Forest Dewey Dodrill: Heart Surgery Pioneer. Michigan Heart, Part II

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INTRODUCTION

There have been at least two books[1,2] written about Dr. John Gibbon, Jr., who worked with IBM to develop a heart-lung machine and performed a successful operation with that machine about a year after Dodrill's first successful operation. Gibbon probably never performed another successful heart operation with his machine. There have been many articles and at least one book[3] written about Dr. C. Walton Lillehei, a heart surgery pioneer at the University of Minnesota, who started performing open heart operations on children using the parent or another adult as the "heart-lung" machine in early 1954. There have been numerous articles written about Dr. John W. Kirklin who established an open heart surgery program at the Mayo Clinic in 1955 using a modified version of Gibbon's heart-lung machine.[4-6] Perhaps the most has been written about Dr. Christiaan Barnard from Capetown, South Africa, who performed the first successful human heart transplant in 1967, but was not a participant in the initial pioneering work with heart-lung machines.

Almost nothing, however, has been written about Dodrill and his historic accomplishment! Incidentally, his colleagues referred to him as 'Dewey,' a birth name given to him honoring U.S. Navy Admiral George Dewey, the hero of the 1898 Battle of Manila Bay. A typical comment from an "old-timer" at Harper University Hospital, remembering Dodrill, would be, "As I recall, Dewey only did that one successful heart operation and gave it up. . . . I don't recall that he ever did another heart operation after that," or "After that first successful case with the GM pump, the next several patients died and he gave it up."

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EDUCATION, TRAINING, AND TEMPERAMENT

Forest Dewey Dodrill was born January 26, 1902 in Webster Spring, West Virginia. Undoubtedly his first exposure to thoracic surgery came in 1918 when he himself was operated on for an empyema. His surgeon was Dr. Herbert Sloan, Sr., father of Dr. Herbert Sloan, Jr., currently Professor Emeritus of Cardiothoracic Surgery at the University of Michigan.[7] After receiving a Bachelor degree from West Virginia University in 1925, Dodrill attended Harvard Medical School, graduating in 1930. He then served an internship and surgical residency at Harper Hospital in Detroit and subsequently became a surgeon on the Harper Hospital staff. In 1941-1943 (or 1942-1944), he served a thoracic surgery residency under Dr. John Alexander at the University of Michigan and also received a master's degree in surgery at the same time. Returning to the staff at Harper Hospital, he mainly limited his practice to chest and vascular surgery.

Dodrill married Ardis Twork from Dearborn, a suburb of Detroit (Fig. 1). She had graduated from Harper Hospital's nursing school and then worked for a while at Harper Hospital. At the time they were married in 1938, she had been working as a private nurse for David Whitney, Jr., a wealthy Detroiter, and traveled extensively with him and his family on their private yacht and elsewhere. The Dodrills had three daughters, one of

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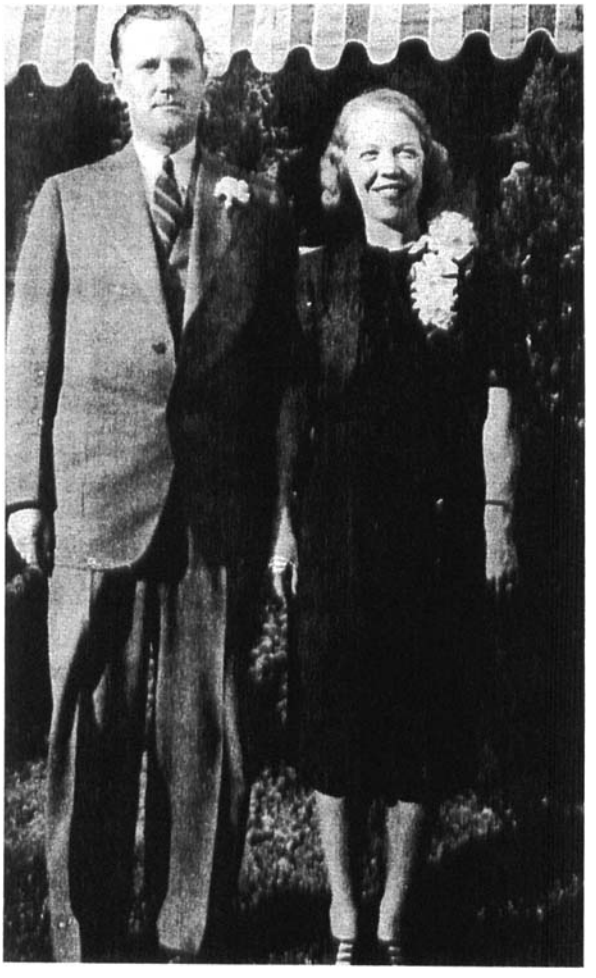

