeat surgery for bleeding subsequent ARDS, stroke 6/3, pneumonia 7/85	alive neurologically intact partially respirator dependent[b]
rejection of heart transplant	none reported	11 hrs. on device; died 24 hrs. after transplant
CHF renal insufficiency	June, visual problems (clot?) early Sept., stroke; bleeding	229 days
CHF (idiopathic cardiomyopathy) Mild COPD renal insufficiency	poor fit of device caused difficult implantation day 2, hemorrhage, repeat surgery, acute tubular necrosis day 10, renal dialysis, intrathoracic bleeding, cardiac tamponade	10 days
viral cardiomyopathy	day 7, minor strokes	9 days on device; alive post-transplant
severe CAD and multiple heart attacks	neurological episodes causing stuporous periods	10 days on device; died 17 days after transplant
idiopathic cardiomyopathy	day 2, surgery for bleeding	4 days on device; alive post-transplant

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Artificial Heart Recipients: Summary through 2/28/86 (*cont.*)

	Patient	*Age*	*Date of implant*	*Purpose*[a]	*Surgeon and institution*	*Type of device*
12.	Mary Lund	40	12/18/85	B	Joyce Abbott Northwestern	Jarvik-70
13.	Joseph Burrello	39	2/2/86	B	Griffith Presbyterian Hosp. Pittsburgh	Jarvik-7
14.	Bernadette Chayrez	40	2/3/86	B	Copeland Univ. Arizona	Jarvik-70
15.	Harris Kent	41	2/4/86	B	Cooley/Frazier Texas Heart Inst.	Jarvik-7
16.	Bernadette Chayrez	40	2/9/86	B	Copeland Univ. Arizona	Jarvik-70

[a] P = Permanent implant; B = Bridge to transplant.
[b] Mr. Hayden died 6/19/86, 488 days post-implant; Mr. Schroeder died 8/6/86, 620 days post-implant.

effective anti-coagulation therapy. Like the tightrope that must be walked with transplant patients—enough immunosuppressive drugs to prevent rejection, but not so much that overwhelming infection will occur—artificial heart recipients must receive enough anti-coagulation treatment to prevent disabling or fatal emboli, but not so much that equally life-threatening bleeding problems will occur.

As the chairman of the FDA's advisory panel, Dr. Charles McIntosh, pointed out at Congressional hearings on the artificial heart in February 1986, "strokes and complications associated with anti-coagulation therapy are not unique to the Jarvik-7, for they continue to be major problems in patients requiring either a tissue or mechanical heart valve and in other forms of cardiovascular disease" (46, 11). Moreover, strokes have multiple causes, including an embolus, hemorrhage into the brain, or infected material that travels to the brain like a clot. These events, in turn, can have multiple causes, including but not limited to the artificial heart. And, due to state-of-the-art limitations in diagnostic testing, "the multiple potential causes of stroke make it difficult to [definitively] implicate the device" (46, 11). Here, we have a classic statement of the uncertainties that surround the assessment of early clinical trials. The current view of the artificial heart team, and of the FDA's panel of expert advisors, is that strokes are "both device and management-related, and that the new monitoring and anti-coagulation regimen may potentially decrease this risk in future patients" (46, 11).

THE CLINICAL MORATORIUM REVISITED

Depending upon specifiable types of circumstances, several sets of factors will interact in ways that can induce, deter, or terminate a moratorium. We have previously identified six such sets of contributory factors: 1) the state of the art of relevant biomedical knowledge and practice; 2) issues associated with the experiment–therapy dilemma; 3) the physician–investigator's dual role; 4) the physician–investigator's institution and colleagues; 5) the mass media and lay opinions; and 6) cultural conceptions and beliefs (29;62).

Primary indications	*Reported complications*	*Length of survival/status*
idiopathic cardiomyopathy	comatose and on respirator for 15 days renal failure	45 days on device; alive post-transplant
ischemic cardiomyopathy	none reported	14 days on device; alive post-transplant
viral infection	none reported	5 days on device; transplant 2/7 (see #16)
balloon pump; kidney failure	day 1, surgery for bleeding	alive; awaiting transplant
acute transplant rejection	day 9, surgery to reposition heart	alive; awaiting transplant

These sets of factors have been involved in the case of the artificial heart; some elements have a greatly enhanced role, even in comparison to heart transplantation. These include the role of the media and the significance of our cultural conceptions and beliefs about the human heart and technology.

The artificial heart also involves contributory factors that historically were not present in earlier moratoria we have examined, but which have come to exert a strong influence over medical research and practice during the past decade. They include, first, social structural changes such as the regulatory context in which research with human subjects is now embedded, and the growing role of for-profit or investor-owned corporations in medical care. Second, our society has become increasingly aware of and concerned about a number of value and belief questions related to health, illness, and medicine. "Bioethical" issues are now highly visible in the U.S., and bioethics and public policy have increasingly intertwined roles.

CONCERNS AND CRITICISMS: MORATORIUM PRESSURES

The concerns and criticisms about the clinical use of the artificial heart that have interacted to generate pressures for a moratorium fall into four main clusters. The first two focus on the device itself and related aspects of its experimental use in patients, while the second two involve a broader mix of medical and social politics and policy, economics, and ethics converging on the artificial heart: 1) arguments as to why it was premature to begin implanting the device in patients; 2) arguments for halting human use; 3) critiques of the corporate medicine context in which the Jarvik heart is enmeshed; and 4) intertwined bioethical and economic concerns about bridge-to-transplant use and larger scale future use of permanent implants.

