Cardiac surgery before cardiopulmonary bypass

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To completely cover a topic such as this and to do justice to all of the people who were involved in the evolution of cardiac surgery is virtually impossible. Many texts and papers have been written regarding the early days of cardiac surgery and one has to draw on the information derived from various specific publications to have a grasp of the overall picture. Many important contributions were made and reported in various countries and the publications may have been in many different languages. At the outset, I apologize for any omissions, but I hope to capture the essence of the time, which, for the most part, encompasses the first part of the twentieth century.

Milestones

This era was preceded by a few significant milestones, which laid the groundwork for the cautious approach to heart surgery (the first 40 years), followed by the veritable explosion of developments after which cardiac surgery would never be the same. These significant stepping stones were chosen purely arbitrarily by me because of the great impact they would have upon future developments.

Milestone #1

In the period from 1768 to 1772, William Heberden published his thoughts regarding the clinical picture of angina pectoris, which he described in such accurate detail that it remains the classic model of the manifestations of angina that we still use today.1

Milestone #2

One of the earliest attempts at the development of a device for artificial oxygenation and circulation was that of von Frey and Gruber.2 Fifty-five years would pass before the first successful use of such a method.

Milestone #3

Prior to 1896, several reports were published regarding a direct approach to the heart, almost all of which involved treatment of a traumatic injury to the heart, usually a stab wound. Dalton3 and Williams4 reported successful suture of traumatic lacerations but these involved only injuries to the pericardium. Cappelen5 and Farina6 directly sutured myocardial lacerations but both of the patients reportedly died. On 7 September 1896, in Frankfurt, Germany, Ludwig Rehn (much to the dismay of his Chief and many of his colleagues) took the bold step of closing a right ventricular stab wound laceration using three silk sutures.7 Not only did he successfully save the patient’s life, but he laid to rest the oft-touted axiom that the heart was an inviolable organ. It is of interest to note that several years later, at a surgical meeting when Rehn was to report on other cases that he had performed regarding a direct surgical approach to the myocardium, he was placed last on the program and almost no one was left in the audience. He lost interest in pursuing this any further after that time. Incidentally, the first American surgeon to successfully repair a laceration of the heart was Luther Hill of Montgomery, Alabama, in 1902.8

Significant happenings

Although many events occurred at the beginning of the last century, five are worth noting because of the roles they would play in the future of cardiac surgery.

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1) In 1901, Landsteiner developed a method of **blood typing**, which later led to cross-matching for safer use of transfusions so vital to the early days of cardiac surgery.\(^9\) Sergei Yudin first used cadaver blood for transfusion in man on 23 March 1930.\(^10\) Although it was used for the first time in Russia, the risk of transmission of infectious disease made it unacceptable for widespread use.

2) The discovery of the anticoagulant effect of **heparin** (originally called antithrombin) by Jay McLean in 1915 was a true landmark event.\(^11\) It was later purified and improved by Charles Best and coworkers in Toronto in the 1930s.\(^12\) Without heparin or some other effective anticoagulant, cardiac surgery, as we know it today, would not have been possible.

3) **Antibiotics** were developed in the early part of the twentieth century as a spin off from the aniline dye industry (sulfa drugs). In 1929, Sir Alexander Fleming announced the discovery of penicillin.\(^13\) Fortunately, over time, multiple generations of more effective antibiotics have appeared on the scene to combat the changing flora that might cause infections, which can be catastrophic in cardiac surgery.

4) **Anesthesia** and **monitoring** have kept pace with the growth of heart surgery, starting with Sauerbruch and his closed chamber technique for intrathoracic surgery.\(^14\) Since that time, the field of anesthesiology has blossomed to the point where no longer does the surgeon/operator need to have concern for the anesthesia/monitoring management of the cardiac surgery patient. Although the perfusionist is intimately involved with the interactions of all components of the operating team, this area, of necessity, did not develop until after the time of John Gibbon.

5) Another significant happening has been the involvement of **industry** and **biomedical engineering** in the field of cardiothoracic surgery. Improved communication between these groups and surgeons/physiologists/researchers has increased the rate and improved the quality of instruments, devices, and complementary equipment.

