A History of Cardiac Surgery

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An Adventurous Voyage from Antiquity to the Artificial Heart

By

Ugo Filippo Tesler

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To my wife Cristina, my constant companion, support and source of wisdom, with gratitude and love

Le Coeur qui est domicile de l’ame, organe de la faculté vitale, principe de vie, fontaine & source de l’esprit vital & de le chaleur naturelle fluant, & pource premier vivàt & dernier mouràt, à cause qu’il devoit avoir mouvement de soy meme, est fait de chair grosse & dure, & plus solide qu’autre de tout le corps.

—Ambroise Paré

Les Ouvres d’Ambroise Paré, Conseiller et Premier Chirurgien du Roy.

Le Quatrieme Livre, Traictant de l’Anatomie lequel contient les parties vitales.

Chap XI. Du Coeur, p. 147

Quatriesme Edition, Chez Gabriel Brun, Paris 1585

(The Heart that is home of the soul, organ of the vital faculty, principle of life, fountain & source of the vital spirit & of the flow of natural heat, & the first to live & the last to die, because it must be able to move on its own, it is made of a harder & stronger substance than any other of the whole body.)

***

It is not in the nature of things for any one man to make a sudden violent discovery; science goes step by step, and every man depends on the work of his predecessors. and it is the mutual influence which makes the enormous possibility of scientific advance. Scientists are not dependent on the ideas of a single man, but on the combined wisdom of thousands of men, all thinking of the same problem, and each doing his little bit to add to the great structure of knowledge which is gradually being erected.

—Ernest Rutheford

Nobel laureate in Chemistry 1908

Concluding remark in 1936 Lecture on 'Forty Years of Physics'

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NOTES AND ACKNOWLEDGEMENTS

This book is an updated English language version of the book entitled Viaggio nel Cuore. Storia e Storie della Cardiochirurgia (A Voyage in the Heart: History and Stories of Cardiac Surgery) originally published in Italian in 2012 by the publisher UTET.

In this book I have endeavoured to recount the development and evolution of cardiac surgery from its beginnings to the present day, intertwining the rigorously documented scientific history with a narrative incorporating noteworthy events together with their protagonists.

Together with colleagues from the generation that entered the world of cardiothoracic surgery during the early 1960s, I shared the fortune and the privilege of living through the transition from closed to open-heart surgery. I witnessed the impetuous development of that specialty which, within a decade, brought about the introduction of many of the surgical procedures that are still adopted to this day.

During that remarkable season the advances that took place in the most diverse medical and technological fields induced a profound transformation of the approach to cardiac surgery. This gradually evolved from an individual endeavour into a scientifically supported multidisciplinary effort that led to the development of procedures, which brought about the successful treatment of hitherto incurable diseases affecting the heart and the great vessels.

There is another notable consequence of the introduction of an effective surgical therapy of heart diseases where results are significantly dependent on a precise diagnosis. The definition of the latter was no longer a hypothesis whose accuracy could only be confirmed at the anatomical dissecting table. Instead, the accurate cardiological evaluation of heart diseases became an integral part of the therapeutic process bearing its share of responsibility for the surgical outcomes. The awareness of this necessity has fostered the development of increasingly advanced diagnostic tools. This allows the attainment of ever more accurate diagnosis of diseases of the heart and the great vessels, thus significantly contributing to improvement in the surgical results.

I have deliberately excluded descriptions of technical details associated with surgical procedures from the book, especially those relating to the repair of congenital heart diseases, as I felt that they addressed problems too excessively specialized to be of general interest. I chose instead to recount the multifaceted, and at times even dramatic, circumstances concerning the development and the adoption of these procedures. Many of the events that are mentioned I have either personally witnessed or had been recounted to me by the protagonists themselves.

Information found in these chapters regarding the evolving aspects of cardiac surgery stems from both existing published material and from lectures delivered at the cardiac surgery courses which I have been organizing at regular intervals since 1983 at the Ettore Majorana Foundation and Centre for Scientific Culture, an internationally noted institution set in the ancient Sicilian town of Erice. I am grateful to the many distinguished colleagues who, over the years, have participated in these courses and given lectures. These included John Kirklin, Francis Fontan, Hans Borst, Gerard Brom, Alain Carpentier, Jaroslav Stark, Robert Anderson, Robert Frater, Magdi Yacoub, Ottavio Alfieri, Gerald Lemole, Vincent Dor, Arrigo Lessana, Stephen Westaby, Manuel Antunes, José Pomar, O. H. Frazier, Lorenzo Menicanti, Marko Turina, Jean Bachet, John Pepper, Gaetano Thiene, Andrew Wechsler, Francis Wells, Gilles Dreyfus, Joseph Coselli, Jane Somerville, Ross Reul, Gianni Angelini, Gino Gerosa, Pascal Vouhe, Peter Sleight, Giuseppe Specchia, Pieter Kappetein, Paul Sergeant, Martin Czerny, Francesco Musumeci, Romuald Cichon, Ruggero De Paulis, Toufic Khouri, Giuseppe Mancia and many others.