Figure 1. *Dodrill and his wife, Ardis on their wedding day in 1938. (Photo courtesy of the Dodrill family.)*

whom became a physician. "My dad was so modest," said one daughter. "He shunned publicity and really kept a very low profile about his accomplishment."[8] Relatives described him as having a heart of gold.[8] Most of his colleagues thought of him as a quiet man; some said almost non-communicative. Physically, he was described as tall and lanky, and a former nurse added, "who dressed well."[9]

One operating room nurse, Veronica Staron, who spent many years working with Dodrill, said with amusement, "He never lost his cool. If something bad was happening in the operating room, he would look over his glasses and say, 'Girlie, we have a problem. Here's what we are going to do.' "[9] She remembered helping him perform many closed mitral commissurotomies. Surgeons used an instrument or, more often, their finger to dilate a narrowed mitral heart valve. Of the surgeons that used their finger, not all used a glove; some, including Dodrill, felt they had better feel with the tip of their exposed finger during this sensitive surgery. Veronica Staron said, "He would dip his hand in an antiseptic solution and place his finger directly through a pursestring suture through the left atrial appendage and crack the valve without a surgical glove."[9]

THE BUMPY TRAIL OF A HEART SURGERY PIONEER, AMBUSHES AND ALL!!

Some of what we know about Dodrill on a professional level comes from scientific articles and published discussions of those articles when they were presented at major medical meetings. On February 21, 1947, at the annual meeting of the Central Surgical Association in Chicago, Dodrill reported on 13 patients on whom he had attempted Blalock-Taussig shunts, a surgical procedure that had first been performed in 1944 by Dr. Alfred Blalock at Johns Hopkins Hospital and became better known to the general public as the 'blue baby' operation. There were three deaths in Dodrill's series of 13 Blalock-Taussig shunt patients, including one patient on whom he was unable to perform the shunt at all. In his article, there was an addendum documenting that Dodrill had performed shunts in an additional 11 children with only one additional fatality.[10]

In March 1949, Dodrill presented a paper in New Orleans at the annual meeting of the American Association for Thoracic Surgery in which he described a method for using an instrument that he had developed to close atrial and ventricular septal defects in dogs. He simulated the defects by making holes in the walls of the upper or lower pumping chambers of the heart. Approximately 50 operations had been done using his instrument.[11] During his early trials, the mortality rate was approximately 50%. However, with experience and practice, he was able to close an atrial or ventricular defect with only an occasional death to the animal. As far as we know, Dodrill never used this clamp-type instrument in humans. Interestingly, the time frame in which he presented this work in New Orleans coincides with the approximate time that he approached the Michigan Heart Association for support in building a mechanical heart pump. It was probably becoming gradually apparent to Dodrill that

such a machine, as opposed to his innovative clamp instrument, had to be built to repair defects inside the heart.

In 1945, Drs. Clarence Crafoord in Sweden and Robert Gross in Boston had each reported on the successful repairs of coarctation of the aorta. In December 1951, Dodrill reported surgical correction of coarctation of the aorta in three older patients, 30, 40, and 42 years of age.[12] All survived the surgical repair. As we well know, coarctation surgery in older patients tends to be much more difficult than in the young. Gross was also the first to report on successful repair of another birth defect, vascular ring. In June 1951, Dodrill submitted a paper on the double aortic arch variant of this problem with successful surgical repair in two patients.[13]

In 1951, Charles DuBost from Paris, France, was the first to resect an abdominal aortic aneurysm and to replace it with a piece of aorta from a human cadaver. Dodrill described his first successful case of abdominal aortic aneurysm resection and homograft replacement on July 21, 1953.[14]

Synthetic grafts were pioneered in 1952 by Dr. Arthur Voorhees at Columbia University, where a team of doctors developed cloth tubes to replace the aorta and other arteries. There is the oft-told story of how Dr. Michael DeBakey went into a department store to buy some nylon material for grafts he planned to make on his wife's sewing machine. The store had just run out of nylon, but the clerk suggested he try a new material they had just received called Dacron. He bought several yards of the material, made tube grafts, tested them in the animal laboratory, and the rest is history.

Recently, Dodrill's oldest daughter Judith, now a physician, recalled that during the early 1950s her father asked her mother to order an entire bolt of the very best white silk satin. Dodrill planned to make vascular grafts and test them in the animal laboratory, believing that the highest quality fabric would have certain desirable characteristics when used as a graft. The silk satin grafts did not work, perhaps because of leakage through them. But for years to follow, Judith remembers her mother, who was "a wonderful seamstress," sewing countless white silk satin cuffs and collars for Judith and her two sisters![15]

It was in May 1952, that Dodrill first presented his experimental work with the General Motors heart-lung machine at the annual meeting of the American Association for Thoracic Surgery held in Dallas, Texas.[16] He reported on 65 experiments carried out on dogs. In some, he used the machine to divert blood from the right side of the heart and in others, from the left side. In the third group, he used his machine to completely bypass the heart and lungs, using a mechanical oxygenator of his team's design to substitute for the lungs.

