History of Cardiopulmonary Bypass

The development of cardiopulmonary bypass was the result of years of basic and clinical science by physicians challenged by exploring what many considered the final frontier of medicine – the heart and by default the soul of the human being. The Boston surgical community has made very significant contributions to the advancement of this science (Table 1). Many look to the year 1953 as the birth of cardiac surgery but many brave surgeons established techniques and practices which ultimately resulted in the creation of the bypass machine (Table 2). This year we will celebrate the 60th anniversary of Dr. John Gibbon's historic achievement that opened the door to a new realm of surgery and management of diseases of the heart and thoracic surgery. Bypass has been followed by the development of longer extracorporeal support, pacing devices, and balloon pumps (Table 3). Our generation will likely see the realization of a truly artificial fully contained artificial heart. Our accomplishments and anesthesiologists, physicians, perfusionists, and nurses working in cardiac surgery are reached from the shoulders of giants.

French Surgeon **Alexis Carrell, M.D.** worked with aviator **Charles Lindberg** in the early 1930's on the development of an artificial means to provide extracorporeal circulation. Dr. Carrell ultimately won the Nobel Prize for his work. Together they published, The Culture of Organs which described an artificial heart.

Dr. Robert Gross performed the first successful ligation of the ductus ateriosus on August 26, 1938 on a 7-year-old girl. She was out of bed the following say and left the hospital in 10 days. His next 10 patients underwent successful procedures. The 12th underwent a seemingly successful operation but 12 days after surgery dies suddenly. Autopsy demonstrated that the ligation had eroded through causing massive hemorrhage. Subsequently he practiced dissection, double clamping the ductus, dividing, and suturing over the separated ends. Dr. Gross also performed the first successful repair of an aortic coarctation in 1945.

Helen Taussig, M.D., Alfred Blalock, M.D. and **Vivien Thomas** a surgical technician developed the Blalock-Taussig shunt to relieve the cyanosis associated with Tetraology of Fallot in the 1940's. This procedure could be completed without the need for cardiopulmonary bypass.

Dr. Dwight Harkin performed over 130 procedures to remove shrapnel from the mediastinum of soldiers injured during World War II. Dr. Harkins was also instrumental in the practice of opening the mitral valve in patients with mitral stenosis without the use

of bypass. Purse string sutures would be placed in the apex of the left ventricle. A finger would be placed through an incision, open the valve, and then be removed while the apex was closed.

Dr. Arthur Vineburg developed a technique where the internal mamillary artery could be mobilized and inserted into the left ventricle to supply blood flow to areas affected by ischemia. He first demonstrated this technique in 1946.

Dr. John Lewis may have the strongest claim as the father of "open heart surgery". On September 2, 1952 he successfully performed a closure of an atrial septal defect in a 5 year old girl under general hypothermia and inflow occlusion.

Dr. John Heysham Gibbon was performing an emergency pulmonary embolectomy on a patient with Dr. Edward Churchill. No patient had ever survived such a procedure and neither did his. He then developed and idea to bypass blood from the thoracic cavity, orygenate the blood then return it to the body. The initial work occurred at the Massachusetts General Hospital.

On May 6, 1953, open heart surgery was officially born. Dr. Gibbon performed a closure of an atrial septal defect in 18-year-old Cecelia Bavolek at Jefferson Medical College. She was connected to the bypass circuit for 45 minutes and was fully dependent for 26 minutes.

Dr. C. Walt Lillehi was present when Dr. Lewis performed his historic operation. Dr. Lillehi noted that hypothermia only provided a very short duration of protection. He developed the technique of "cross circulation" where a patient (generally a child) would be connected to a second patient. The "donor" would provide the oxygenation and ventilation capabilities of the patient. This allowed a longer period of safety. He performed a closure of a ventricular septal defect on March 26, 1954.

Dr. John Kirklin at the Mayo Clinic in Minnesota and the University of Alabama is credited with utilizing bypass on a regular basis and developing it as a safe means to provide care during complicated procedures.

Table 1 Historic Moments in Boston Heart Surgery

Surgeon	Milestone	Boston Connection
John Gibbon, M.D. 1930's	Development of bypass machine	Fellow at MGH Surgical Labs
Robert Gross, M.D. 1930's	1st successful PDA ligation	M.D. Harvard Boston Children's Hospital
Dwight Harkin, M.D. 1940's	Shrapnel from the mediastinum Mitral valve opening	M.D. Harvard Brigham & Women's Mt. Auburn Tufts
Walter Lillehi, M.D. 1950's	Cross circulation	M.D. Harvard Son Craig – MD Harvard, resident MGH