### Landmark events

**Carrel**

Shortly after the start of the last century, Alexis Carrel moved from France to the USA. Because of a dispute between Carrel and his Chief concerning the authenticity of miracles at Lourdes, Carrel was dismissed from the Institute of Medicine in Paris and became associated with the Rockefeller Institute in New York City, where his contributions to cardiothoracic and vascular surgery and investigations into physiology were legion.\(^15\) These contributions included the development of a triangulation technique for blood vessel anastomosis, experimental coronary artery bypass, and heart-lung transplantation.

**Coronary disease**

In 1912, James B Herrick published in the *Journal of the American Medical Association*\(^16\) his observations of the correlation of coronary thrombosis found at autopsy in five cases to the clinical picture of angina pectoris. This was the first firm evidence that angina was caused by occlusive coronary artery disease.

**Mitral stenosis**

Early proposed surgical approaches for the relief of mitral stenosis were suggested by Lauriston Shaw,\(^17\) Daniel Samways,\(^18\) and Sir Lauder Brunton.\(^19\) This last report suggested the use of a lady’s hatpin to be inserted along the finger to enlarge the mitral valve orifice sometimes through a transventricular, sometimes through a transatrial, approach.

The first successful surgical approach for the relief of mitral stenosis was performed by Elliott Cutler and his team at the Peter Bent Brigham Hospital in Boston on 20 May 1923.\(^20\) The patient was a 23-year-old girl with severe mitral stenosis and a tenotomy knife was inserted via the transventricular approach. Most likely, the surgery resulted in significant mitral regurgitation and, although the patient survived 4.5 years, her later course was fraught with increasing cardiac failure.

On 6 May 1925, at the London Hospital, Sir Henry Souttar performed a successful transatrial approach to the mitral valve on a 19-year-old girl.\(^21\) Although the lesion was predominantly mitral insufficiency, the patient survived and died as a result of a cerebral embolus five years later.

Nothing of note regarding mitral valve surgery occurred until the late 1940s, partially due to the impact of the second world war. Horace Smithy\(^22\) of Charleston, South Carolina, and Gordon Murray\(^23\) of Canada, both described clinical experience with approaches that used a valvulotome, actually excising portions of the stenotic valve leaflet (obviously creating variable degrees of mitral insufficiency). Although three of Smithy’s seven patients survived with clinical improvement, his further efforts were terminated by his early death at the age of 34 in late 1948 because of aortic stenosis.
Charles Bailey of Philadelphia had operative mortality with three consecutive attempts of closed mitral commissurotomy, resulting in the placement of his hospital surgical privileges at high risk. On 10 June 1948, he scheduled one patient for surgery in the morning at the Philadelphia General Hospital (the patient died on the operating table), and he and his team hurriedly drove to the Episcopal Hospital for a second case scheduled in the early afternoon. Fortunately for the future of mitral valve surgery, this operation was successful. Bailey had performed this surgery using a tenotomy knife to open the postero-lateral commissure, avoiding excision of any valve leaflet tissue. The operation required only 80 minutes and 10 days later the patient traveled by train to appear on the stage at the annual meeting of the American College of Chest Physicians in Chicago. Bailey’s surgical triumph pre-empted Dwight Harken of Boston by six days. However, because Harken was a close friend of the editor of the New England Journal of Medicine, his paper reporting a successful mitral operation was published first.

Throughout this brief era, it soon became apparent that splitting or incision of the commissures was essential to a successful mitral valve dilatation, not the removal of any valve leaflet tissue that had dominated the thinking of the previous two decades. Because of the enormous competitive egos of the key players and the drive to achieve notoriety in the field, much was made in an evangelistic sort of way for the individually favored approach, even down to the correct terminology—for example, valvotomy, valvuloplasty, neostrophingic mobilization (using classic Greek to describe ‘making a new hinge’). The development of the transventricular dilator (principally the Tubbs-Logan dilator developed by an engineer and an urologist) was a significant addition to the armamentarium and is still widely used for closed mitral commissurotomy even today in third world or underdeveloped countries.