The Move from the Laboratory to the Clinic Was Premature. In a previous section we examined the decision to begin testing the Jarvik heart on patients. Arguments that the Jarvik 7 heart—and indeed any TAH model—was not ready for human use had been advanced prior to the Barney Clark implant. And, as is usually the case when serious problems occur for the first patients, criticisms become retrospectively sharper. Five principal sets of criticisms have been leveled

at the decision to initiate clinical trials, and at the approvals granted by the FDA for both permanent and temporary implants.

1. The major bioengineering problems facing artificial heart developers since the 1950s—biomaterials, pump, and power source—had not been resolved adequately in the Jarvik heart models, and the reliability and durability of the device had not been demonstrated adequately in animals.

2. The morbidity and mortality experienced by laboratory animals made human use dubious at best.

3. Because of the way recipients are "tethered" to the pneumatically powered drive unit, systems liike the Jarvik heart are "importantly suboptimal" in terms of the limitations they impose on relatively normal activity (51, 33). Partly for this reason permanent implants are "not a reasonable medical experiment" (2, 4). This type of argument illustrates the blurred boundaries between experimentation and therapy that complicate assessments of success and failure. It also implies that it is unethical to use a drug, device, or procedure with patients unless it is in its final developmental form. This thesis is also advanced by Wolfe in his call for a moratorium: since it is doubtful that the Jarvik-7 "or its close relatives" will be the device that ultimately works, "it is time to go back to the drawing board and more experiments on animals" (67, 4).

4. A more general concern is the extent to which any artificial heart can replicate adequately the sophisticated control system and functions of the human heart, and thus let recipients lead relatively normal lives in terms of cardiac function. This issue, in turn, reflects important shifts in biomedicine's view of the heart during the twentieth century: from an organ too vital and fragile to withstand manipulation or surgical trauma, to a strong, resilient, fairly simple muscular pump, to the still evolving recognition that the heart has a complex system of controls and functions. The belief that "the heart's function is simply mechanical" was an important one in the effort to replace it with an artificial version, but may be another example of ritualized optimism (38).

5. IRB procedures and consent processes for artificial heart implants are inadequate. These arguments involve, first, concerns about the special vulnerability of terminally ill patients; the special protections they need because of "the coercions of fear and hope" that may induce them to serve as research subjects (6;40). Second, for reasons that seem to involve the literal and symbolic meanings of replacing the human heart with a man-made device, some commentators see the artificial heart as a unique chapter in the history of human experimentation. Because it is unique, they believe, no IRB is adequate to the task of dealing with the protocol and consent form and process: it is "like asking them to design a Boeing 747 with Wright Brothers parts" (2, 13). Third, and most specifically, the protocols and consent forms and processes for permanent and temporary implants have been criticized sharply and judged inadequate on a number of grounds (2;5).

6. The final major criticism has been leveled primarily at the NHLBI and FDA, and secondarily at the researchers who initiated clinical use in the absence of guidelines or standards from these sources. The NHLBI has been faulted for not having formulated "clear, well-publicized" standards for experimental use of the heart, and the FDA has been faulted for not having developed clear, objective criteria for evaluating success and failure before permitting clinical use of the TAH (8, 62;5).

This point underscores the fact that clinical research now involves a large number of groups directly and indirectly concerned with its conduct and outcomes, and that our expectations of their advisory, oversight, and regulatory functions are varied and evolving.

Clinical Trials should be Suspended. The types of concerns and criticisms about clinical trials that can generate a moratorium have concentrated most strongly on permanent implants; to a lesser extent, and more recently, bridge-to-transplant use is being questioned as well. In addition to the points summarized above, three major sets of concerns and criticisms about the clinical experience to date have been marshalled in arguments for a moratorium.

1. The first concern, and the one that is usually most salient in decisions to suspend clinical use of a new drug, device, or procedure, is the morbidity and mortality of the artificial heart recipients. Mortality figures are often judged, and reported, in a "box score" fashion; it is not only how many recipients of a therapeutic innovation live or die that is weighed, but how many hours, days, weeks, or months of added life are achieved. Morbidity tends to be a separate and sometimes more difficult calculus, because it often is difficult to pinpoint the cause or causes of the complications patients experience.

"Failure" is often equated, simply and starkly, with a patient–subject's death. By that yardstick, failure is much easier to define than "success." As we shall discuss more fully, however, permanent implants are judged most severely not in terms of patient mortality, but in terms of the survivors' complications and resultant quality of life.

Evaluating success or failure, in short, is a complex, multifactorial process with both quantitative and qualitative components. Judgments are inextricably linked with, and complicated by, the shifting interrelationships between experiment and therapy in the first trials with humans. And, partly contingent on what they see as the balance between research and treatment objectives, various participants and observers may use very different criteria, at different times, for judging success and failure.