History of Cardiopulmonary Bypass

Year	Pioneer /Facility	Contribution
1812	Jean Julien Cesar Legallois	
1930's	John H. Gibbon Massachusetts General Hospital	Dr. Gibbon asked to watch a young woman that had undergone a cholecystectomy. After surgery she developed hypotension and shortness of breath. She was ordered to be moved to the operating room. Gibbon observed her overnight and recorded vital signs every 15 minutes and notified team when she was close to death. Over time her venous pressure increased, blood pressure decreased, and she became cyanotic. She underwent an open pulmonary embolectomy referred to as the "Trendelenberg procedure" at 8:00 AM, but did not survive.
1934	John H. Gibbon Massachusetts General Hospital	Development of a heart-lung machine able to sustain circulation on a cat for 30 minutes
1946-1953	John H. Gibbon Thomas Watson (President, IBM) E.J. Clark (Medical student)	Development of 3 different machines (I, II, III)
1952-1953	John H. Gibbon Thomas Watson (President, IBM) E.J. Clark (Medical student)	Model II used >2000 lbs Blood pumped by 3 DeBakey roller pumps Screen oxygenators Flows up to 5L/min Volume and pH of blood in reservoir watched Back-up battery system Experiments resulted in survival of 9/10 dogs
1952	Clarence Dennis University of Minnesota	Performed 2 procedures. One patient suspected of having an ASD but had an atrioventricular canal and died during surgery. Second patient died of massive accidental air embolism.
1952	John Lewis University of Minnesota	Performed a successful closure of an ASD on Jacqueline Johnson under hypothermic arrest (30^{o}C). Credited with first successful *open* heart surgery
1952	John H. Gibbon Jefferson Medical College	15-month-old child with a possible ASD Child placed on bypass No ASD noted, rapid deterioration Postmortem revealed large PDA
May 6, 1953	John H. Gibbon Jefferson Medial College	18-year-old college student, Cecelia Bavolek, with recurrent right heart failure diagnosed with large ASD Chest opened, placed on bypass, ASD closed Partial bypass 45 minutes, full bypass 26 minutes During closure clots developed on oxygenator, Gibbon moved case along, closed with running suture. Patient survived
1953	John H. Gibbon Jefferson Medical College	Gibbon operated on 2 more patients both of which died. He ceased surgery.
1950-1955	William Mustard University of Toronto	Heart lung machine that utilized a monkey lung
1950-1955	Forest Didrill Wayne State University	Dodrill-GMR Bypass machine Design would bypass either the right or the left heart but

		utilize the patients lungs. Ultimately performed 4 operations with 3 survivors. Quit after 4 procedures
19501-1955	John Gibbon Jefferson Medical	Utilized the DeBakey roller pump and film oxygenator
1950-1955	Clarence Dennis University of Minnesota	Rotating disc oxygenator
1950-1955	Walter Lillehi University of Minnesota	"Controlled cross circulation" arose when Lillehi was discussing a colleague's wife's preganncy and realized that his she was the oxygenator for the fetus. First patient , a 1-year-old boy underwent a VSD closure but died due to pneumonia. Second 2 patients with VSDs did well. Lillehi credited with first successful VSD closure, repair of Tetrology of Fallot, and persistent common AV canal. 28/45 patients survived
1950-1955	John Kirklin Mayo Clinic	Heart lung machine based upon Gibbon work with a vertical oxygenator and roller pumps
1950's	William T. Mustard University of Toronto	Utilized a pair of rhesus monkey lungs as an oxygenator. First 7 patients died, many due to high-risk procedures
1955	Walt Lillehi Richard DeWall University of Minnesota	Bubble oxygenator developed
1955	John Kirklin Mayo Clinic	First use of the Mayo-Gibbon heart lung machine, 4/8 patients survived
1957	William Mustard	Reported experience with surgery on 21 infants with only 3 survivors in *Canadian Medical Association Journal*
1959	Charles Drew Westminster Hospital	Developed technique to cool body to 15^{o}C. Surgery could last as long as 60 minutes. Technique did not gain traction until the 1980's due to fears about neurologic injury

Table 2 Milestones in the Development of Mechanical Support

Year	**Milestone**
1810	Le Gallois proposes extracorporeal support
1920's	Charles Lindbergh expresses interest in cardiovascular support
1937	Demikhov implants the first "artificial heart" in a dog
1952	First external pacemaker
1953	First use of cardiopulmonary bypass
1954	American Society for Artificial Organs (ASAIO) conceived
1954	Cross circulation first used by Dr. Walt Lillehi
1959	First successful use of an internal cardiac pacemaker
1962	Dr. Clarence Dennis describes technique for removal of blood from the left atrium and return to the femoral artery via pump
1963	First successful implantation of a pneumatic ventricular assist device (VAD) by Dr. Michael DeBakey
1964	National Heart, Lung, and Blood Institute began to sponsor development of mechanical support devices
1966	First successful use on an LVAD as a successful bridge to recovery
1967	First heart transplantation by Dr. Christian Bernard
1968	First use of the intraaortic balloon pump (IABP) by Dr. Adrian Kantrowitz
1969	First implantation of an "artificial heart" by Dr. Denton Cooley
1970	Invention of first internal defibrillator
1971	Dr. Michael DeBakey published landmark article outlining challenges to development of heart support devices
1976	FDA begins regulating medical devices – Medical Device Amendment to the Food,

	Drug, and Cosmetic Act
1979	First percutaneous implantation of an IABP
1980's	Introduction of cyclosporine leads to resurgence of heart transplantation
1982	Dr. Barney Clark became first patient to receive a permanent implant of an artificial heart as a destination device (Jarvik-7)
1984	Thoratec ventricular support device developed as a bridge to transplantation
1984	Novacor VAD first implanted
1988	Dr. O.H. Frazier implants the first HeartMate device as a bridge to transplantation
1992	FDA approves the Abiomed BVS 5000 for short-term use
1994	FDA calls for heightening efforts at ventricular assist
2001	REMATCH trial demonstrates the benefit of mechanical support over medical treatment for patients with end-stage heart failure
2004	ASAIO celebrates 50th anniversary
2004	FDA approves the Cardiowest Total Artificial Heart as a Bridge to Transplant

References:

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