Extracorporeal Life Support: Gibbon Fulfilled

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In December 1992, a young woman was brought to the emergency room at University of Michigan Hospital with acute shortness of breath and shock. She was stabilized and sent to the radiology suite with a presumptive diagnosis of massive pulmonary embolism. A CT scan demonstrated a very large saddle pulmonary embolism. She arrested in radiology and the extracorporeal membrane oxygenation (ECMO) team was called during CPR. She was placed on venoarterial extracorporeal life support (ECLS) and was supported with that device for the next 5 days. During that time the clot lysed, her right ventricular failure resolved, her gas exchange improved, and she was ultimately discharged with good heart and lung function. Twenty-one years later, she was in attendance at the American College of Surgeons Gibbon Lecture and met the surgeons assembled for that presentation. At Michigan, we managed 16 cases of massive pulmonary embolism with ECLS between 1992 and 2006, thirteen had a healthy survival (80%).

In February 1931, a young woman suffered a massive pulmonary embolism at the Massachusetts General Hospital. The resident on duty was a 26-year-old research fellow in Dr Edward Churchill’s laboratory named John Gibbon. Dr Gibbon was pursuing a research year during his surgical residency at the Pennsylvania Hospital in Philadelphia. Like many residents in the laboratory, he was pressed into clinical service and was responsible for the care of that young woman. Young Dr Gibbon is shown with Dr Churchill’s laboratory technician in Figure 1. Dr Gibbon attended to that patient throughout a long night, but her vital signs deteriorated and she died early in the morning. Dr Gibbon’s description of the events of that night is an eloquent example of what would now be described as the beginning of translational surgical research (Fig. 2). Dr Gibbon recorded “...the idea naturally occurred to me ‘that extracorporeal circulation should be possible.’” Every surgeon sees unsolved clinical problems every day, and every surgeon thinks “it naturally occurred to me” that there should be a solution to the problem. However, very few of us ever have the opportunity to bring that idea to conclusion. Dr Gibbon returned to Philadelphia and established a surgical practice and an academic position in the Jefferson Medical School. He started to work on the problem of extracorporeal circulation in the laboratory. During the next 20 years, Dr Gibbon studied devices to pump blood, to oxygenate blood, and servo regulate the control of extracorporeal circulation. He succeeded in establishing extracorporeal circulation for minutes, even an hour, in experimental animals. Working with many colleagues, including engineers from the IBM Company, he developed what was called the heart—lung machine. The oxygenator component of Gibbon’s heart—lung machine involved creating very thin films of deoxygenated blood flowing over a screen and exposing it to oxygen in the process. In 1953, Dr Gibbon operated on a young woman with atrial septal defect and closed the defect under direct vision using cardiopulmonary bypass made possible by the heart—lung machine. That day in the operating room of the Jefferson University Hospital marked the beginning of modern cardiac surgery and most modern intensive care and cardiology, all growing from a single patient cared for by Dr Gibbon 22 years earlier. During the next decade, the pioneering surgeons who developed cardiac surgery used the heart—lung machine to repair congenital defects and damaged heart valves. One of those surgeons was the father of pediatric surgery, Robert E Gross, chief of surgery at the Boston Children’s Hospital.

In 1965, I was a resident in surgery at the Peter Bent Brigham Hospital in Boston, spending a year at the Children’s Hospital with Dr Gross. As you can tell from Figure 3, Dr Gross, in the middle of the front row, was serious, a perfectionistic, and had a commanding presence to the senior residents in the middle row, and especially to the junior residents in the back row. Those junior residents included Allan Gazzaniga on the far right and me in the middle of the back row. At that time, the mortality for repair of major congenital cardiac lesions with the heart—lung machine was 50%. Many children came out of the operating room in profound circulatory shock and were managed by the residents during the next few days. We knew that if a child could recover good cardiac function in a day or 2, the ultimate result would be lifelong survival. Realizing that the heart could recover in a short time, I asked Dr Gross if we could consider keeping these children on the heart—lung machine for a day or 2...
until their native heart recovered. He pointed out that the heart—lung machine itself was lethal after an hour or 2 and, in fact, was the cause of much of the problem, but he said “why don’t you work on it?” That started me on a laboratory and clinical journey that continues today.

