Special Reports

Some Thoughts about the Historic Events

that Led to the First Clinical Implantation of a Total Artificial Heart

Denton A. Cooley, MD

Recently, I had the pleasure of reading *Failure Is Not an Option*,[1] a book about the history of the United States space program from Mercury to Apollo 13 and beyond. This fascinating account transported me back to the American-Soviet space race and reminded me of what an important impact it had on me and my scientific career.

Soon after World War II ended in Europe in 1945, Americans began to realize that peace was not possible with the Soviet Union, our former ally. The U.S. implemented the Marshall Plan to assist European countries ravaged by the war, but the Soviets made it clear that they had their own plan. They had already annexed much of eastern and central Europe, establishing Communist regimes loyal to Moscow. From 1945 through 1948, hostility between the U.S. and the Soviet Union grew, giving rise to a new conflict—the Cold War—symbolized by the Iron Curtain.

In 1948, the Soviets blockaded western Berlin, hoping to drive out the Allied powers. In response, the British and Americans instituted the Berlin Airlift, which became the only source of food and fuel available to western Berlin for almost a year. The success of this massive humanitarian effort increased American confidence that we were superior to the Soviets. However, the Cold War escalated during the 1950s, giving rise to numerous crises that threatened world peace. The Communists' eventual goal was to dominate the globe. Indeed, Soviet premier Nikita Khrushchev threatened that his country would bury America.

On 4 October 1957, America's fears were intensified when the Soviets became the first to launch a satellite into orbit, proving that they had the technology to deliver nuclear weapons anywhere in the world. Dubbed Sputnik, the satellite was visible as it passed over the U.S. It became an ominous symbol of our scientific inferiority and a potential threat to our national security. Thus, Sputnik served as a "wake-up call" to American leaders. President Dwight D. Eisenhower and Congress responded by establishing the National Aeronautics and Space Administration (NASA), which began operations in late 1958. The German scientist Wernher von Braun and some of his colleagues from Hitler's V-2 rocket program had moved to the U.S. to continue advancing the science of rocketry. Their presence helped to assure Americans that we had the personnel and scientific knowledge to surpass any program that existed behind the Iron Curtain. We took pride in watching our space program grow. In 1959, we were elated when the U.S. launched its own satellite. In April 1961, however, American leaders received another wake-up call when the Soviet cosmonaut Yuri Gagarin became the first human to be launched into space. He orbited Earth for 107 minutes and landed back on Russian soil.

Despite tensions with the Soviets, most Americans experienced the 1960s as an exciting time marked by prosperity and optimism. The decade started with the inauguration of John F. Kennedy, a young, idealistic, extremely charismatic president. Under his leadership, Americans began to believe that all types of new scientific goals—even a manned trip to the moon—might be within their grasp.

Like the space pioneers, those of us who were involved in the exciting new field of open heart surgery had the same zeal for exploration. As astronaut Eugene Cernan stated:

> A common bond between [moonwalkers and heart surgeons] was the nature of the territories we explored: the moon was an "almost mythical land" that had long been

Key words: *Heart failure/therapy; heart transplantation/history; heart-assist devices; history, 20th century; history of medicine, 20th century*

From: *Texas Heart Institute at St. Luke's Episcopal Hospital, Houston, Texas 77030*

Address for reprints: *Denton A. Cooley, MD, MC 3-258, P.O. Box 20345, Houston, TX 77225-0345*

E-mail: *dcooley@texasheart.org*

> regarded as a religious icon and a romantic symbol; likewise, the human heart was traditionally viewed as the seat of the soul and emotions. In venturing into these unexplored territories, both of us challenged long-held beliefs and attitudes. We took risks that few others would have dared to consider.[2]

In the early 1960s, my team and I at the Texas Heart Institute at St. Luke's Episcopal Hospital had the largest volume of open heart operations in the world. We continued to make important breakthroughs as the decade progressed. However, in late 1967, I received a wake-up call of my own when Christiaan Barnard performed the first human heart transplant—in Cape Town, South Africa, of all places. In my opinion, the first such operation should have been performed in the United States. I had expected that it would be done at Stanford University by Dr. Norman Shumway, who had the most experience with this procedure in animals. Frankly, I was sorry that I had not been the first. Barnard's feat was my own personal "Sputnik." The day after the news broke, I sent him a telegram: "Congratulations on your first transplant, Chris. I will be reporting my first hundred soon." In May 1968, I performed the first successful heart transplant in the U.S., then rapidly did a dozen more, assuring myself that American medicine remained globally competitive.

Long before then, Soviet researchers had made important breakthroughs in heart transplantation, albeit only in animal experiments. In 1946, Vladimir Demikhov[3,4] performed the world's first orthotopic heart-lung transplant, in a dog that survived for 2 hours. The next year, he carried out the first isolated lung transplant, achieving 7-day survival in a dog. In 1951, Demikhov performed the first orthotopic heart transplant, again in a dog, which survived for 11 hours. Because of the language barrier, Americans first learned about these breakthroughs in 1962, when Demikhov's publications began to be translated into English. His work influenced Barnard, who visited Demikhov in Moscow that same year.