And of course, it was July 3rd of that year when Dodrill performed his first human operation using his pump to bypass the left side of the heart while he operated on the mitral valve.[17] On October 21 of that same year, Dodrill used the Dodrill-GMR Mechanical Heart to perform a pulmonary valvulotomy under direct vision on a 16-year-old male with severe congenital pulmonary stenosis.[18] The authors have all viewed the operative movie made of that surgery in color. That patient also did well and is presently alive in 2002, almost 50 years after the surgery. Dodrill presented this case at the annual meeting of the American Association for Thoracic Surgery in San Francisco in March 1953. During that talk, Dodrill mentioned the blind (closed) pulmonary valvuloplasty procedure developed by Brock and the concern about recurrence of the pulmonary stenosis over time with that procedure. He then stated, "Although much good has been accomplished by blind procedures within the heart, it is probable that advancement from this point on must be made by exposure of the anatomic structure."[18]

Dr. John Gibbon, Jr., in Philadelphia, had developed a heart-lung machine which he used in a series of five patients in attempts to correct various types of heart defects. Only one of those patients, the third of the five done in 1953, survived the operation.[1,2] Dr. Gibbon became very discouraged by the fact that four of his five patients had died and, therefore, declared a moratorium on further human heart surgery at his institution until the problems that were responsible for the deaths could be worked out.

John Kirklin, later referring to this period, stated, "Most people were very discouraged with the laboratory progress. The American Heart Association and the National Institutes of Health had stopped funding any projects for the study of the heart-lung[19] machines because it was felt that the problem was physiologically insurmountable." Fortunately, General Motors and the Michigan Heart Association continued to fund Dodrill's research!

At the annual meeting of the American Medical Association, June 3, 1953, Dodrill presented his experience with six clinical cases using the Dodrill-GMR heart pump with four hospital survivors.[20] At this point, he seemed in no hurry to use the mechanical oxygenator he had been testing in the animal laboratory and said, "If the lungs can be used for their natural functions, however, it is probably more satisfactory than mechanical oxygenation."

Later that year, on September 16, 1953, there was a symposium on recent advances in cardiovascular physiology and surgery held at the University of Minnesota. Gibbon presented his work there, including the successful operation he had done the previous May with his heart-lung machine. A portion of the proceedings of that meeting, and Gibbon's successful operation, was originally published in a 1954 issue of *Minnesota Medicine*.[21] That publication also included an extensive discussion by Dodrill of approximately two and one-half pages that includes diagrams and intraoperative photographs of patients' pulmonary and mitral valves. He starts by commenting on Gibbons' presentation, "You have just heard the leading pioneer in this country. . . ." Dodrill states that by then his team had performed more than 100 animal experiments using the Michigan Heart both with and without a mechanical oxygenator. Dodrill described five of the operations he had performed in humans before that September 16 symposium. This included his first successful open heart operation of July 3, 1952. His other surgeries mentioned included the right heart bypass for his patient with pulmonary stenosis; another patient with mitral valve regurgitation; a patient with aortic stenosis; and, finally, another patient with pulmonary stenosis. All of these procedures had been done using his mechanical heart pump. Unfortunately, the last patient mentioned with pulmonary stenosis also had marked obstruction of the right ventricle outflow tract leading to that valve, which Dodrill could not sufficiently relieve. In this patient he bypassed both the right and left heart, but used the patient's own lungs to oxygenate the blood. That patient died of complications 4 days after the surgery. By September 16, 1953, Dewey Dodrill had performed at least nine open heart operations using the mechanical heart with five or six survivors—an important accomplishment! (See Table 1.)

Calvin Hughes, who was the GM employee operating the Michigan Heart, recalls that Dodrill had a heart defibrillator that may have been the only one in Detroit at the time. They were weaning a patient from bypass when the heart developed ventricular fibrillation and they discovered that their defibrillator was inoperable. They discussed their options, while Dodrill manually massaged the heart.

What would you have done? In desperation, Hughes cut off the end of an electric extension cord, separated the two copper wires, quickly removed the insulation, and frayed the top of the wires out into a fan shape. He then handed the wires to Dodrill in two sterile towels. Dodrill carefully placed the wires across the heart and when he said, "ready," Hughes quickly turned the switch on and off and the ventricular fibrillation broke. For a long time after that they all kidded Hughes about his 10-cent defibrillator.