**Early investigation of cardiopulmonary physiology**

In 1870, Adolph Fick of Wurzburg first described his approach to a method for determining cardiac output. Some 40 years later (circa 1912), Professor Unger in Germany passed a catheter through the arm vein of his colleague, Professor Bleichroeder. After the catheter had passed for some considerable distance, Bleichroeder developed sharp chest pain; however, the position of the catheter tip was never identified or confirmed by radiography. In 1929, in Eberswalde, Germany, Werner Forssmann passed a ureteral catheter through his own left basilic vein and confirmed the presence of the tip of the catheter in the right atrium by X-ray. This was the basis for future investigations into cardiopulmonary physiology and continuous monitoring.

**Patent ductus arteriosus (PDA)**

In Philadelphia, on 6 May 1907 (46 years to the day before John Gibbon’s first successful surgery using extracorporeal circulation), John Munro proposed surgical obliteration of a patent ductus to avoid the frequent sequelae of endocarditis. Similar approaches were advocated by Emile Holman and colleagues and Maude Abbot. On 6 March 1937, John Strieder of Boston successfully closed a patent ductus complicated by bacterial endocarditis. The ductus was too large for ligation and closure was accomplished by division and suture. Although the murmur disappeared, the patient died on the fourth postoperative day of acute gastric dilatation and at autopsy extensive bacterial vegetations were found on the pulmonic valve. One year later (August 1938), Robert Gross, at the Boston Children’s Hospital, performed the first successful ligation of a patent ductus on a seven-year-old girl. The patient was ambulatory by the third postoperative day.

**Coarctation of the aorta**

Clarence Crafoord’s first successful coarctation repair was performed at the Karolinska Institute in Stockholm, Sweden, on a 12-year-old boy on 19 October 1944. The procedure was accomplished by excision of the narrowed aortic segment and direct anastomosis of the aorta. His second successful case was performed 12 days later, also in Stockholm.

**Tetralogy of Fallot**

In the early 1940s, Dr Helen Taussig, at the Johns Hopkins Hospital, astutely observed that patients with pulmonic stenosis did not become cyanotic until the ductus arteriosus closed. This observation led to the first successful application of a Blalock-Taussig shunt (effectively creating the same dynamics as a PDA) on a critically ill, 15-month-old, cyanotic girl. Following initial improvement, the patient died six months later following a second shunt procedure. However, several successful operations were accomplished over the next few weeks and the procedure was firmly established as part of the cardiac surgical armamentarium.

**Myocardial revascularization**

In the early twentieth century, various operations remote from the heart were carried out in attempts to palliate the symptoms of angina pectoris. These
included sympathectomies and ganglionectomies to diminish chest pain and thyroidectomy to decrease metabolism, thus, ‘diminishing the demands on cardiac function’. As surgeons moved close to the heart itself, and during a frequently performed procedure of the time (pericardiectomy, 1934), Claude Beck noted brisk bleeding from both ends of a divided pericardial adhesion. This led to multiple approaches for the purpose of bringing in new blood to the myocardium via extracardiac collaterals. Sources of the extracardiac blood supply included use of adjacent lung, chest wall muscle, pericardial fat, and omentum. Because the epicardium was felt to be a barrier to the ingrowth of collaterals, removal of the epicardium (de-epicardization) was carried out using dental burrs and toothbrushes for mechanical removal and trichloroacetic acid and phenol for chemical removal. Many substances were introduced into the pericardial space alongside the denuded myocardium in hopes of stimulating, by irritation, new adhesions - such materials included asbestos, talc, Aleuronat, and even ground-up ox bone. Beck’s first case was a 48-year-old coal miner with severe and debilitating chest pain. The revascularization procedure was performed at Lakeside Hospital in Cleveland on 13 February 1935 and consisted of ‘rougthening the surface of the heart with a burr and attaching a left pectoralis muscle flap to the left ventricular wall’. Seven months later the patient was pain free and had returned to work. Many other investigators during this period were involved in this approach to myocardial revascularization, notably Dwight Harken of Boston and Lawrence O’Shaughnessy of London. O’Shaughnessy developed the technique of cardio-omentopexy and was killed in the evacuation of Dunkirk during the second world war. Soon thereafter, a semi-direct approach to revascularization was popularized by Arthur Vineberg of Montreal. In 1950, after numerous animal experiments, Vineberg placed a skeletonized internal mammary artery with freely bleeding side branches into a myocardial tunnel with the hope of the development of new collateral vessels past the point of obstruction in the coronary artery. Also, the new blood could have a runoff into the myocardium because of the syncytial nature of its structure. This procedure received wide public acceptance over the next several years and 15–20% of these patients actually had demonstrable, significant collateral connection to the coronary arteries as demonstrated later by arteriography.