The artificial heart is clearly defined by the FDA as a significant risk investigational device. As stated repeatedly in the consent form for permanent implantation of the Jarvik-7, it is being implanted on an experimental basis, with two objectives: "in order to determine if it will help other people with [the recipient's] condition, and for the possible beneficial affects (sic) that [the recipient] may obtain from the experiment" (22). But in practice, no matter how often and how clearly the experimental nature of the device and the primacy of research objectives are affirmed, the boundaries between experiment and therapy blend and shift, and therapeutic hopes and judgments are virtually inevitable. This is true for professionals who are at once caregivers and researchers, and for ill persons who are at once patients and subjects. And, if they are ambivalent about their intentions and aspirations, more distant observers and reporters, and the public at large, find it even more difficult to disentangle the research/treatment aspects of such an innovation and understand the criteria by which its relative successes and failures should be judged.

To the extent that the artificial heart is judged as an experimental device—used in man to garner research data, and hopefully but not predictably provide

therapeutic benefit as well—the results to date can be deemed at least a qualified success. When permanent implants are presented and judged primarily as therapy, however, as the media has been prone to do, the results to date indeed seem "devastating." Defined solely or primarily as therapy, it is ethically difficult to justify further permanent implants. Chapman trenchantly offers this judgment: "to define *good* solely in terms of days or weeks of biologic survival is [morally] untenable; so, in many and probably most cases, is the kill-or-cure therapeutic principle" (12, 7).

2. The second set of arguments for a moratorium on TAH implants, which we have already reviewed, involves judgments that the rights and welfare of patient-subjects are not being protected adequately in terms of patient selection criteria, protocols, and consent forms and proceedings, and the adequacy of IRB and FDA oversight for both permanent and temporary implants.

3. For reasons that merit more analysis than we can provide in this paper, concerns about bridge-to-transplant implants have been far more muted than those about permanent implants; Annas' reasoned and pointed commentaries are an exception (2;3;4). By and large, temporary implants have been portrayed by physicians involved in heart replacement and by the media as particularly dramatic instances of "rescue medicine"—as desperate interventions to save the life of a dying patient until a heart transplant can be performed (15). And they have been accepted largely as such by the FDA, which has exercised essentially *pro forma* regulatory oversight under the "emergency use" guidelines issued in October 1985 (25). Responding to criticisms about the number of temporary implants performed without prior FDA approval, an FDA official has explained that the agency must act as a "brake pedal" on permanent implants, because of the patients' complications, but is reluctant to "interfere" with temporary implants because the FDA also must act as an "accelerator" to increase the development of new technologies. This explanation, Annas observed, reveals that "there is a horrible double standard at work now. Dr. DeVries has attempted to provide everything the FDA wants of him, and everybody else gets to do as they please. That is not good public policy, and it's certainly not good science" (43).

As the number of temporary implants escalated in late 1985-early 1986, some concerns were expressed that a "bandwagon" might be underway, akin to the early phase of heart transplantation. Related concerns began to surface: too many implants were being performed without prior FDA approval; implants need to be conducted under a far more rigorous protocol, in terms of patient selection, consent, and data gathering, rather than in their present *ad hoc*, emergency use fashion (2;10;20). But the greatest emerging concern about temporary implants, as we shall see, has to do with the allocation of donor hearts. There has been little if any systematic thought given to the implications of suspending clinical research with permanent implants, while at the same time allowing the same experimental significant-risk device to be implanted on a temporary basis in the name of recurrent life-or-death emergencies.

The Corporate Medicine Context. The growth of for-profit medicine and its largely speculative implications for various aspects of health care in the United States is the subject of intense controversy and largely polemical debate (33;58;60). The fact that two major facets of artificial heart work are lodged in

an investor-owned or for-profit context (the Jarvik heart's laboratory development and testing by Symbion, Inc., and, since DeVries' departure from Utah in August 1984, the underwriting of the permanent implant series by Humana, Inc.) has added substantially to the artificial heart controversy.

This is not to suggest that the concerns about the artificial heart would not have occurred without the "corporate connection." But we would argue that the debate would have been far less intense and public had the Jarvik heart's development and early clinical use taken place *only* in an academic context with its traditional grant and contract funding mechanisms. The aspects of the for-profit context that have received the most attention and criticism include:

1. Questions about the propriety of for-profit companies assumming control of a device developed largely with federal research funds (11;59).

2. Constraints on accessibility to and dissemination of data about the Jarvik heart protocol and clinical findings, due to the proprietary nature of Symbion (10;55).

3. The motivations of Humana, Inc. for agreeing to subsidize the costs of up to 100 permanent implants. Critics of the corporation, and of the artificial heart (the two camps have many overlaps) have charged that Humana's primary if not sole motive has been to garner as much corporate publicity as possible, to attract more business and increase revenues (42;59).

4. The extraordinary and perhaps medically unprecedented amount of coverage that the artificial heart has received from the print and electronic media. Much like heart transplants in the late 1960s, Humana and the mass media have been faulted for turning artificial heart implants into a "highly publicized media extravaganza," with far too much "emphasis on theatrics and too little on science and ethics" (1;31;45). DeVries has not been alone in his concern that the intensive and extensive publicity surrounding implants has led to a "hunger for quick positive results" and a "case-mentality"—"a tendency to judge the experiment in terms of how the most recent artificial heart recipient is doing . . . as defined by others" (20, 33–34;47).

5. The adequacy of IRB review and approval. Humana Hospital Audubon has been condemned, largely *a priori*, as a rubber stamp for Humana, Inc. because it approved DeVries's protocol (56). To more moderate critics, the Audubon IRB lacks sufficient expertise in clinical research, ethics, and law to provide adequate review and approval functions.