THE GENERAL MOTORS HEART AND HENRY FORD HOSPITAL

A somewhat interesting medical political situation occurred in Detroit during 1955, when the folks at Henry Ford Hospital, located a few miles from Harper, hosted what was called the "Henry Ford Hospital International Symposium on Cardiovascular Surgery," March 17, 18, and 19. It is likely that at least part of the motive for holding this event was to offset the local publicity Harper Hospital and Dodrill's team were getting related to the Dodrill-GMR Mechanical Heart. In fact, it is conceivable that indirectly the GMR Heart was responsible for the Ford event happening.

According to Conrad Lam, who was then chief of cardiothoracic surgery at Ford Hospital, and who was known for taking verbal potshots at Dodrill and the 'Michigan Heart' project, particularly after the summer of 1952, "During the summer of 1954, the staff of Henry Ford Hospital . . . decided to sponsor an international symposium on the subject of surgery of the heart and great vessels. The local program committee sought and obtained the assistance of four eminent authorities from outside the staff of the hospital. Invitations to participate in the symposium were sent to 60 workers in the field, many of whom resided in countries other than the United States. The response on the part of the invitees was nearly 100% in the affirmative. Several weeks before the date of the symposium, there were more

TABLE 1
Clinical Cases Performed by Dodrill Using the Michigan Heart July 1952–December 1955

Patient #	Date	Age, Gender, Weight	Type of Bypass; Length of Bypass	Surgical Procedure	Outcome
1.	July 3, 1952	41-year-old male 148 lb	Left heart 50 min	Separate fused mitral chordae	Survived[17]
2.	August 1, 1952	100 lb	Left heart 60 min	Finger fracture of mitral valve; thrombus also removed	Died Ventricular fibrillation coming off Massage for ½ hr.
3.	October 21, 1952	16-year-old male 172 lb	Right heart 87 min	Pulmonary valve opened under direct vision	Survived[18]
4.	November 18, 1952	118 lb	Left heart 25 min	Mitral valve surgery	Survived
5.	December 4, 1952	24 lb	Right heart 68 min	Pulmonary valvulotomy Arrested while cannulating heart and great vessels	Died in operating room Arrested several times during case
6.	February 3, 1953	female 116 lb	Left heart 18 min	MS finger fracture	Survived
7.	February 18, 1953	59-year-old female 130 lb	Left heart 28 min	Photos taken of mitral valve during repair procedure	Survived
8.	February 26, 1953	18-year-old female 132 lb	Right heart and left heart 42 min	Pulmonary valvuloplasty Unable to sufficiently relieve infundibular stenosis	Died on 4th postoperative day
9.	(before September 16, 1953)		Left heart	Finger fracture of aortic valve stenosis	?
10.	1953		Right or left heart	?	?
11.	1954 after June 4		Perfuse body below chest level with oxygenated blood	Replace section of thoracic aorta with cadaver graft	Cases 11-13 probably referred to in reference[31]
12.	1954 after June 4		Perfuse body below chest level with oxygenated blood	Replace section of thoracic aorta with cadaver graft	?
13.	1954 after June 4		Perfuse body below chest level with oxygenated blood	Replace section of thoracic aorta with cadaver graft	?
14.	1955 (early 1955)		Heart-lung machine	Repair VSD unrecognized blockage of endotracheal tube for several minutes	Died, Postoperative Day 1
15.	1955 (early 1955)		Heart-lung machine	Attempt to repair common ventricle (ventricular septum)	Died, Postoperative Day 2
16.	1955 (November)	35-year-old female	Left heart bypass	Repair mitral stenosis and regurgitation	Survived
17.	December 1, 1955	3-year-old female 32.5 lb	Heart-lung bypass 32 min.	Repair VSD	Survived[25]

applications than there were seats in the Clinic Building Auditorium. Thereafter, the local committee was obliged to send letters of regret. The final registration list contained the names of 478 doctors from 35 states and . . . (22) countries. . . . "[22]

The proceedings of the symposium were published in a hardcover book of more than 500 pages with a list of the names of the 60 participants and 17 discussants, which reads like a list of 'Who's Who in cardiovascular surgery' well, almost.[22] By the time the symposium was held, John Gibbon and Clarence Crafoord had each performed one successful clinical case using their heart-lung machines. It was 3 days after the conference when the Mayo Clinic's John Kirklin performed his first case using a heart-lung machine and 13 months later when Conrad Lam performed his first successful case. Dr. C. Walton Lillehei with his successful string of open heart cases, using controlled cross circulation, was the star of the show and "electrified the audience with a masterly presentation of surgical correction of VSD, tetralogy of Fallot and atrioventricular canal."[23] The cross-circulation technique, however, would be abandoned by the end of that year (Table 2).

By then a number of participants and Dodrill were using total body hypothermia as an adjunct to correcting some less complex heart defects.