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A work of synthesis devoted to such extensively explored territory as the development of the surgery of the heart and of the great vessels incurs huge debts. The references constitute a detailed bibliography indicating the specialized literature on which the scientific aspects of this book are based. Besides the countless strictly scientific sources that have been utilized, mention must be made of books describing both the personal and the general history of the development of cardiac surgery.

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Acierno, Louis. *The History of Cardiology*. New York, NY: The Parthenon Publishing Group, 1994.

English, Terence. *Follow Your Star: From Mining to Heart Transplants – A surgeon's Story.* Milton Keynes, UK: Authorhouse, 2011.

Cooley, Denton A. *100,000 Hearts – A Surgeon's Memoir*. Austin, TX: Dolph Briscoe Center for American History, 2012.

Moreover, I wish to indicate a series of excellent books from which I have gathered a wealth of valuable information that has been especially important for the realization of this work. These books are listed according to the date of publication.

Barnard, Christian and Pepper, Curtis Bill. *One Life*. 3rd ed. New York, NY: Macmillan, 1970.

Thomson, Thomas. *Hearts; Of Surgeons and Transplants, Miracles and Disasters Along the Cardiac Frontier.* New York, NY: McCall, 1971.

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FOREWORD

In April 1960, the English surgeon Sir Russell Brock gave his inaugural speech to a conference held in Philadelphia. He observed that the technical and scientific progress in cardiac surgery was developing with a rapidity that he himself was struggling to comprehend, while being one of the protagonists of this course of events. He resorted to an allegory to illustrate how the scientific community was experiencing the impetuous development of this specialty. (Fig. F-1)

Sir Russell Brock narrated that Francis Drake, after crossing the Atlantic Ocean in 1573, had dropped anchor in a quiet bay near the Isthmus of Panama. During the stay, he went inland until he reached the top of a hill. From that vantage point, over the extent of hills covered by tropical forest, he saw in the distance the bright mirror of a boundless sea: it was the Pacific Ocean. "I pray God" said Drake, "to give me life and leave to sail once on an English ship upon that sea". His prayer was answered: five years later in September 1578, after passing the Strait of Magellan, Drake entered the stormy waters of the Pacific Ocean. Then, skirting the west coast of the American continent, having attacked and plundered the Spanish colonies settled there, he began the crossing of the Pacific Ocean. He reached Indonesia, crossed the Indian Ocean and sailed back into the Atlantic Ocean, rounding the Cape of Good Hope. On 26 September 1580 he triumphantly entered the port of Plymouth with the rich booty taken from the Spaniards, having circumnavigated the globe in nearly three years of sailing. Francis Drake and the surviving sailors were showered with honours and glory but, emphasized Brock, the price paid was very high: together, they had faced stormy seas, sickness, betrayal, mutinies and battles. Of the five ships that had left on 13 December 1577 from Plymouth, only one returned. Of their comrades, two-thirds had perished during the voyage.

Sir Russell Brock's choice in 1960 to compare the development of cardiac surgery to the exciting and dramatic adventures of Sir Francis Drake and his sailors was both revealing and prophetic. Revealing, because it attested that the surgeons of his generation felt like explorers of worlds that were fascinating, mysterious and just as full of perils. Barely a few years before, they had moved from performing surgical procedures which consisted of extra-cardiac palliative interventions and blind "closed-heart" operations to a surgery that, following the adoption of extracorporeal circulation in 1953, allowed the accomplishment of "open-heart" procedures under direct vision within the bloodless heart chambers. This progress had taken place through the work of pioneers, both daring and determined, who had not hesitated to continue their clinical trials even in the face of results burdened with a mortality rate that the medical community judged prohibitive until they achieved techniques that allowed an acceptable rate of their patients' survival. Prophetic, because the aspiration for surgeons, like for Drake to sail one day on the ocean that he had only glimpsed from afar, was to be attained within the next decade. During this time, the vast majority of the cardiac surgical procedures that are still widely adopted were devised and applied clinically.