6. More generally, Dr. Arnold Relman, editor of *The New England Journal of Medicine*, and others, have questioned the adequacy of Humana-Audubon, being a hospital that is at once non-academic, service-oriented, and for-profit, as an institutional setting for the level of clinical research demanded of the artificial heart (36;59). A related concern, expressed by a number of prominent physicians, has been the lack of publications by DeVries' group. It is unusual for the results of early clinical trials to be published on a case-by-case basis. But DeVries' professional community, in part we think because he is in a non-academic setting, is anxious to have information other than that supplied by the media (10;47;55).

Costs, Benefits, and Resource Allocation. The last major set of concerns and criticisms involves conjoint cost-benefit and allocation of resource issues. In this arena of debate, the artificial heart, like the artificial kidney before it, in part is

a lightning rod that is attracting and focusing broader economic and bioethical concerns about advanced medical technologies. The following sorts of paradigmatic questions have been evoked by the artificial heart (8;27;51;52;56;63).

1. What are the merits of the government's long-term financial investment in mechanical assist devices, in relation to support for research into other treatments and the prevention of heart disease?

2. If an artificial heart proves clinically viable, will the benefits to recipients, in terms of quantity and quality of life, outweigh the economic costs to those recipients, and to society at large? Estimates of the potential number of TAH recipients, and individual and aggregate costs, have varied widely, but all projections agree that it could equal or surpass the costs of dialysis.

3. This, in turn, has provoked discussion of who will, or should, receive an artificial heart, who will pay for it, and who will make these at once medical, moral, and socio-economic decisions about the allocation of resources.

4. The use of the TAH as a bridge-to-transplant has begun to generate very immediate allocation concerns, with respect to the scarcity of human donor hearts and the criteria and procedures by which heart transplant recipients are selected. The issues here are much like those raised by the relationships between dialysis and kidney transplantation in the early 1960s, but the parallels and possible lessons to be learned seemed to have escaped notice. The central worry is that temporary implant recipients will be given priority for a heart transplant, jumping them to the head of the queue and thus creating even greater inequities in an already problematic system for allocating human hearts. Related concerns include the possibility that the effects of the artificial heart may make a transplant less likely to succeed, and that the recipient of a temporary device may experience a serious enough complication to become ineligible for a transplant, thus becoming a permanent implant patient. For these reasons, Senator Albert Gore, Jr., a leader of the federal government's involvement in organ transplantation, has notified the FDA that he is "deeply troubled by the diversion of donor hearts from use in heart transplants, an accepted medical therapy, to 'bridge to transplant,' an experimental use" (32).

POINT-COUNTERPOINT: SOURCES OF CRITICISM AND SUPPORT

Controversy is not one-sided, and each concern and criticism catalogued above has been met with counter-arguments for continuing clinical research with the artificial heart. In assessing the controversy about clinical use of the TAH, it is important to realize that all of the concerns and criticisms have not been linked directly to calls for a moratorium. Conversely all those who have offered reasons for continuing clinical research are not, therefore, strong advocates of the artificial heart. Nor does their support for going forward mean that they are not, at the same time, deeply concerned about the clinical outcomes to date.

When one examines the nature and sources of criticism and support for clinical trials with the TAH, as we have done in analyzing hundreds of print and electronic media reports, scores of publications in professional literature, transcripts of conferences and hearings, and personal interviews, they fall into several fairly distinct and revealing clusters in relation to the moratorium phenomenon.

Only two critics have persistently called for a moratorium, first on permanent implants and then on temporary ones as well, and worked individually and collaboratively to have the FDA halt clinical work. They are health lawyer George Annas and physician and consumer activist Sidney Wolfe, head of Ralph Nader's Public Citizens' Health Group. Annas and Wolfe are recognized as highly expert and skilled in their respective professional domains. But the force of their arguments and their political strategies has not yet carried the day, for several reasons. These include negative reactions to some of the tactics they have employed, the fact that they are viewed in medical circles as strongly "anti" most aspects of medical practices and their governance, and, perhaps most importantly, because they do not speak with the authority of experts in the study and treatment of cardiac disease.

A somewhat larger but still relatively small group have been highly critical of various aspects of what one has termed the "misguided quest for the artificial heart." They have written and lectured extensively about their misgivings for lay and professional audiences, and are regularly quoted by the media when accounts of problems with the artificial heart are written. The most prominent members of this group include cardiologist Thomas Prestion, Dr. Arnold Relman, historian Barton Bernstein, and bioethicist Arthur Caplan. At various times, each has argued that clinical use should not have started or that a moratorium might be in order, at least on permanent implants. But these critics have not been as actively and uniformly opposed to the artificial heart as have Annas and Wolfe, nor have they had the same direct interactions with bodies such as the FDA and Congress.

The mass media and public attitudes and opinions are assuming increasingly influential roles in many realms of medical decision making, including research with human (and animal) subjects and therapeutic innovation. The artificial heart, even more than developments in heart and other organ transplants, is a vivid example of the ways that electronic and print media can both shape and reflect public, professional, and policy-making attitudes toward a therapeutic innovation. DeVries and members of his team, as well as others at Humana Audubon and its parent corporation, feel that overall the media have done a responsible and accurate job of conveying the artificial heart story (9;19;35;39). They recognize that some of the confusion and uncertainty that has occurred in media accounts, as well as the perspectives or slants at various times, are partly due to the types of information that various institutional spokespersons have conveyed, as well as the ways that reporters have chosen to present and color the "news."