We knew that the major problem with the heart—lung machine was the direct exposure of blood to oxygen in the artificial lung. Lou Plazk (in the second row of residents) and I built some envelopes out of the newly discovered dimethylpolysiloxane polymer, otherwise known as silicone rubber. Silicone rubber has the unique property of transferring respiratory gases. We attached an experimental dog to our membrane envelope. Blue blood turned bright red in an instant, but as we increased blood flow, only blue blood exited the system. We presented that observation to our chief, Francis Moore, at the weekly research conference. With characteristic foresight, Dr Moore (Fig. 4) had recruited a young engineer from the Massachusetts Institute of Technology (Phillip Drinker, PhD) to see if there would be a role for engineers participating in hospitals and surgical practice. Phil Drinker was working on trying to create hemolysis with a device that created intense mixing of blood, but hemolysis did not occur as long as there was no air interface. At the research conference, Dr Moore said “Bartlett, your problem is there’s no mixing of the laminar flow of blood. Drinker, your problem is there’s no air in your test system. You two need to get together to build a membrane oxygenator.” Phil Drinker and I set out to do that and developed a membrane lung that was very efficient at transferring gas without damaging the blood. This led to experiments on prolonged extracorporeal circulation. By 1968, we could maintain animals on extracorporeal circulation for as long as 4 days, which was exciting stuff at that time (Fig. 5). We developed access cannulas, heparin titration based on activated clotting time, servo-regulated pumps, and used all of this apparatus to begin the study of prolonged extracorporeal circulation.

In 1970, Al Gazzaniga and I had finished residency and were recruited to join the fledgling Department of Surgery at a brand new medical school, the University of California at Irvine. The chairman of that new department, Jack Connolly, recruited young faculty members who had completed training in general, thoracic, cardiac, pediatric, and vascular surgery. When we asked prominent academic surgeons in Boston how to get to California, we were advised to go through Dedham. The University of California at Irvine clinical program was based in Orange County Medical Center, a 600-bed acute care hospital serving the Orange County barrio. The University of California at Irvine also established an affiliation with the excellent private St Joseph Hospital and Children’s Hospital of Orange County nearby. We set up surgical services in our newly designated university hospital; we divided up the jobs to manage the operating room, the burn unit, the intensive care unit, and the emergency room; we established a private practice at St Joseph’s and Children’s Hospital; and we taught residents and medical students. We had a marvelous surgical practice that, on any given day, ranged from cardiac surgery to gunshot wounds to inguinal hernias to pyloric stenosis.

During that long night, helplessly watching the patient struggle for life as her blood became darker and her veins more distended, the idea naturally occurred to me that if it were possible to remove continuously some of the blue blood from the patient’s swollen veins, put oxygen into that blood and allow carbon dioxide to escape from it, and then to inject continuously the now-red blood back into the patient’s arteries, we might have saved her life. We would have bypassed the obstructing embolus and performed part of the work of the patient’s heart and lungs outside the body.
We were having a wonderful time. Dr Moore thought we had gone to a Third World country.

We established a research laboratory and began the serious study of prolonged extracorporeal circulation.\(^4\)\(^6\) By 1971, we had demonstrated that the use of a membrane oxygenator would allow safe prolonged extracorporeal circulation for many days at a time. This was supported by my first NIH grant. Our laboratory and clinical research has been continuously supported by NIH since that time, for which I am very grateful. There were several research laboratories working on extracorporeal circulation at that time and 3 of them developed the devices and techniques of prolonged extracorporeal circulation: Kolobow\(^7\) at NIH, Hill\(^8\) at San Francisco Medical Center, and our group at Irvine.\(^9\) In 1971, we were asked to see a patient in Santa Barbara who had severe acute respiratory failure after trauma, identified by the “new” diagnosis of ARDS. We were not ready for clinical application, but we called Don Hill from San Francisco who came to Santa Barbara and put that patient on ECLS. The membrane lung was a device developed by Morrie Bramson, a biomedical engineer, and took 6 hours to assemble. Don Hill had attempted it with other patients without success, but this patient regained good lung function after 36 hours of extracorporeal support and became the first survivor of what is now called ECMO.\(^10\) In 1972, Al operated on a little boy with transposition of the great vessels. This patient went into profound cardiogenic shock after the operation and we brought our modified heart—lung machine from the laboratory and supported his circulation for 36 hours. He recovered and represented our first successful use of ECMO, and the first successful cardiac support patient, some 7 years after we began work on that problem.\(^11\) In 1975, we were called to see a full-term newborn infant with profound respiratory failure secondary to meconium aspiration and what later proved to be persistent fetal circulation syndrome. We had tried our device in newborn infants without success in a few cases before that, but this child recovered during a week of extracorporeal support and was the first successful newborn infant supported with ECMO. Her case, and the unusual social and surgical issues surrounding it, have been reported in some