Together with colleagues from the generation which began to be involved with cardiac surgery during the early 1960s, I shared the fortune and the privilege to have witnessed the introduction of many new procedures: among these, the correction of complex congenital heart diseases, the implantation of the first prosthetic heart valves, the first coronary artery bypasses, the repair of the complications of myocardial infarction, the surgery of the aortic arch, the first heart transplants and the implantation of the very first artificial heart. Reality is inevitably more complex and less seductive than an allegory. The history of the development of heart surgery is no exception to this rule. However, having participated in experiences so innovative and daring which could give the feeling of discovering new continents, has undoubtedly produced in our generation of surgeons emotions comparable to those that Sir Russell Brock had attributed to Francis Drake and his fellow adventurers.

Most of the leading figures of those events have now passed away and the interventions that had aroused so much interest in the scientific community and such a bewildered clamour among the general public, are nowadays commonly performed in many hospitals around the world without attracting particular attention. The principal object of this book is to narrate the fascinating and even dramatic events that came about during that extraordinary season that led to the development and the adoption of heart surgery, by weaving together the rigorously documented scientific history with a first-hand account of some of these events along with their protagonists.

Fig. F-1 Sir Russell Brock, right, and Charles Bailey in Philadelphia in April 1960

Chapter One

The bases, the beginnings and the evolution of Cardiac Surgery

The repair of heart wounds

In the afternoon of Monday 7 September 1896 in Frankfurt am Main, Wilhelm Justus, a 22-year-old gardener, was involved in a brawl and was stabbed in the chest. He was brought to the municipal hospital and immediately admitted to the Department of Surgery. The Head of the Department, Professor Ludwig Rehn, was out of town and the young man was placed under the care of his senior associate, Dr Siegel. Wilhelm's condition was good at the time of admission but with the passing of the hours it began to deteriorate: his breathing was becoming more laboured, the veins of his neck were gradually swelling, his face was turning cyanotic and his pulse was becoming progressively feebler.

As no other diagnostic method existed at the time the doctors had to rely solely on clinical examination to diagnose a heart wound. In November of the previous year, X-rays had been discovered by the physicist Wilhelm Conrad Roentgen. Roentgen immediately recognized their diagnostic potential, but it would take many more years before the adoption of radiological equipment in hospitals became a reality. At this time electrocardiographs were also an instrument of the future: electrocardiograph prototypes had been developed in the early years of the twentieth century, but at least another twenty years would have to pass before they would become sufficiently reliable to be adopted clinically.

When, two days later, Professor Rehn returned to town and went to the hospital, he was immediately informed of the patient's condition which appeared critical. In a desperate attempt to save his life, Rehn decided to operate on him (Fig. 1-1). It was not the first attempt to repair a heart wound: at least two historically documented interventions of this kind had already been performed. Just a year before, on 4 September 1895 at the hospital in Kristiania (today Oslo), the Norwegian surgeon Axel Coppelen had sutured a wound of the left ventricle in a 24-year-old man. Another case had been performed on 8 January 1896, by the surgeon Guido Farina who had sutured a stab wound in the heart of a 30-year-old man at Our Lady of Consolation Hospital in Rome (an ancient hospital founded in 1470 that was closed in the 1930s). Although both patients survived the surgery, they died a few days later from infective complications.

Ludwig Rehn started the intervention in the afternoon of 9 September 1896 assisted by Dr Siegel. He made an incision in the chest wall and exposed the pericardium, the membrane that surrounds the heart, which was tense and distended as it was filled with blood and clots. He incised the pericardial sac freeing blood and clots which poured out exposing the heart and revealing a tear about a centimetre and a half in length on its surface from which a jet of blood spurted with every heartbeat. With some difficulty due to the cardiac pulsation, Ludwig Rehn applied three silk sutures to the tear and the bleeding ceased. The chest incision was closed and the patient proceeded towards a complete recovery.[1]

The success of this intervention put an end to the widespread belief, espoused only a few months previously by the most renowned surgical academic authorities of the time, Stephen Paget in London and Theodor Billroth in Vienna, that nature had placed the heart beyond the reach of surgery. Billroth is attributed with the statement that “any surgeon who would attempt an operation on the heart should lose the respect of his colleagues”, while Paget, in his book *Surgery of the Chest* published in 1896, the same year as Rehn’s operation, had written that “Surgery of the heart has probably reached the limits set by Nature to all surgery: no new method and no new discovery can overcome the natural difficulties that attend a wound of the heart”.[2]