Given the limitations of deadlines and space, media reporters have done an excellent job of educating the public about the nature of the artificial heart and the underlying medical problems that may lead to its use. There also have been some sound accounts of the experimental nature of the work, and how it relates to clinical research more generally. But even the best medical reporters have tended to be swept away by the therapeutic hope of artificial heart implants, portraying them as particularly heroic life-against-death interventions and down playing or ignoring their experimental nature and research objectives. They have also tended to emphasize and sometimes create controversy about the device and those involved in its use.

There are multiple reasons for the ways that the media at times have subtly and not so subtly distorted the artificial heart story. One is the compelling drama

of the recipients and their families, which is made all the more intense by the symbolism of the human heart and the import of its replacement by a man-made device (53;64). Another factor is what Winsten calls the "dominant distorting influence of the 'competitive force' in journalism." To get space for a story, as one reporter described to Winsten, "we have to almost overstate, we have to come as close as we can within the boundaries of truth to a dramatic, compelling statement. A weak statement will go no place" (66, 8–9).

The ability of modern journalism to provide instant coverage has been a very important influence on views of the artificial heart. In particular, the vivid immediacy of television has made the public privy to focused glimpses of the implant surgery and of the recipients and their families to a degree that is unique in the development of organ replacement and clinical research more generally.

One consequence of these reportage patterns is that the public and some professionals have tended to judge successes and failures according to the most current *therapeutic* status of recipients and, over time, by the haunting thoughts of strokes and their mental and physical consequences. These thoughts have been intensified by the images that we have seen on TV and in newspapers of Barney Clark and William Schroeder.

Both literally and symbolically, our society's views of what it means to be fully "human" or a "person" involves our capacity to interact with others. Impairments in our ability to communicate, to think, and to exercise a "normal" range of physical functions threaten our idea of what it means to be a "person," involving all the concerns coded into the phrase, "quality of life." We postulate that this has been the single most important factor in the controversy about continued clinical use of the artificial heart. Both medical professionals and the lay public, we suggest, find it easier to accept a recipient's death, given the gravity of his/her preimplant condition and the experimental nature of the device, than the possibility that artificial heart patients may experience strokes. The concerns and cautions voiced by the fourth relevant group of commentators on the artificial heart indeed have focused primarily on the neurological complications recipients have experienced. This group is composed of DeVries' professional colleagues in cardiovascular surgery and heart replacement. From clinical research and practice perspectives, they have expressed concerns about the extent to which the TAH may be responsible for strokes, as well as other issues about its clinical use, and for this reason have tended to support bridge-to-transplant use more strongly, at least as reported by the press, than permanent implants. But only a few of DeVries' peers, at one time or another, have been reported to favor a moratorium on his clinical trials (48;65).

Other peers, and they are in the majority of those who have expressed an opinion, have been concerned but have supported the continuance of clinical trials. They include, for example, Dr. Y. Nosé of the Cleveland Clinic, who points out that "those of use working on new artificial organ technologies know that similar initial [morbidity and mortality] problems were faced in all of the successful devices that have been developed so far" (54, 221).

In terms of the FDA's regulatory authority over permanent implants, the most significant judgments have been those of the medical experts testifying at the December 20 hearing and serving as members or consultants with the advisory panel. In their testimony, physicians representing the American College of Car-

diology, the Medical Devices Committee of the American College of Surgeons, and the Ad Hoc Committee on Circulatory Devices of the Society of Thoracic Surgeons, maintained that 1) decisions need to be based on scientific data, not press accounts; 2) a moratorium ruling would be premature in terms of the small number of cases to date and the need for a more thorough evaluation of the scientific evidence; 3) the problems are common to phase I or early clinical research; and, if studies of the artificial heart are stopped, where would the FDA draw the line with other phase I work?; and 4) important information has been gained and can be gained from human implants that cannot be obtained by research with other species. Therefore, each concluded, the imposition of a moratorium on permanent implants by the FDA at present would be premature and counterproductive.

Finally, how do those most closely involved with permanent implants of the Jarvik heart feel about its successes and failures and whether it should continue to be tried on human subjects? In public statements and personal interviews, Jarvik, DeVries and members of his team, hospital IRB members, Humana officials such as its chairman, David Jones, and the patient-subjects or their families, support continuing the experiment. Their support has not been automatic and reflexive, or unambivalent. Each participant that we have interviewed has thought deeply and reflectively, and often very painfully, about what they are doing and why, and the nature and degree of knowledge learned in relation to the costs and gains to the first patient-subjects and their families. Most, at times, have wondered if the experiment is worth it, if they should go on. Each, for his or her own reasons, has answered yes.