Figure 3. Boston Children’s Hospital surgery staff in 1965. (From Dr Bartlett, reprinted with permission.)

Figure 4. Francis Moore in 1966. Chief of Surgery at Peter Bent Brigham Hospital. (From Dr Bartlett, reprinted with permission.)
The nurses named this little orphan girl Esperanza and she has remained a friend of the life support community since that time (Fig. 6). The system we used for Esperanza and hundreds of babies thereafter is shown in Figure 7. This essentially illustrates the basic components of a heart-lung machine with venous blood access from the right atrium via the jugular vein, blood draining through a servo-regulated pump to a membrane lung through a heat exchanger and back into the systemic circulation with access via the common carotid artery. During the next decade, we applied this technology to more infants with respiratory failure with consistent success.13,14

In the mid-1970s, it seemed that ECMO would be the ideal treatment for an epidemic of the “new adult respiratory distress syndrome.” The Lung Division at NIH sponsored a 9-center prospective randomized trial of ECMO in ARDS published in 1979.15 We were 1 of the 9 centers (and 1 of the 3 that had any experience with ECLS). The study was stopped for lack of efficacy after 90 patients (90% mortality with ECMO or conventional care). This study of a new technology was done prematurely in inexperienced centers, without standardized techniques and protocols. In retrospect, this has become a classic example of how not to conduct a trial of a life support device. Publication of that trial stopped development of ECMO for adult respiratory failure for the next 20 years, except in a few centers. However, the results in newborn infants were encouraging and many neonatologists and pediatric surgeons established ECMO programs for the management of newborn infants and small children with respiratory failure. In 1980, I moved to the University of Michigan with responsibilities for general surgery, surgical ICU, and thoracic surgery at the county hospital, the Critical Care fellowship, and development of the Life Support Program. Arnie Coran, an old resident buddy (between me and Al in Fig. 3), was Chief of Pediatric Surgery. We continued to develop prolonged extracorporeal circulation for heart or lung failure.16 We continued laboratory studies, including development of a double lumen cannula for venovenous access.17 We brought continuous hemofiltration for acute renal failure from Germany to the United States.18 We conducted courses on ECMO with the hope that the participants would share their data as programs developed. We collected these data in a standardized format and reported the experience with 715 neonatal ECMO patients in 1988.19 The ECMO registry and courses were formalized into the formation of the Extracorporeal Life Support Organization (ELSO) in 1989. By 1998, we had treated 1,000 patients.20 We learned that resting the lung from high pressure, high oxygen ventilation, and resting the circulation from high-dose vasopressor and ionotropic drugs allowed recovery of the heart and lung in most cases of severe acute cardiopulmonary failure. These findings influenced our care of patients with severe heart and lung failure, in that we learned not to damage the heart and lungs excessively, having the option of ECMO for those patients who failed on optimal conventional management.21,22

Extracorporeal support for cardiac failure requires venoarterial access through cannulation of peripheral vessels, or direct cardiac cannulation in the case of failure to come off cardiopulmonary bypass. For respiratory support, venoarterial access can be used, but we prefer
venovenous access, which leaves the lungs in series with the extracorporeal circuit, not in parallel. Venovenous also has the advantage of avoiding systemic arterial access and embolism. With extracorporeal support, ventilator and pharmacologic support can be turned down to very low levels and the patient is maintained by the circuit until the heart or lung recovers or is replaced. When recovery occurs, the patient is weaned by decreasing the ECMO flow until the native organs can support life at nondamaging settings. A specialty of ECMO technical specialists has developed based on specialized training of ICU nurses, respiratory therapists, or perfusionists to manage the ECMO procedure and program. Today, all pediatric and neonatal ICUs have an ECMO program or an arrangement to transfer patients to an ECMO center. Extracorporeal membrane oxygenation is becoming standard management in advanced adult ICUs.