TABLE 2
Open Heart Surgery's Twilight Zone 1951–1955

**Clinical Status of Open Heart Surgery*

1951 April 6–Clarence Dennis at the University of Minnesota used a heart-lung machine to repair an ostium primum or A-V canal defect in a 5-year-old-girl. Patient could not be weaned from cardiopulmonary bypass.[32]

May 31–Dennis attempted to close an ASD using heart-lung machine in a 2-year-old female who died intraoperatively of a massive air embolus.[32] Although unsuccessful, these were probably the first two surgeries where a heart-lung machine was used while the surgeon attempted to correct a human heart defect.

1951 August 7–Achille Mario Dogliotti, Professor of Surgery, University of Turino, Italy, used a heart-lung machine of his own design to **partially** support the circulation (flow was 1 L/min for 20 minutes) while he resected a large mediastinal tumor compressing the right heart.[33] The cannulation was through the right axillary vein and artery. The patient survived. This was the first successful clinical use of a heart-lung machine, but it was not used as an adjunct to heart surgery.

1952 February (1952 or 1953 John Gibbon, see February 1953)

March–John Gibbon used his heart-lung machine for right heart bypass only, while surgeon Frank Allbritten at Pennsylvania Hospital, Philadelphia, operated to remove a large clot or myxomatous tumor suspected by angiography.[34] The right atrium and triscupid valve were very dilated. No tumor or clot was found. The patient died of heart failure in the operating room shortly after discontinuing right heart bypass.

1952 July 3–Dodrill used the Dodrill-GMR pump to bypass the left heart while he repaired a mitral valve.[17] Patient survived. This was the first successful use of a mechanical pump for **total** substitution of the left ventricle in (humans and arguably the first successful open heart operation in a human) man.

September 2–John Lewis, University of Minnesota, closed an ASD under direct vision in 5-year-old girl. The patient survived. This was the first successful clinical heart surgery procedure using total body hypothermia. Mechanical pump and oxygenator were not used. Others, including Dodrill, soon followed, using total body hypothermia techniques to close atrial septal defects and perform pulmonary valvulotomies. By 1954 Lewis reported on 11 ASD closures using hypothermia with two hospital deaths.[35] He also operated on two patients with ventricular septal defect in early 1954 using this technique. Both resulted in intraoperative deaths.

October 21–Dodrill performed pulmonary valvulotomy under direct vision using Dodrill-GMR pump to bypass the right atrium, ventricle, and main pulmonary artery.[18] The patient survived.

Although Dr. William Mustard in Toronto would later describe a type of 'corrective' surgical procedure for transposition of the great arteries (TGA) in 1964, which, in fact, for many years, would become the most popular form of surgical correction of TGA, his early results with this lesion were not good. In 1952 he used a mechanical pump coupled to the lung that had just been removed from a monkey to oxygenate the blood in 7 children while attempts were made to correct their TGA defect.[36] There were no survivors.

1953 February (or 1952)–Gibbon at Jefferson Hospital in Philadelphia operated to close an ASD on a very sickly 15-month-old female weighing 11 lb.[1] He used his heart-lung machine. No ASD was found. She died intraoperatively. Autopsy showed a large patent ductus arteriosus.

May 6–Gibbon used his heart-lung machine to close an ASD in an 18-year-old female with symptoms of heart failure.[1] She survived the operation and became the first patient to undergo successful open heart surgery using a heart-lung machine.

July–Gibbon used the heart-lung machine on two 5-year-old females to close ASDs.[1] Cardiac arrest occurred after the chest was opened in the first. The heart and great vessels were cannulated during CPR. Cardiopulmonary bypass was commenced. The patient died intraoperatively. The second patient was found at operation to have A-V Canal and a small PDA. The A-V canal was partially closed. She died intraoperatively. Gibbon was extremely distressed and declared a moratorium on further cardiac surgery at Jefferson Medical School until more work could be done to solve problems related to heart-lung bypass. This was probably the last heart operation he performed using the heart-lung machine.

TABLE 2 *(CONTINUED)*
Open Heart Surgery's Twilight Zone 1951–1955

**Clinical Status of Open Heart Surgery*

1954 March 26–C. Walton Lillehei and associates at the University of Minnesota closed a ventricular septal defect under direct vision in a 15-month-old male using a technique to support the circulation that they called controlled cross circulation. An adult (usually a parent) with the same blood type was used more or less as the heart-lung machine. The adult's femoral artery and vein were connected with tubing and a pump to the patient's circulation. The adult's heart and lungs oxygenated and supported the circulation while the child's heart defect was corrected. The first patient died 11 days postoperatively from pneumonia, but 6 of their next 7 patients survived.[37] Between March 1954 and the end of 1955, 45 heart operations were performed by Lillehei on children using this technique before it was phased out. Although controlled cross circulation was a short-lived technique, it was an important stepping stone in the development of open-heart surgery.