ON STARTING AND STOPPING A CLINICAL MORATORIUM

As noted earlier, the types of contributory factors converging on the artificial heart will interact in specifiable ways that can induce, deter, or terminate a moratorium on this or other instances of clinical research. Logically and empirically, various contributory factors can combine in several ways. And if a moratorium occurs, it can be invoked and later ended by informal or formal means. One can array the ways and places that pressures for and against a moratorium can converge and decisions made along a spectrum. At one end is the physician-investigator, at the other larger and more formal societal bodies such as the FDA. In between are other informal and formal groups and entities. These include the research team or teams; the institution's administrative, professional, and governing groups, including the IRB; and the researcher's wider network of professional colleagues. Each has the professionally or societally legitimate authority to decide whether an innovation like the artificial heart should continue to be tried on patients. And each has the capacity, through informal or formal means, to bring about a moratorium.

It is difficult to understand the controversy engendered by the artificial heart without understanding the patterns involved in the moratorium phenomenon and in clinical research more broadly. Many of the patterns in the artificial heart story to date are largely familiar ones. At the same time, the newer elements that the artificial heart story involves cannot be underemphasized. They involve social structural changes in clinical research and medical care, and pervasive awareness

of and concern about a particular set of values and beliefs. To summarize, more specifically, these newer dimensions include: (1) the involvement of corporate medicine; (2) the role of formal regulatory bodies in decisions about the initiation and continuation of clinical research; (3) far greater public awareness and concern about a range of bioethical matters, such as human experimentation, the quality of life, death and dying, and the allocation of scarce resources; and (4) the extent to which such bioethical issues, and those seen as having special expertise in them, have become prominent in health and medicine policy-making arenas at local and national levels. These factors do not seem to be unique to the artificial heart, which suggests to us that they represent more widespread, patterned changes in the sociocultural context of medical research and care.

Since William DeVries implanted the first permanent artificial heart in Barney Clark in December 1982, there have been two moratorium phases in its clinical use. The first moratorium period began in August 1983, when DeVries submitted a revised protocol to the Utah IRB for the required case-by-case approval to perform a second implant. It ended in November 1984, when DeVries performed his second implant, on William Schroeder, at the Humana Heart Institute in Louisville, Ky. The chief cause of this moratorium phase was the lengthy period required to gain formal regulatory approval for a second implant. For reasons involving both the substance of the protocol and a web of medical and regulatory politics and policies, IRB approval was not granted until January 1984, and FDA approval until June 1984. Then, for a combination of professional and personal reasons, DeVries left the University of Utah to join the Humana Heart Institute's private group practice and continue his artificial heart work with funding from Humana. A new round of regulatory approvals were required, and were granted by the Audubon Hospital IRB and the FDA in September and November 1984.

The second moratorium phase has run from DeVries' fourth implant, on Mr. Jack Burcham in April 1985, to the present. It has had two sources. First, an acceptable recipient for implant number 5 has not yet been found. Candidates have been referred, but their numbers have decreased for reasons DeVries attributes both to the expanding number of patients now eligible for heart transplants, and to legitimate concerns by referring physicians and patients about strokes and other complications. Of those patients evaluated by the artificial heart team, some have been ruled ineligible because they are not yet ill enough or because they are transplant candidates; others have decided, themselves, to withdraw as candidates; and at least one person consented to an implant if he could not be taken off the heart–lung machine, which he was (19). This has been an externally generated and informal type of pause, akin to the phase in heart transplants when the "stream of donors dried up" because of the high mortality rates of transplant recipients.

The second source of the current suspension was external and formal in nature, and lasted from late December, 1985 until late February 1986. It was what might be termed a "technical" moratorium, imposed by the FDA while they reviewed a revised IDE protocol that Symbion was required to submit after the December 20th hearings. The recommendation of the Cardiovascular Devices Advisory Panel surprised the critics who predicted that a moratorium would be called on permanent implants, given the experience with the first recipients. Based on the views of the professional society representatives who testified during the

morning, and, chiefly, on the data presented by Symbion, DeVries, and his colleagues in the closed afternoon session, the advisory panel unanimously recommended and the FDA agreed that permanent implants "proceed, but with caution." The decision not to call a moratorium was a qualified one, involving an even tighter regulatory control by the FDA. Information required in the revised IDE included "the experience gained with the last four patients," specific new patient management and data acquisition plans derived from this experience, and, related to those plans and concerns about the range of expertise on the heart team, "the addition of scientists with needed specialized medical and scientific expertise who will collaborate with Dr. DeVries." The FDA has also assumed "a more direct oversight role . . . and will permit [or deny permission for] subsequent implants on a case-by-case basis . . . conditioned upon an analysis of data derived from the preceeding implant" (46, 10–11).

Pending a new patient-subject, clinical research with a permanent artificial heart will continue, at least for now. In the dynamic of pressures and counterpressures that have been exerted, by the experiment itself and those involved with it, a moratorium has not been called by those who could do so: the FDA; the IRB; the corporate sponsors who still firmly support the project; and the physician-investigator himself, William DeVries, who, as he told Swazey and Fox in 1986 though he feels at times like he "has been through the Civil War singlehandedly," remains intensely committed to his work.

Our revisit to the clinical moratorium has been an incomplete one, for the finale is unknown and largely unpredictable. Phenomenologically, in fact, it has even been ambiguous to those most involved with the artificial heart's use and regulation as to whether or not some sort of moratorium on permanent implants is or has been in place. This ambiguity is one reason why the case of the artificial heart suggests that, despite the appearance of a clearer ethical and regulatory structuring, there is now more, not less, uncertainty and anomie in medicine and in American society about the proper ends, conduct, and governance of biomedical research and therapeutic innovation.