Rehn’s successful operation proved to be no accident: on the contrary, it reflected the general progress being achieved in surgery. This progress was confirmed by the many other cases of heart wounds which were successfully operated on in the years immediately following the first intervention. In fact, in subsequent years the repair of cardiac lesions rapidly increased, so much so that in 1907 Ludwig Rehn reported his experience of 124 cases of surgical repair of heart wounds with a survival rate of 40%.[3]

In those times these interventions were often performed in dramatic circumstances as can be illustrated by the story of the first case of a successful repair of a heart wound in the United States that took place in Montgomery, Alabama.[4] In the early hours of 15 September 1902, Dr Luther Hill was called urgently by two doctors who were trying to treat Henry Myrick, a 13-year-old boy who had been repeatedly stabbed in the chest the previous afternoon. Luther Hill hurried to Myrick’s house and when he arrived he noticed that the wound was still bleeding and that although he was still conscious, the boy's condition was rapidly worsening. Hill convinced the family to let him attempt an intervention. Having obtained their permission and assisted by the two colleagues who had summoned him he placed Henry on the kitchen table. One of the doctors administered the anaesthesia with chloroform and, under the light of an oil lamp, Hill opened Henry's chest cavity and incised the pericardium. The heart was exposed and a bleeding laceration appeared on its surface. Hill repaired the tear with a few stitches and the bleeding ceased. Luther Hill completed the operation by closing the boy's chest: the whole procedure had lasted 45 minutes. The boy survived and made a complete recovery within a few weeks. In adulthood, he left Montgomery and moved to Chicago. Ironically, in 1942, at the age of 53, Henry Myrick was involved in a brawl and was again stabbed in the chest with a knife that reached his heart. Unfortunately this time Henry Myrick's luck had run out and he died before reaching the hospital. The autopsy showed that the new wound was very close to the old one which was perfectly healed.

The beginning of modern surgery

During the second half of the nineteenth century, surgery developed to a great extent due to the introduction of two methods that were critical to its progress: anaesthesia and antisepsis.

Anaesthesia

Anaesthesia in surgery spread rapidly after the public demonstration of its effectiveness on 16 October 1846 at the Massachusetts General Hospital in Boston when William Green Morton, who had previously used the method in his dental surgery, induced general anaesthesia on a 20-year-old patient by having him inhale ether vapours. The surgeon, John Collins Warren, removed a congenital vascular malformation from the young man's neck. Once awake after surgery, the patient stated that he had never felt any pain. John Warren himself, who had performed the surgery with scepticism, turned to those present and said, "Gentlemen, this is no humbug".

Antisepsis

Antisepsis was adopted in surgery particularly due to the work of Joseph Lister (Fig. 1-2) who, when he was Professor of Surgery at the

University of Glasgow, learned about the research carried out in Paris by the chemist and biologist Louis Pasteur. Pasteur had shown that fermentation and putrefaction could take place by the action of microorganisms even in the absence of oxygen. This finding invalidated the widely held belief that infections were due to so-called miasma, a hypothetical poisonous vapour that was believed to be present in the air. Pasteur demonstrated that microorganisms could be eliminated by heat or by the action of chemical agents. Lister's experiments confirmed Pasteur's findings and he decided to apply those principles to fighting surgical infections.

After experimenting with various substances he chose carbolic acid, now generally known as phenol, a chemical agent that was used for cleaning sewers. Lister sprinkled a carbolic acid solution directly on wounds, on the dressings and on surgical instruments. Later he had carbolic acid sprayed in the air to purify the operating room environment. (Fig. 1-3) Finally, he urged surgeons to wash their hands and to sterilize their instruments before operating. With the adoption of these methods, infections of surgical wounds and mortality caused by post-operative infective complications markedly decreased. In 1867 Lister published the results of his technique in a series of articles in *The Lancet* in which he introduced the term antisepsis.