With Barnard's historic transplant, it became obvious that the human heart functioned only as a pump; it could be removed and replaced by a transplanted organ. However, donor hearts were scarce—so why not implant a synthetic or mechanical pump? Mankind had long dreamed of creating a total artificial heart (TAH) that could replace the failing human heart. This goal was expressed in a colorful 1921 science-fiction story:

> It was of silver, shaped like a flattened egg, and a trifle smaller than that laboring, human blood-pump. To it was attached a pair of long, flexible silver pipes, which led to Billie knew not where. And near one extremity the egg was provided with eight curious nozzles. . . . [T]he arrangement provided duplicate sources, in vest-pocket size, of power for operating a mechanical heart. The electricity worked the air-pumps, which in turn supplied the little silver egg—implanted in the patient—with both pressure and vacuum, while doubtless the artificial organ itself housed a valve system which did the rest. The regulating device kept the blood circulating at the proper rate. The surgeon seemed satisfied with it all. . . .[5]

In 1937, Demikhov designed a mechanical cardiac-assist device that kept a dog alive for several hours, but this fact was not widely known outside Russia at the time. In the U.S., much of the initial work on the TAH was done in the 1950s by Willem Kolff at the Cleveland Clinic. A few other researchers were also active in this field, notably Domingo Liotta at the National University of Córdoba, in Argentina. In 1957, Kolff and his associate Tetsuzo Akutsu implanted a TAH in a dog. By the early 1960s, their dogs were living longer than a day with the device. Toward the end of the decade, many researchers believed that implantation of a TAH in a human being would be the next major breakthrough. I had more experience in cardiovascular surgery than anyone else in the world. Was it presumptuous of me to believe that I was the surgeon most qualified to take that step if the opportunity arose?

In thinking about the artificial heart, I was reminded of a speech President Kennedy gave at Rice University in 1962, challenging Americans to put a man on the moon:

> We choose to go to the moon. We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too.[6]

His words resonated with me, echoing my long-held commitment to excellence and my eagerness to pursue new challenges. I, too, wished "to organize and measure the best of my energies and skills" while advancing the cause of science.

Unexpectedly, in December 1968, a way opened for me to realize that goal by becoming involved in TAH research. Domingo Liotta, by then a member of the Baylor University College of Medicine's laboratory research team, came to me for advice. He had joined the Baylor staff to develop a left ventricular assist device for which Dr. Michael E. DeBakey had received a federal grant. Domingo had done preliminary work on a TAH before leaving Argentina for Houston. However, when he began working at Baylor, DeBakey forbade him to

work further on a TAH. Domingo wanted to know whether I thought he should pursue the TAH project on his own and whether I would be willing to work on it with him. I agreed that the device could be useful in my transplant program, for keeping patients alive until suitable donor hearts could be found.

That is how I first became involved with the TAH. The ensuing developments that led to the first clinical implantation are covered in my memoir,[2] so I will not describe them here. Suffice it to say that, in April 1969, with Domingo assisting, I performed the first implantation of a TAH in a human. Three months later, Apollo 11 landed on the moon, carrying Neil Armstrong and Buzz Aldrin. Both America's national goal and my personal goal were achieved.

Once our astronauts reached the moon, the space race was all but over. The Soviets and Americans gradually began to participate in joint space projects. With time, the astronauts and cosmonauts even became friends—sharing vodka and trading stories.[7] In similar fashion, the 2 countries began to collaborate on cardiovascular research. We need not have worried that the Soviets would surpass us in that field. It was not until 1987 that the first successful heart transplant was performed in Russia, by the pioneering surgeon Valery Shumakov.[8] Even after the Cold War ended in 1991, there was little public or logistical support for heart transplantation in the former Soviet Union. The first clinical TAH implant there was performed in 2010.[9]

Today, researchers are still seeking to create a safe, effective mechanical substitute for the human heart. So far, TAHs have been plagued with problems, including thromboembolism and infection. In contrast, ventricular assist devices—partial artificial hearts—have had a much more successful history and are now in widespread use. Currently, one of the most promising systems for cardiac replacement combines 2 continuous-flow left ventricular assist devices. This system was developed in our laboratories by Drs. O.H. "Bud" Frazier and William E. Cohn—who, in 2011, made history by implanting it in a 55-year-old dying man.[10] We believe that ultimately such devices may work better than the larger, traditional TAHs as cardiac substitutes.

The purpose of this essay has been to explain some of my personal reasons for responding to the unique scientific challenge posed by the first TAH implantation. For more about this subject, please stay tuned: further details may be forthcoming in my next memoir.

References

1. Kranz G. Failure is not an option: Mission Control from Mercury to Apollo 13 and beyond. New York: Simon & Schuster; 2009.
2. Cooley DA. 100,000 hearts: a surgeon's memoir. Austin (TX): Dolph Briscoe Center for American History; 2012. p. xi.
3. Konstantinov IE. A mystery of Vladimir P. Demikhov: the 50th anniversary of the first intrathoracic transplantation. Ann Thorac Surg 1998;65(4):1171-7.
4. Konstantinov IE. At the cutting edge of the impossible: a tribute to Vladimir P. Demikhov. Tex Heart Inst J 2009;36(5): 453-8.
5. Flint HE. The devolutionist. Argosy; July 1921. Available from: http://www.premierathome.com/Library/Science%20Fiction/The%20Devolutionist.txt [cited 2013 Mar 4].
6. Kennedy JF. Address at Rice University on the space effort. September 12, 1962. Available from: http://www.explore.rice.edu/explore/Kennedy_Address.asp [cited 2013 Mar 4].
7. Cernan E, Davis D. The last man on the moon. New York: St. Martin's Press; 1999.
8. Lichterman B. Valery Ivanovich Shumakov [obituary]. BMJ 2008 Apr 5;336:778.
9. First artificial heart implant in Russia a success. Available from: http://www.rt.com/news/russia-artificial-heart-transplant [revised 2010 Apr 6; cited 2013 Mar 4].
10. Frazier OH, Cohn WE. Continuous-flow total heart replacement device implanted in a 55-year-old man with end-stage heart failure and severe amyloidosis. Tex Heart Inst J 2012;39 (4):542-6.