REFERENCES

1. American Medical Association, Judicial Council Statement. [Guidelines for experimental or clinical research on the artificial heart and animal organ transplants] *American Medical News*, December 14, 1984.
2. Annas, G. J. Legal and ethical issues in artificial heart experimentation. Testimony presented before the Subcommittee on Investigations and Oversight, Committee on Science and Technology, U.S. House of Representatives, February 5, 1986.
3. Annas, G. J. No cheers for temporary artificial hearts. *Hastings Center Report*, 1985, 15, 27–28.
4. Annas, G. J. The Phoenix heart: What we have to lose. *Hastings Center Report*, 1985, 15, 15–16.
5. Annas, G. J. Statement before the Food and Drug Circulatory System Advisory Panel Hearing on Artificial Heart Implants, December 20, 1985.
6. Annas, G. J., Glantz, L. H., & Katz, B. F. *Informed consent to human experimentation: The subject's dilemma*. Cambridge, MA: Ballinger, 1977.
7. Barber, B. & Fox, R. C. The case of the floppy-eared rabbits: An instance of serendipity gained and serendipity lost. *American Journal of Sociology*, 1958, 64, 128–36.

8. Bernstein, B. J. The misguided quest for the artificial heart. *Technology Review*, 1984, 87, 12ff.
9. Brown, P. [Clinical Director, Humana Heart Institute.] Personal interview, December 1985.
10. Buckley, M. J. [American College of Cardiology] Testimony before the Food and Drug Circulatory System Advisory Panel Hearing on Artificial Heart Implants, December 20, 1985.
11. Carter, M. N. The business behind Barney Clark's heart. *Money*, April 1983, 131–44.
12. Chapman, C. B. The Jarvik-7 blood pump; New hearts for old. 1985. Unpublished.
13. Cooley, D. A. Staged cardiac transplantation: Report of three cases. *Heart Transplantation*, 1982, 1, 145–153.
14. Cooley, D. A., Akutsu, T., Norman, J. C., et al. Total artificial heart in two-staged cardiac transplantation. *Cardiovascular Diseases, Bulletin of the Texas Heart Institute*, 1981, 8, 305–319.
15. Copeland, J. G. Total artificial heart as a bridge to heart transplantation. Testimony presented before the Subcommittee on Investigations and Oversight, Committee on Science and Technology, U.S. House of Representatives, February 5, 1985.
16. Cutler, E. & Beck, C. The present status of the surgical procedures in chronic valvular disease of the heart. *Archives of Surgery*, 1929, 18, 403–16.
17. DeVries, W. C. The artificial heart. Presentation at conference on transplantation and artificial organs in Boston, Massachusetts, November 4–5, 1985.
18. DeVries, W. C. Personal interview. June 1983.
19. DeVries, W. C. Personal interview. December 1985.
20. DeVries, W. C. Statement to the Subcommittee on Investigations and Oversight, Committee on Science and Technology, U.S. House of Representatives, February 5, 1986.
21. DeVries, W. C. Testimony before the Food and Drug Circulatory System Advisory Panel Hearing on Artificial Heart Implants, December 20, 1985.
22. DeVries, W. C. & Symbion, Inc. Special patient consent for the implantation of the total artificial heart and related procedures. 1983. Unpublished.
23. Eichwald, E. J., Woolley, F. R., Cole, B., et al. Insertion of the artificial heart. *IRB*, 1981, 3, 4–5.
24. *Federal Register*, Vol. 45, No. 13, Friday, January 18, 1980, 3732–3759, Medical Devices; Procedures for Investigational Device Exemptions. Amended, *Federal Register*, Vol. 45, No. 174, Friday, September 5, 1980, 58841–43.
25. *Federal Register*, Vol. 50, No. 204, Tuesday, October 22, 1985. Guidance for the Emergency Use of Unapproved Medical Devices; Availability.
26. Fields, A., Harasaki, H., Sands, D., et al. Infection in artificial blood pump implantation. *Transactions of the American Society of Artificial Internal Organs*, 1983, 29, 532–38.
27. Fineberg, H. Irresistible medical technologies: Weighing the costs and benefits. *Technology Review*, 1984, 87, 17ff.
28. Fox, R. C. "It's the same, but different": A sociological perspective on the case of the Utah artificial heart. In M. W. Shaw (ed.), *After Barney Clark*. Austin: University of Texas Press, 1983, 68–90.
29. Fox, R. C. & Swazey, J. P. *The courage to fail*. 2nd ed, revised. Chicago: The University of Chicago Press, 1978.
30. Fox, R. C., Swazey, J. P., & Cameron, E. M. Social and ethical problems in the treatment of end-stage renal disease patients. In R. G. Narins (ed.), *Controversies in nephrology and hypertension*. New York: Churchill Livingstone, 1984, 45–70.
31. Glaser, R. J. The artificial heart—show business or science? (editorial) *The Pharos*, 1985, 48, 38.
32. Gore, Senator Albert, Jr. Letter to Frank E. Young, Commissioner, Food and Drug Administration, February 5, 1986.