Today, there are >300 member centers of the ELSO consortium throughout the world. The ELSO hosts an annual meeting, publishes guidelines and textbooks on ECMO technology, and still maintains the registry, now at nearly 60,000 cases. The latest registry report is shown in Table 1. The data are presented by age group and by primary diagnosis. Extracorporeal membrane oxygenation—assisted cardiopulmonary resuscitation refers to the use of ECMO in conjunction with CPR for resuscitation. The survival to discharge outcomes ranges from 30% to 75%. This is encouraging, considering that ECMO is only used for high mortality risk patients, but also indicates that there is much room for improvement.

### Table 1. Overall Patient Outcomes, Extracorporeal Life Support Organization Registry, July 2013

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<th>Age Group</th>
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<th>Survive to DC</th>
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<td></td>
<td>n</td>
<td>%</td>
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(From the Extracorporeal Life Support Organization Registry, reprinted with permission.)

DC, discharge; ECLS, extracorporeal life support; ECPR, extracorporeal membrane oxygenation—assisted CPR.

**Figure 7.** A diagram of venoarterial extracorporeal life support in a neonate. Venous blood is drained from the right atrium to a servo-regulated pump, and pumped through a membrane lung, heat exchanger, and into the aorta. (From Dr Bartlett, reprinted with permission.)
improvement in all of these categories. The type of patients entered into the registry for the last 20 years is shown in Figure 8. In 1990, 80% of the cases were newborn infants, which decreased 20% in 2013. There are 2 reasons for the decrease in neonatal cases. We have learned (partly through the ECMO experience) better ways to manage neonatal respiratory failure, so ECMO is needed less frequently. In addition, the application to pediatric and adult respiratory failure and cardiac failure in all ages changes the distribution of cases in the registry each year.

Cardiac support is currently the largest application of ECMO. In adults, ECMO is used for acute cardiogenic shock or arrest providing short-term support to assess the other organ function, particularly brain function, support interventional cardiology procedures to treat the initial problem, then bridge to recovery or implantable ventricular assist device. Until recently, ECMO was the only cardiac support system for children. The most frequent use in children is to support patients after cardiac surgical operations when the patient cannot come off conventional bypass. The ELSO registry data of ECMO for cardiac support in children was used in a matched-pairs study of the Berlin Heart pediatric cardiac assist device. This approach was suggested and supported by the US Food and Drug Administration to address the ethical and logistic problems of comparing with a control group in acute potentially fatal cardiac illness. This type of study is a precedent for approval of life-support devices in acute fatal illness.

From 1980 until 2008, the use of ECMO for adult respiratory failure was limited to a small number of advanced critical care facilities. In 2008, the H1N1 influenza epidemic resulted in thousands of cases of severe respiratory failure combined with septic shock. This epidemic began in the winter of 2008 in the southern hemisphere. The critical care research group in Australia and New Zealand reported the severity of the syndrome and reported that ECMO was the only intervention that improved survival. In fact, the survival rate was >70% in moribund patients. Countries in the northern hemisphere had time to prepare and organized ECMO triage programs in most countries. The adult intensive care community learned how to use ECMO to care for the sickest H1N1 patients. That pandemic is one factor that resulted in a significant increase in cases of adult respiratory failure reported to the registry (Fig. 9).