1954 July–Clarence Crafoord and associates at the Karolinska Institute in Stockholm, Sweden, used a heart-lung machine of their own design coupled with total body hypothermia (patient was initially submerged in an ice-water bath) to remove a large atrial myxoma in a 40-year-old woman.[38] She survived.

1955 March 22–John Kirklin at the Mayo Clinic used a heart-lung machine similar to Gibbon's, but with modifications his team had worked out during 2 years in the research laboratory, to successfully close a ventricular septal defect in a 5-year-old patient. By May of 1955, they had operated on eight children with various types of ventricular septal defects and four were hospital survivors. Although their mortality was 50%, this was the first successful series of open heart operations using a heart-lung machine.[39] As Kirklin continued on in 1955, his open heart mortality rates dropped.[40]

May 13–Lillehei and colleagues begin using a heart-lung machine of their own design to correct intracardiac defects. By May of 1956, their series included 80 patients.[37] Initially they used their heart-lung machine for lower risk patients and used controlled cross circulation with which they were more familiar for the higher risk patients. Starting in March 1955, they also tried other techniques in patients to oxygenate blood during heart surgery, such as canine lung, but with generally poor results.[37]

(Early in the year 1955) Dodrill attempted repairs of ventricular septal defects in two patients using the Dodrill-GMR heart pump with a mechanical oxygenator of his team's design. The first patient died 1 day after surgery when the endotracheal tube became obstructed, which was undetected for several minutes. The other patient had a common ventricle (no ventricular septum), which Dodrill attempted to repair. This patient died on the second postoperative day. On December 1 he closed a VSD in a 3-year-old female using his heart-lung machine. She survived. In May, 1956 at the annual meeting of the American Association for Thoracic Surgery, he reported on six children with ventricular septal defects, including one with tetralogy of Fallot who had undergone open heart surgery using his heart-lung machine. All survived at least 48 hours postop.[25] Three were hospital survivors, including the patient with tetralogy of Fallot.

June 1955 Clarence Crafoord and his associates used their heart-lung machine to resect a large left ventricular aneurysm in a 52-year-old man.[38] The patient survived.

Mustard successfully repaired a VSD and dilated the pulmonary valve in a 9 month old with a diagnosis of tetralogy of Fallot using a mechanical pump and a monkey lung to oxygenate the blood.[41] He does not give the date in 1955, but the patient is listed as Human Case #7. Unfortunately, in the same report, cases #1-6 and #8-15 operated on between 1951 and the end of 1955 with various congenital heart defects did not survive the surgery using the pump and monkey lung, nor did another seven children in 1952, all with TGA (See 1952) using the same bypass technique.

*This list is not all-inclusive, but likely includes most of the historically significant open heart events during this period. A twilight zone can mean an ill-defined area between two distinct conditions, such as the area between darkness and light.

By March 1955, Dodrill had operated on approximately 13 to 15 patients using the Michigan Heart with a number of survivors, and yet his name does not appear on the list of the 77 participants and discussants. In fact, some local Detroiters who attended did not recall seeing Dodrill there. Many of the attendees did, however, visit Dodrill's Harper Hospital research facilities during the time of the Detroit symposium.

Did Dodrill decide not to attend? Was Dodrill invited to the symposium??? Dodrill should not have felt like the "Lone Ranger' however. At the August Henry Ford symposium held 20 years later, even C. Walton Lillehei and Christiaan Barnard didn't make the cut![23]

DODRILL'S HEART-LUNG MACHINE AND BEYOND

Dodrill's laboratory work with the heart-lung machine continued to progress after the 1952 report he had given to the American Association of Thoracic Surgery members.[16] At the April 1955 annual meeting of the American Association for Thoracic Surgery held in Atlantic City, New Jersey, Dodrill gave a talk on "arterialization of blood as it applies to mechanical heart-lung apparatus."[24] He used his General Motors pump connected to a more advanced device to oxygenate the blood and presented a number of dog experiments in which the animals had their hearts open for 30 minutes and 75% of the animals survived

the heart-lung bypass. At the May 1956 meeting of the American Association for Thoracic Surgery in Miami Beach, Florida, he gave a talk entitled "The Use of the Heart-Lung Apparatus in Human Cardiac Surgery."[25] Again, Dodrill presented a number of dog experiments with a couple of different ways that the heart-lung machine was connected to the circulation. This time, he also presented six patients who had undergone surgery for various types of ventricular septal defects. All six patients survived for at least 48 hours and three, including one with tetralogy of Fallot, were discharged from the hospital. The only person to discuss Dodrill's paper was John Gibbon, who agreed with most of the points Dodrill made (Fig. 2)

In June of 1959, Dodrill presented a paper at the annual meeting of the Society of Vascular Surgery in which he discussed his research using cardioplegic solutions.[26] Dodrill advocated using high energy phosphate solutions such as ATP to protect the arrested heart. He showed the superiority of this solution over various types of potassium cardioplegia solutions. Work on this subject continues today, but at that time, his work would have been considered very innovative and cutting-edge research.