33. Gray, B. H. (ed.) *The new health care for profit*. Washington, DC: Institute of Medicine/National Academy Press, 1983.
34. Hastings, W. L., Aaron, J. L., Deneris, J., et al. A retrospective study of nine calves surviving five months on the pneumatic total artificial heart. *Transactions of the American Society of Artificial Internal Organs*, 1981, 27, 71–76.
35. Hazle, D. [Director of Public Relations, Humana Hospital Audubon] Personal interview. December, 1985.
36. The heart of the experiment (editorial). *New York Times*, January 7, 1985.
37. Jarvik, R. K. The total artificial heart. *Scientific American*, 1981, 249, 74–80.
38. Jarvik, R. K. et al. Recent advances with the artificial heart (letter to the editor). *New England Journal of Medicine*, 1978, 298, 404–5.
39. Jones, David. [Chief Executive Officer, Humana Inc.] Personal interview. December, 1985.
40. Jonsen, A. R. The selection of patients. In M. W. Shaw (ed.), *After Barney Clark*. Austin: University of Texas Press, 1983, 5–10.
41. Joyce, L. D., DeVries, W. C., Hastings, W. L., et al. Response of the human body to the first permanent implant of the Jarvik-7 total artificial heart. *Transactions of the American Society of Artificial Internal Organs*, 1983, 29, 81–87.
42. King, M. AMA officials criticize Humana heart project. *Louisville Courier-Journal*, December 6, 1984, B1.
43. King, M. Experts question increased use of Jarvik-7 as temporary tool. *Louisville Times*, February 12, 1986, A1.
44. Kolff, W. J. Artificial organs—forty years and beyond. *Transactions of the American Society of Artificial Internal Organs*, 1983, 29, 6–21.
45. Korcok, M. The business of ethics. *Canadian Medical Association Journal*, 1985, 132, 676–87.
46. McIntosh, C. L. Statement by [the] Chairman, Circulatory System Devices Advisory Panel, U.S. Food and Drug Administration, before the Subcommittee on Science and Technology, U.S. House of Representatives, February 5, 1986.
47. Mattox, K. L. [American College of Surgeons] Testimony before the Food and Drug Circulatory System Advisory Panel Hearing on Artificial Heart Implants, December 20, 1985.
48. Merz, B. Artificial hearts: An uneasy marriage of machinery and flesh. *Medical World News*, May 27, 1985, 40–57.
49. Murray, K. D., Hughes, S., Bearnson, D., et al. Infection in total heart recipients. *Transactions of the American Society of Artificial Internal Organs*, 1983, 29, 539–45.
50. Murray, K. D. & Olsen, D. B. The Utah artificial heart: Success in the laboratory and its application to man. *Journal of Contemporary Law*, 1984, 1, 4–28.
51. National Heart, Lung, and Blood Institute, Working Group on Mechanical Circulatory Support. *Artificial heart devices: Directions, needs, costs, societal and ethical issues*. May 1985.
52. National Institutes of Health. *The totally implantable artificial heart: Economic, ethical, legal, medical, psychiatric, and social implications*. Bethesda, MD: National Institutes of Health, 1973.
53. Nelson, M. Stout heart: Jarvik woman sits up, chats. *USA Today*, January 1, 1986, 1.
54. Nosé, Y. The total artificial heart: From development to clinical trials (editorial). *Artificial Organs*, 1985, 9, 221.
55. Pennington, G. [Society of Thoracic Surgeons] Testimony before the Food and Drug Circulatory System Advisory Panel Hearing on Artificial Heart Implants, December 20, 1985.
56. Preston, T. A. The artificial heart controversy: Research, rationing, and regulation. *Medical World News*, February 11, 1985, 37.

57. Reiser, S. J. The machine as means and end: The clinical introduction of the artificial heart. In M. W. Shaw (ed.), *After Barney Clark*. Austin: University of Texas Press, 1983, 168–75.
58. Relman, A. S. The new medical-industrial complex. *New England Journal of Medicine*, 1980, 303, 963–70.
59. Relman, A. S. Privatizing artificial-heart research (letter to the editor). *Wall Street Journal*, December 26, 1984.
60. Starr, P. *The social transformation of American medicine*. New York: Basic Books, 1983.
61. Strauss, M. J. The political history of the artificial heart. *New England Journal of Medicine*, 1984, 310, 332–36.
62. Swazey, J. P. & Fox, R. C. The clinical moratorium: A case study of mitral valve surgery. In P. A. Freund (ed.), *Experimentation with human subjects*. New York: George Braziller, Inc., 1970, 315–57.
63. U. S. Congress, Office of Technology Assessment, *Case study #9, The artificial heart: Costs, risks and benefits*, prepared by D. P. Lubeck & J. P. Bunker. Washington, D.C.: Government Printing Office, 1982.
64. Valentine's Day holds special meaning for heart patients. Camden, NJ *Courier Post*, February 15, 1986.
65. Vinocur, B. Debating the value of artificial hearts. *Boston Globe*, September 23, 1985.
66. Winsten, J. A. Science and the media: The boundaries of truth. *Health Affairs*, Spring 1985, 5–23.
67. Wolfe, S. M. Statement before the Food and Drug Circulatory System Advisory Panel Hearing on Artificial Heart Implants, December 20, 1985.
68. Woolley, R. [Chair, Artificial Heart Subcommittee, University of Utah Medical Center I.R.B.] Personal interview, June 1983.
69. Wrenn, M.-C. The artificial heart is here. *Life*, September 1981, 29–33.