Another factor that coincided with the H1N1 flu epidemic was the development of major improvements in the devices and technology used for ECMO. Before that time, there was no specific ECMO device. To conduct ECMO, a hospital ECMO team would acquire membrane oxygenators, pumps, heat exchanger, monitoring equipment, and access cannulas from a variety of sources and assemble the ECMO support system on site. Most of these devices were made primarily for cardiac surgery or other applications. Around 2008, three types of devices specific for use in ECMO were brought to the market: new membrane lungs based on hollow fiber gas-exchange membranes, which were low-resistance, very efficient, blood-compatible devices; centrifugal pumps modified with a hole in the center of the rotor, which solves the heating and thrombosis problems of other centrifugal pumps, allowing these pumps to be used for prolonged support; and a family of new percutaneously placed vascular access cannulas, including a unique double-lumen cannula specifically for prolonged gas-exchange support in the venovenous mode. All of this resulted in a new era in prolonged life support that I call ECMO II. Management of ECMO now is much safer, simpler, and less complicated. Because the centrifugal pump cannot generate high pressure to blow out on the reinfusion side, the ECMO specialist is no longer needed at the bedside continuously.

Figure 8. Cases in the Extracorporeal Life Support Organization Registry, July 2013. (From the Extracorporeal Life Support Organization Registry, reprinted with permission.)

Figure 9. Adult respiratory cases, Extracorporeal Life Support Organization Registry July 2013. (From the Extracorporeal Life Support Organization Registry, reprinted with permission.)
Experienced ICU nurses can assume the minute-to-minute care of the ECMO device as well as care of the patient. Bleeding complications have gone from common and fatal to moderate and manageable. Formerly, the availability of ECMO was limited by the number of trained specialists who could manage the ECMO system. Now, with ECMO-trained ICU nurses, the use of ECMO is limited only by the number of devices in any hospital. At the University of Michigan, for example, it is common to have ECMO patients running simultaneously in 5 different ICUs, with emergency systems available to the emergency department. The use of a single cannula placed via the internal jugular vein allows for total support in the venovenous mode. Because gas exchange is totally supported, the patient can be managed awake and even ambulatory. A patient can be extubated or managed with a tracheostomy with minimal or no mechanical ventilation. Management during ECMO II is feasible for a month or more without major complications, leading to a new era of understanding of lung injury and recovery biology.

An example of these phenomena is the case of a 6-year-old girl who was healthy on 1 day in February 2011, dying of H1N1 and streptococcal septic shock the next day (Fig. 10A). She was managed with venovenous ECMO and by day 2 had no lung aeration, which is typical of severe respiratory failure early in ECMO (Fig. 10B). Obviously with no gas exchange she would have died without the extracorporeal support. In the past, we would have hoped for lung recovery within a week or 2, and often declared failure from irreversible lung disease (and terminated support) after that time. Her chest x-ray on day 25 still showed with no aeration, requiring total extracorporeal support (Fig. 10C). Because patients like this can now be safely supported for longer periods, we persisted with support in her case. Abruptly, on day 35, her lungs recovered (Fig. 10D). She was decannulated and discharged 2 weeks later. There are now many cases reported of total lung recovery after a month or more of no lung function.34,35 We have learned that the lung can recover from apparently irreversible lung injury,
which will lead to study and characterization of this un-
expected phenomenon.

One of the challenging aspects of ECMO clinical
research has been the problem of how to study a life-
support technique in acute fatal illness in which the
end point is death.36 In fact, ECMO is the only life-
support technique that has been studied with comparable
control groups. There have been 10 controlled studies of
ECMO in babies, children, and adults.15,37-45 The study
designs to address the ethical and logistic problems
have been addressed in several ways. One example is
the prospective randomized study of ECMO for ARDS
conducted in the United Kingdom between 2000 and
2006.39 Many adult ICUs participated in this trial.
Patients who met criteria for high mortality risk ARDS
were randomized to continue the best available conven-
tional care in those ICUs, or be transferred to the
ECMO center at Leicester for care, including ECMO
if needed. The study was powered for 300 patients, but
stopped after 180 patients for efficacy. The survival in
the control conventional care group was 50% at 28
days, higher than we might have expected probably
because of the Hawthorne effect. The survival in the
ECMO center group was 76% at 28 days, not quite as
good as we would have expected because 5 patients
died after randomization but before management in the
ECMO center. The same group in England reported a
controlled study using matched-pairs analysis, focusing
on patients with H1N1 influenza respiratory failure.37
That study also showed a 25% actual improvement in
survival for patients treated in ECMO centers. Based
on the controlled ECMO studies, we conclude that the
matched-pairs method is the best design for controlled
trials of life support in acute fatal illness.