As it had happened some twenty years earlier to Ignaz Semmelweis in the University Hospital in Vienna who successfully introduced simple hygienic measures for defeating the life-threatening problem of puerperal fever, his methods were not initially appreciated and even ridiculed by the scientific community. However, in Lister's case the results were rapidly accepted and in a short period of time his methods of antisepsis had become universally adopted. In subsequent years, the validity of his approach was confirmed by the discoveries made in the field of bacteriology, especially thanks to the efforts of Robert Koch, who in 1905 was awarded the Nobel Prize for Physiology or Medicine. Joseph Lister moved from Edinburgh to King's College Hospital in London where his research activities and innovative techniques contributed to advances in many surgical fields. In 1885, he became President of the Royal College of Surgeons and in 1897 Queen Victoria made him a baron. He died on 12 February 1912.

Among the most passionate advocates of the antisepsis method advocated by Lister was the Swiss surgeon Theodor Kocher (Fig. 1-4) who introduced the antisepsis techniques at the University of Bern and later became an advocate of asepsis and its logical evolution, which facilitates the preventive elimination of germs in everything that may come into contact with the operating field. In the latter years of the nineteenth century the Baltic German surgeon Ernst von Bergmann introduced this technique at the University of Berlin using an autoclave, which permitted effective sterilization of surgical instruments by using high pressure steam at temperatures above 100°C.

Advances in surgery at the end of the nineteenth century

The introduction of anaesthesia and antisepsis in the second half of the nineteenth century quickly led to great progress in all fields of surgery. In that fertile period new instruments were invented and new procedures were introduced, many of which are still used today. A number of surgical schools were established which became renowned for their innovative techniques and the excellence of their results. These schools were generally identified by the name of the master surgeon who had founded and developed them. Belonging to these schools signified possessing a patent of professional nobility. As the students brought up through a school under the guidance of the great mentors gained increased responsibilities and eventually became heads of surgical departments in their own right, the illustration of the branching out of the various schools resembled the genealogical tree of aristocratic dynasties.

One of the most illustrious examples of these schools was the one founded and headed by Theodor Billroth (Fig. 1-5) of the University of Vienna, who conceived and applied surgical procedures that are still in use today. Among his disciples were the Italian Edoardo Bassini, the Polish-German Jan Mikulicz-Radecki, the Swiss Theodor Kocher, the Austrian Julius von Hochenegg, and the American William Halsted, all of whom went on to become master surgeons and heads of surgical schools that consolidated and expanded the cultural heritage of the Viennese school.[a] Among these, of particular importance was the school of surgery at the University of Bern in Switzerland headed by the aforementioned Emil Theodor Kocher, who was awarded the Nobel Prize for Medicine in 1909 for his studies on the physiology of the thyroid.

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[a] Theodor Billroth had an innate aptitude for music, which even enabled him to successfully perform as a violin and a cello soloist, as well as to lead a symphonic orchestra on certain occasions. He was a friend of Johannes Brahms, with whom he formed the core group of conservatives who opposed the musical innovations of Richard Wagner and Franz Liszt. Johannes Brahms dedicated the String Quartets 1 & 2 Op. 51 to him. It was his passion for music that, despite the precarious state of his health, led him to attend the first performance of Giuseppe Verdi's Otello at the La Scala opera house in Milan on 29 March 1887.

Of the many adherents to Billroth's surgical approach, special attention must be paid to William Halsted whose teachings and legacy profoundly shaped the American surgical world. It is interesting to note that his influence, through Henry Cushing and Alfred Blalock's teaching, stretched down through the years to reach Denton Cooley. Thus, all of us who have been his students are linked, albeit at a distance of centuries, to the surgical science and teachings of Theodor Billroth. In Britain Sir James Paget, who became President of the Royal College of Surgeons, was quite famous. His titles also included surgeon to Queen Victoria, Vice-Chancellor of the University of London and President of the International Congress of Medicine that was held in London in 1881 (Fig. 1-6). The 1800s also saw the establishment of professional surgical societies, among which were the Royal College of Surgeon, the American Surgical Society and the Italian Society of Surgery.

The bases of cardiac surgery

It is generally held that the intervention performed by Ludwig Rehn on 9 September 1896 heralded the beginning of cardiac surgery. However, many decades would pass before techniques allowing operations inside the heart chambers would be developed and heart surgery would become a well-established and reproducible activity.

Among the most significant and immediate problems, besides the absence of reliable diagnostic methods, was that surgeons had not yet mastered the technique of suturing blood vessels. Furthermore, blood transfusion did not exist and the problem of how to ensure open-chest ventilation of the lungs had not been solved. These problems were overcome in successive years with the gradual acquisition of innovations derived from the general progress that was taking place in several scientific and technical fields. Two of the main achievements in the early years of the twentieth century were the suture of blood vessels and the transfusion of blood, which were accomplished by two exceptionally gifted individuals, Alexis Carrel and Karl Landsteiner. Although very different in character and personality, they were united by a similar professional career path: both were born in Europe and initiated their research careers in European laboratories before moving to the United States and the Rockefeller Institute in New York, from where they would both be awarded the Nobel Prize.