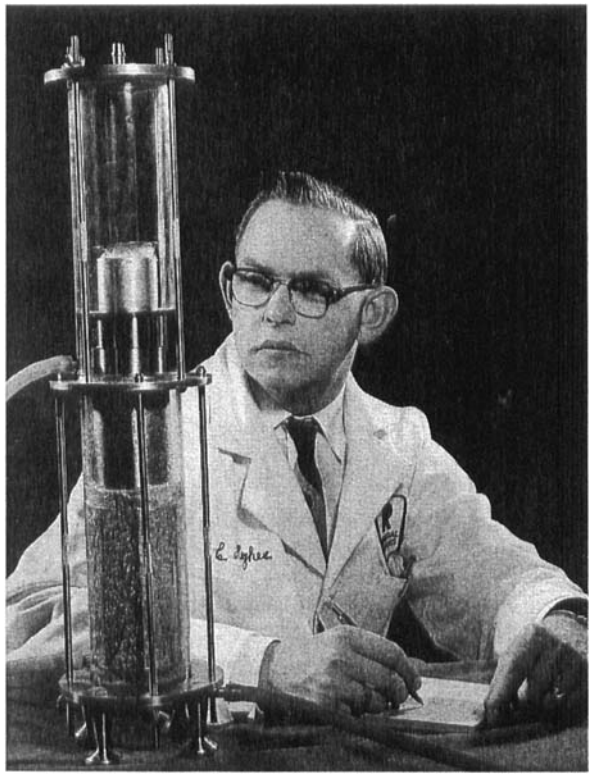

Figure 2. *Later model of the oxygenator developed by the GM-Dodrill team. This version was extensively tested in the animal laboratory during 1954 and used in human cases in 1955. Notice the General Motors Research insignia over the left pocket of Hughes' laboratory coat. (Photo courtesy of Calvin Hughes.)*

In 1960, Dodrill published a paper entitled, "Present Status of the Surgical Treatment of Tetralogy of Fallot."[27] This paper contained a series of 18 patients on whom he had performed complete surgical correction with only two hospital deaths, clearly outstanding results in those early days of heart surgery.

Today, cardiologists perform cardiac catheterizations, but in the early days many of the pioneer heart surgeons performed their own cardiac catheterizations. In those days, Dodrill performed many cardiac catheterizations, seeking information as to whether patients might require heart surgery. He reported on one patient with valvular heart disease on whom he was preparing to do a cardiac catheterization using direct cardiac puncture, which means sticking a needle directly through the skin into the heart.[28] The patient's electrocardiogram was being monitored, as was the femoral arterial pressure. While the patient's chest area was being infiltrated with a local anesthetic, the patient suddenly developed ventricular fibrillation. The substance of Dodrill's article was the blood pressure tracings obtained during the closed chest massage while he was attempting to resuscitate the patient. He eventually had to open the patient's chest and massage the heart directly and perform direct electric shock to the heart. Dodrill said, "It is of interest that (external chest) compression applied by the experienced thoracic surgeon was most effective in producing normal systolic pressure; that applied by the radiologist with knowledge acquired from a recent film demonstration [of CPR] was moderately effective; and the same effort by a resident physician with no experience was almost totally ineffectual until he was properly instructed."[28]

Drs. Agustin Arbulu and Joseph Bassett, who finished their cardiothoracic residency training in the Wayne State Affiliated Programs during the 1960s, remember assisting Dodrill both as residents and after completing their residency training. As they remembered, Dodrill was then mainly performing heart valve surgery and congenital heart surgery. They considered Dodrill a good, sound surgeon and described him as polite,

calm, and in control in the operating room. Bassett actually helped Dodrill do his first saphenous vein coronary bypass operation in about 1971.

Dodrill served as clinical associate professor of surgery at Wayne State University School of Medicine, and was chief of the Section of Thoracic Surgery at Harper Hospital (recently renamed 'Harper University Hospital') from 1963 through 1965. He stopped operating at Harper Hospital in about 1972. By then it is estimated that he had performed more than 1,000 open heart operations. He subsequently developed Parkinson's disease and died in June of 1997 at the age of 95.

WHAT IS OPEN HEART SURGERY ANYWAY?