The occasion of the Gibbon lecture offers an oppor-
tunity to reflect on this example of surgical research
(defined as research that only surgeons can do). Most
important, the research began and continues with a
major clinical problem: severe cardiopulmonary failure.
Like any fortunate investigator, I had perceptive and
supportive mentors, fertile laboratory and clinical envi-
rónments, bright and enthusiastic colleagues, and
patients willing to trust me. This research all occurred
within the development of “critical care,” from nothing
to a full-fledged specialty with boards, journals, and
societies; ECMO is at the cutting edge of this discipline.
My research has been funded by NIH for more than 40
years—evidence that addressing an important problem
with a novel approach and good results leads to success-
ful funding, even if the investigator is a surgeon. Then
there are some specific factors that, in my opinion,
facilitated this project. I had a wide—some would say
old-fashioned—practice throughout my career. I went
between the neonatal/pediatric ICUs and the adult hos-
pital daily, which improved my understanding and skills
on both sides of the street. I managed all aspects of care
for my patients. I practiced applied physiology and
taught physiology to students and residents. Al and I
were interchangeable in the early years, so the combina-
tion could accomplish more than most partnerships.
Ideas moved between the laboratory to the bedside
easily. I had responsibility for the clinical programs
and ICUs so I set the policies and involved all the
team, especially the nursing staff. Finally, I am a
surgeon. Whether the problem was cannulation, repair-
ing a bronchus or femoral artery, replacing an oxygen-
ator, balancing bleeding and clotting, deciding when
to treat and operate, how to do it, and when to stop,
I just did it.

As with many laboratory and clinical research projects,
the spinoff has been as useful as the study itself. Our
understanding of cardiopulmonary bypass, life-support
devices, physiology and pathophysiology, bioengineering,
and the biology of heart and lung injury and recovery
have all benefited from the experience with ECMO.
The first steps toward a permanent implantable artificial
lung have been taken with bridging to lung transplanta-
tion. In the past, a patient on the lung transplant waiting
list with a severe exacerbation requiring mechanical venti-
lation was removed from the list because of the high risk
of transplantation in a patient on a mechanical ventilator.
With ECMO II, such a patient can be supported with
ECMO, extubated, and conditioned with nutrition and
physical therapy until a suitable donor is found. This
approach, originally championed by Hoopes and col-
leagues,46 has now become routine practice in major
lung transplantation centers. Another application of
ECMO has been the use of high-flow venoarterial
support in profound septic shock. This approach was
originally reported by a group from Melbourne, Australia
and is now being implemented in other centers
throughout the world.47 At the University of Michigan,
we have used venoarterial ECMO to resuscitate abdomi-
nal organs after cardiac death.48 This technique has
proven very successful in salvaging transplantable organs
under conditions of elective withdrawal of care in
patients with irreversible brain injury (controlled dona-
tion after cardiac death). We have studied the details of
this technique in the laboratory and find that we can
resuscitate transplantable organs after a full hour of
absent circulation.49 Applied to uncontrolled, unexpected
cardiac death, this technique could vastly improve the
number of donor organs for transplantation. Similarly,
the use of ECMO associated with CPR results in 40%
successful survival. However, these cases have been primarily in hospital patients in which arrest was anticipated, the ECMO machine was quickly available, and immediate cannulation was possible. Now this approach is being extended to unexpected cardiac arrest in emergency rooms. A group from San Diego developed a protocol for the use of ECMO-assisted CPR in arrest patients and implemented the full protocol in 20 patients.50 Eight of these patients were successfully resuscitated and 5 were discharged from the hospital neurologically intact. Similar programs have been instituted in other institutions.