Alexis Carrel and the suture of blood vessels

Alexis Carrel, to whom an entire chapter will be devoted due to the importance he bears in the development of cardiac surgery, began experimenting on the suture of vessels in 1894. He had been deeply moved by witnessing the inability of surgeons from his native Lyon to repair the laceration of the hepatic veins that French President Sadi Carnot had suffered when he was stabbed in the abdomen by the anarchist Sante Caserio.

During the following years, Alexis Carrel developed a technique for suturing blood vessels and, when he had mastered it, he used it in a series of organ transplantation experiments, and in surgery on the heart and vascular system. His approach pre-dated its eventual clinical application by over half a century.[5] His notable contributions were recognized when he was awarded the Nobel Prize in Physiology or Medicine in 1912. He worked for over thirty years at the Rockefeller Institute in New York, mainly studying in vitro cultures of tissues and entire organs, the latter with the collaboration of Charles Lindbergh. He retired from the Rockefeller Institute just before the beginning of the Second World War and returned to live in France. During the Second World War he undertook a challenging journey back to New York and, using his influence and connections, managed to set up various humanitarian aid programmes for the people of Britain and France, including the "Blood for Britain" project, which will be described in the following pages. Unfortunately, his subsequent activities as director of the French Institute for the Study of Human Problems, set up at his proposal by the Vichy government, after the liberation of France led to grave accusations of collaborationism. These charges deeply humiliated him and, after suffering a heart attack, he died in Paris in November 1944.

A brief history of blood transfusion

In the early years of the 1900s the Viennese pathologist Karl Landsteiner (Fig. 1-7) identified blood groups A, B, AB and O. He ascertained that these blood types were genetically transmitted and solved the mystery that had plagued generations of doctors who wondered why attempts to transfuse blood from one human being to another caused, in the great majority of cases, haematuria, jaundice, shock and even death.

Landsteiner's discovery clarified the immunological mechanism underlying these reactions and made blood transfusions possible.[6] Reuben Ottenberg was the first to carry out the clinical application of blood transfusion based on Landsteiner's work at Mount Sinai Hospital in New York in 1907. Later on, it was demonstrated that the blood of individuals belonging to group O could be transfused without harm to individuals belonging to all blood groups. This discovery proved to be of great importance in the following years and was instrumental in establishing the first blood banks. For these fundamental achievements Karl Landsteiner was awarded the Nobel Prize in Medicine in 1930.

One of the difficulties initially encountered in performing transfusions was the fact that blood drawn from the donor coagulated immediately before it could be transfused into the recipient. Various methods were developed to overcome this difficulty. These were all based on direct transfusion between donor and recipient, either by surgically joining a donor's artery to a recipient's vein or by using devices designed in such a way as to allow the drawing and infusion of blood from donor to recipient without it coming into contact with air, thus avoiding the formation of clots. A major advance was made in 1914 when the Belgian doctor Albert Hustin successfully transfused stored blood in which coagulation was inhibited by the addition of small amounts of sodium citrate.[7] A few months later two other researchers, Luis Agote of Buenos Aires and Richard Lewisohn at Mount Sinai Hospital in New York, independently reported the positive results of their clinical experiments in which they had adopted techniques similar to Albert Hustin's.[8,9]

All these initial experiments used stored blood that was transfused as quickly as possible as it did not remain viable for longer than a few hours with the techniques available at the time. Later, thanks to research by Peyton Rous and J. R. Turner of the Rockefeller Institute who developed a solution in which glucose was added to the sodium citrate, blood could be stored and maintained viable for weeks.[10] Oswald Robertson who, at the time, was a medical officer in the US Army, developed the first large-scale application of transfusion in France during the First World War employing blood stored using Rous and Turner's technique.[11] It was in those circumstances that Robertson established the first blood bank in the world, drawing blood from donors belonging to the universal group O and then refrigerating it in a solution of glucose and sodium citrate. Over the following decades, blood studies continued, ABO typing technique for donor selection was universally adopted, and the need to organize transfusion services to meet the needs of the population became evident. Blood banks were established in many countries, including the Soviet Union, the United States and Britain while the first associations of volunteer donors were founded in Britain in 1922 and in Italy in 1927.[b]