Also of note during this period (1955) was the amazing contribution of Vladimir Demikhov of Russia who performed direct internal mammary to coronary anastomoses prior to coronary arteriography and without the use of heart-lung arteriography, determining the anastomotic site simply by palpation of a soft portion of coronary artery wall distal to the obstruction.

Atrial septal defect

The unfolding of events in the treatment of atrial septal defect (ASD) is a prelude to the next giant step of surgical correction of any lesion within the heart. Following the second world war, multiple approaches to close an ASD were discussed and many were tried clinically; these included invagination of the atrial wall, invagination of the right atrial appendage and suturing the tip to the wall of the left atrium, using an external button technique. On 15 April 1952, Gross and Watkins in Boston successfully employed the use of an atrial well for ASD closure, which was accomplished blindly, but directly, by placing the sutures in the defect wall by palpation.

Perhaps the most significant event to establish the direct suture of an ASD under direct vision was Bigelow’s studies of hypothermia, which began as an adjunctive measure for the treatment of frostbite in the second world war. This led to investigations that showed short (six minute) periods of tolerance to inflow occlusion under the condition of moderate hypothermia. This was reported to the American Surgical Association in 1950 and led to the first successful open-heart procedure by F John Lewis of Minneapolis on 2 September 1952, which was the closure of an ASD under hypothermia and inflow occlusion.

Heart valves

Because of the very location and anatomy of cardiac valves, no replacement was possible until the advent of extracorporeal circulation. However, Charles Hufnagel of Baltimore developed a very unique approach to the management of aortic insufficiency by inserting a methyl methacrylate, caged-ball prosthesis in the descending thoracic aorta. Its design permitted a quick insertion so that time-consuming suture technique was unnecessary. Although this valve was not in the subcoronary position, it did help alleviate some of the serious symptoms of aortic insufficiency. It had built-in disadvantages since it was very loud and could easily be heard anywhere in a quiet room, which was particularly distressing to a poker player who might have an excellent hand and everyone at the table could hear a rapid increase in heart rate.
Cross-circulation
On 20 April 1954, C Walton Lillehei and colleagues at the University of Minnesota performed the first successful closure of a ventricular septal defect using cross-circulation. A four-year-old boy was the patient and his father served as the heart-lung machine. Surprisingly, the only presurgical approval at the time was a terse note from the Department Chairman, Owen H Wangensteen, which simply said, ‘Walt, by all means, go ahead. OHW’. When this was later presented at a surgical congress, Willis Potts of Chicago was said to have commented, ‘This is the only operation that I know of that carries a potential mortality of 200 per cent.’ (Personal communication to the author by C Walton Lillehei, Minneapolis, MN, 18 October 1979.)

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Finale
This leads up to the time of the first use of a heart-lung machine by John Gibbon Jr. of Philadelphia on 6 May 1953 for the direct closure of an ASD on an 18-year-old girl. Since I started medical school in 1945, I have been most fortunate to have seen much of this drama played out and have known and/or worked with many of the star players on this stage. My gratitude goes out to the courageous pioneers who had the vision and persistence to see all of this through. My apologies to any of the many investigators and clinicians for having omitted mention of them in this treatise.
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