Balancing anticoagulation and bleeding is a universal problem for any artificial organ, which is in contact with the blood. For 5 decades many laboratories have worked on creating nontthrombogenic surfaces, which would obviate the need for anticoagulation with extracorporeal circulation. This research has led to the development of several nontthrombogenic coatings for extracorporeal devices, most of them are based on binding heparin to the surface. Heparin-bonded surfaces do not obviate the need for anticoagulation, primarily because these surfaces do not address the initiation of thrombus by platelet adhesion and activation. The normal endothelium secretes nitric oxide, which briefly anesthetizes any platelet near the surface, preventing platelet adhesion and subsequent thrombosis. In our laboratory, we have developed plastic surfaces that secret nitric oxide at a rate similar to the normal endothelium.51,52 This approach is effective in preventing platelet adhesion and aggregation. We are also developing that technique as our approach to developing the nontthrombogenic surface.

Dr Gibbon and his colleagues worked on the concept of a heart—lung machine for 22 years before his first clinical case. He married Dr Churchill’s laboratory assistant and brought her to Philadelphia, where she continued to help with laboratory research. During those 22 years, Dr Gibbon developed an active surgical practice and an outstanding reputation in academic surgery, published the definitive textbook on surgery of the chest, mentored hundreds of residents and colleagues and thousands of medical students, and was appointed the Samuel D Gross Professor of Surgery at his alma mater Jefferson Medical College. In 1953, Dr Gibbon and his laboratory team decided it was time to try the heart—lung machine to facilitate intracardiac surgery. They focused on atrial septal defect, which was the easiest congenital anomaly to repair. The first patient died. The second patient, an 18-year-old student, recovered and survived. The next 2 children died because the diagnosis was incorrect and the heart—lung machine could not deal with the problems. Dr Gibbon declared a moratorium, pending improvements in the device and better methods of diagnosis. When the clinical studies resumed, he turned the project over to Dr Templeton and his other colleagues.

To Dr Gibbon, the first successful heart—lung machine case was a minor event. In his mind, failure in 3 patients overwhelmed the one success. A few other researchers were working on the concept of extracorporeal circulation at that time and they were all surgical friends. The next year, Dr Gibbon was visiting with the research team at the University of Minnesota headed by Drs Varco, Lillehei, and Dennis. At that meeting, he told the Minnesota group about his successful case. They had tried extracorporeal circulation without success at that time. Dr Dennis thought the case was very important and encouraged Dr Gibbon to publish it. Dr Gibbon was not enthusiastic. It was just a case report and 3 of 4 patients died. However, he agreed to write up a short manuscript, which Dr Dennis arranged to publish in Minnesota Medicine.53 So this landmark article in cardiac surgery is in an obscure state medical journal.54 On the occasion of the Gibbon Lecture, we should also recognize the wisdom of Dr Clarence Dennis in reporting that important case to the world. Dr Dennis became the chairman of surgery at Downstate Medical University in Brooklyn and had a prominent career in cardiac surgery and artificial organs.

Some have wondered why Dr Gibbon turned this lifelong project over to his younger colleagues after 20 years of laboratory work. Consider the circumstances. Dr Gibbon was close to 50 years old, chairman of a major surgical department, prominent in local and national surgical and academic medical institutions, and arguably the premiere lung surgeon of the time. He had many responsibilities aside from the heart—lung machine. In retrospect, he considered that he had demonstrated that the concept of the heart—lung machine was feasible, realized that improvements in cardiac diagnosis and the device itself would be necessary to continue, and wisely turned the project over to his younger medical and surgical colleagues.

One of the many applications of this technology is the treatment of massive pulmonary embolism. At the Gibbon lecture I was proud to introduce our patient with massive pulmonary embolism, treated successfully with our ECMO version of the heart—lung machine in 1992. That patient brings to full cycle the 1931 dream of Dr Gibbon, and hence the title of this discussion: Gibbon Fulfilled.

Consider the perception and perspective of young Dr Gibbon caring for a patient with fatal pulmonary
embolism. “It naturally occurred to me that it should be possible to remove venous blood and pump it into the systemic circulation to solve this problem.” As surgeons, we see patients with hopeless conditions every day. It naturally occurs to us that the problem should be solvable. Few of us have the opportunity to do that. I, with hundreds of colleagues and thousands of patients, have had the opportunity to extend Dr Gibbon’s dream.

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REFERENCES