[b] Oswald Hope Robertson grew up in California and, at a young age, aspired to

In 1923, Karl Landsteiner immigrated to the United States having accepted an offer to work at the Rockefeller Institute in New York. In this institution, in addition to a series of important discoveries in various scientific fields including poliomyelitis, syphilis and rickettsial infections, he continued his research into blood groups. He perfected the work he had begun twenty years earlier by identifying numerous other antigens, though most of these proved to be of minor clinical importance. However, in spite of strict adherence to the principles of the ABO system compatibility, in a number of cases during transfusions inexplicable reactions still occurred, Landsteiner devoted himself to the study of these phenomena. In collaboration with Alexander Wiener, he found the solution in 1937 with the discovery of a new antigen in the red cells of the rhesus macaque monkey and in about 85% of human beings. They called this antigen the rhesus (Rh) factor. The study of clinical cases conducted over the following years led to the conclusion that the vast majority of negative transfusion reactions in individuals who had undergone transfusion with compatible blood according to the ABO system, were caused by this antigen.[12] and transfusions had to take this factor into account. Karl Landsteiner retired in December 1939; he was appointed Professor Emeritus of the Rockefeller Institute and continued to work in his laboratory where, on 24 June 1943, he suffered a myocardial infarction which two days later led to his death.

Meanwhile, the practical application of his discoveries continued to be used at an ever-increasing rate. During the Spanish Civil War efficient blood banks were established in 1936 in Barcelona[13] and Madrid.[14] These experiences proved indispensable in setting up properly organized systems for securing the blood needed to treat the wounded soldiers and civilians

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become a naturalist. He graduated in medicine from Harvard University and dedicated himself to research in pathology. During the First World War he enlisted in the Harvard Medical Unit, under the guidance of Harvey Cushing, the father of neurosurgery. At the end of the conflict he accepted an offer to move to Beijing as Professor of Medicine at Beijing Union Medical College, a university that still exists. It was founded in 1906 under the supervision of American universities and oriented towards Western medical practices. Robertson spent eight years in Beijing, with great professional success and a lot of personal satisfaction. Returning to the United States, he became Professor of Medicine at the University of Chicago, where he was mainly interested in infectious lung diseases. In 1942 the United States Surgeon General appointed him Director of the Commission on Cross Infections in Hospitals of the US Army. In 1950 he retired and returned to California where he could finally devote himself to natural sciences. Stanford University elected him to the Faculty of Zoology. He made important contributions to salmon and trout pathology, working until his death in 1966.

in Britain and France during the Second World War. An important initiative was established in New York hospitals thanks to the influence of Alexis Carrel who, in 1940, returned to the United States where he promoted the "Blood for Britain" project through which blood plasma collected in New York hospitals would be sent to Britain by air for transfusion in wounded soldiers and civilians.[15] The experience gained during the implementation of this programme greatly assisted in the organization of the Army Transfusion Service when, in December of the following year, the United States also entered the war.

In more recent times, progress in the field of blood transfusion has focused on two main aspects: the use of individual blood components rather than whole blood, and the improvement of transfusion safety standards through the introduction of donor screening to identify markers for numerous diseases including HIV, hepatitis B and hepatitis C infections. While the transfusion of whole blood is still used to replace blood loss following traumatic lesions, in recent years progress in the field of transfusion has led to the use of its individual components separated by centrifugation including platelets, red blood cells, white blood cells and coagulation factors. Of particular importance is the administration of immunoglobulins which are used to prevent certain infectious diseases such as tetanus and hepatitis B, but also to protect individuals who have depressed immunologic reactivity against infection. Transfusing only the necessary product to each patient in order to treat a specific disease has the advantage of allowing more effective treatment by providing blood components in concentrated form and in greater quantities.

A brief history of thoracic anaesthesia

Despite the great progress that had been made in many fields of surgery at the beginning of the twentieth century, there was still one area of the body beyond the reach of surgeons. This was the chest; access was denied as the opening of the pleura caused the lungs to collapse, resulting in hypoxia and the patient's death.

In 1904, Ferdinand Sauerbruch (Fig. 1-8), a former student of Johannes von Mikulicz-Radecki, introduced a technique designed to overcome this problem that he termed "negative pressure" ventilation. With this technique the lungs were kept expanded by placing the patient's body within a negative pressure chamber. The patient's head remained outside the chamber allowing them to breathe in a normal air environment at atmospheric pressure. Sauerbruch built entire operating rooms based on this principle that were large enough to accommodate the surgical team.