It is estimated that currently 1,000,000 heart operations are done in the world each year. What is open heart surgery? Originally, it meant being able to open the heart and repair a defect usually under direct vision while the patient's circulation was supported by a pump such as Dodrill's. Another necessary aspect was oxygenation of blood. It could be done using the patient's own lungs or by using a mechanical oxygenator. A pump plus a mechanical oxygenator is a heart-lung machine.

In the early days of repairing congenital defects, some surgeons cooled the patient's body temperature in an ice bath. This stopped the circulation by causing ventricular fibrillation and provided a certain amount of protection for the brain and the heart. Then they would quickly open the heart and repair the defect. This method generally was used to repair less complex heart defects, such as pulmonary valve stenosis and atrial septal defects. Using this hypothermia technique to open the heart and repair it can also be considered open heart surgery. Today, however, the term 'open heart surgery' often means any heart operation in which the heart-lung machine is used. This frequently includes coronary artery bypass grafting (CABG), where only the arteries on the surface of the heart are involved in the surgery. Is off-pump CABG open heart? Was the old atrial well technique used while closing atrial septal defects, open heart?? How about the 'total cardiac inflow occlusion technique' used in some patients during the late 1940s and early 1950s, which gave the surgeon about 1.5 minutes of 'safe' operating time???

'Open heart' has become a victim of semantics and now usually means whatever the speaker wants it to mean.

DODRILL'S PLACE IN HISTORY

Why isn't Dodrill better recognized for performing the first successful open heart operation and why do some folks argue that he was not actually the first to perform a successful open heart operation on a human?

In the first place, Dodrill did not use a heart-lung machine to perform his first operation. He did use a mechanical heart pump to support the patient's circulation, but in the first several operations, he used the patient's own lungs to oxygenate the blood. Therefore, Gibbon, who had one successful case the year after Dodrill's case, is generally given most of the credit because he used both a mechanical heart pump and a mechanical oxygenator to oxygenate the blood. Gibbon performed the first successful open heart operation using a heart-lung machine. Dodrill did have his own mechanical oxygenator and had already reported on experiments with it in a medical journal, but he did not use it on the first several human cases. Interestingly, even today, some heart centers have used mechanical heart pumps while using the patient's own lungs to oxygenate the blood. Recently, surgeons from Russia have reported on a series of patients undergoing heart operations where a mechanical pump supported the patient's circulation while the patient's own lungs supplied oxygen to the blood.[29] The advantages the Russians cited were that it is possibly more physiologic to use the patient's own lungs to oxygenate the blood and, in addition, eliminates the need for an expensive (and nowadays disposable) oxygenator.

Second, when Dodrill performed his first case in July 1952, he used his pump to divert the oxygenated blood returning to the left atrium. The blood bypassed the patient's left ventricle and was pumped back into the patient's aorta. Dodrill's intent was to open the left atrium so he could visualize the patient's mitral valve and repair it. However, in this patient, the left ventricle was quite large, so he was unable to expose the heart valve as he hoped to do. He placed a pursestring stitch around the left atrial appendage and then placed his finger through it and performed manipulations on the mitral valve blindly for 14 minutes while the patient's circulation was supported

by the mechanical pump. Some would argue this is not a true open heart operation since he didn't visualize the defective heart valve. Also, he does not tell us exactly what he did to improve the leaky heart valve. The patient, however, improved dramatically and, even years later, seemed to be asymptomatic. Could this have been a placebo effect? It's possible, but not likely. In two later reports he further described the method used to repair the valve in the July 1952 case.

Lillehei has argued that Dodrill's first patient was not a true open heart operation for the previously cited reasons. Few, however, would argue about the operation where he photographed and corrected a congenitally deformed pulmonary valve under direct vision on October 21, 1952.

On September 2, 1952, between Dodrill's first operation in July and his second operation in October, John Lewis at Minnesota used total body hypothermia while closing an atrial septal defect under direct vision , although he did not use a mechanical heart pump or heart-lung machine.

Finally, Dodrill was a quiet, unassuming person. Some said that he almost seemed shy. Others said that he was introverted. One of his daughters said that her father was very upset with the newspaper articles generated by his first open heart operation and felt they had blown it way out of proportion to what had actually been accomplished. The *Detroit Times* referred to Dodrill as "one of the most publicity-shy doctors in Michigan."[30] These factors probably contributed to him not attempting to receive his proper share of the credit for his accomplishments over time, particularly when there were a number of high-profile heart surgeons soon to follow, both nationally and internationally, in Dodrill's footsteps.

Arguments continue about the origins of open heart surgery and who really was first to do this or that. What is fact, however, is that Dodrill performed the first successful human heart operations that were made possible by a mechanical device that supported the patient's circulation. Perhaps he said it best "to our knowledge, this is the first instance of survival of a patient when a mechanical heart mechanism was used to take over the complete function of maintaining the blood supply of the body while the heart was opened and operated on."[17]

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