In 1908 Sauerbruch, who by then had become the most authoritative exponent of thoracic surgery in Europe, participated in the Congress of the American Medical Association where he presented a duplicate of his negative pressure chamber, which he had brought with him from Berlin. At the end of the congress he did not take the bulky equipment back to Germany; instead, he left it in New York where it was assembled in the German Hospital. This hospital was founded in 1857 by wealthy German immigrants and was situated in the area of Manhattan known as Little Germany, populated by a large German community. During the First World War the name of the hospital was changed to Lenox Hill Hospital. Many years later it was in this hospital, which stands in the heart of the city of New York, that the first cardiac catheterization and subsequently the first coronary angioplasty were performed in the United States.

The Chief of Thoracic Surgery at the German Hospital to whom Sauerbruch had entrusted his equipment was Willy Meyer. Meyer was born in Germany and had graduated in medicine from the University of Bonn before immigrating to the United States in 1884. Within two years he started working at the German Hospital where he began to take an interest in thoracic surgery and was a proponent of Sauerbruch's technique. After receiving Sauerbruch's chamber, in collaboration with his brother Julius who was an engineer, Meyer spent the following years perfecting it. They designed a device, which was called the "universal chamber". This equipment, in addition to functioning like Sauerbruch's "negative pressure chamber" was designed to keep patients' lungs inflated at positive pressure by placing their head inside a box in which the pressure was maintained at a level higher than atmospheric pressure, while the surgical team was standing in the external environment at normal atmospheric pressure. In subsequent years Willy Meyer used this apparatus to perform numerous thoracic surgical procedures.

Meanwhile, other methods to permit open-chest lung ventilation were explored. One notable approach was that of the French surgeon Théodore Tuffier (Fig. 1-9) who in 1891 began experimenting with an open-chest method using a cannula inserted into the patient's trachea to apply positive pressure ventilation in the lungs. At the Rockefeller Institute in New York, after extensive animal testing, Samuel Meltzer and his son-in-law John Auer published the results of a technique using positive pressure endotracheal insufflation in 1909. Their technique was first used clinically the following year by the surgeon Charles A. Elsberg at Mount Sinai Hospital in New York.[16] Adoption of this technique was fostered by the development of the laryngoscope, especially through the work of Chevalier Jackson of Philadelphia, the founder of modern laryngology which, by allowing direct observation of the larynx, facilitated and reduced the risks of tracheal intubation. In a short time, anaesthesia with endotracheal intubation spread widely and by the 1920s and 1930s had already become a commonly adopted practice. Willy Meyer soon recognized the superiority of the positive pressure ventilation technique with tracheal intubation compared to the complex Sauerbruch's technique. The bulky "universal chamber" that had required so much effort in its development was demolished and sold as scrap metal.

Cardiac catheterization

In narrating the development of cardiac surgery advances that were being achieved in other fields in the meantime, and that would become determinant in its evolution, cannot be ignored. The period between the two wars saw the introduction, development and diffusion of fundamental diagnostic techniques, such as electrocardiography and radiology. Among the latter, the introduction of cardiac catheterization was of special importance.

In 1929, Werner Forssmann, a young surgical assistant at the hospital in Eberswalde, a town near Berlin, performed an experiment on himself trying to develop a technique that would allow the injection of drugs directly into the heart cavities. (Fig. 1-10) This experiment had enormous consequences: besides introducing an essential diagnostic tool, it produced a wealth of fundamental scientific knowledge, which included the elucidation of both the normal physiology of the heart as well as the pathophysiology of heart diseases. With the help of a nurse who was holding a mirror, Forssmann inserted a thin catheter into a vein in his arm and threaded it up until its tip reached the heart. He then walked down into the basement to the radiology laboratory and had an X-ray taken of his chest that showed that the tip of the catheter was positioned within the heart chambers. (Fig.1-11) With remarkable foresight, Forssmann published a paper in which he argued that in addition to describing the cardiac catheterization technique, this procedure would permit measurement of the pressures in the various heart chambers and, by means of the injection of radiopaque substances, would make it possible to see the internal morphology of the heart.[17]

His initiative did not meet a favourable response; indeed, his self-experimentation was severely criticized in academic circles. Professor Ferdinand Sauerbruch refused to appoint him to a post in the University Hospital, asserting that he was the Director of the Surgical Department of the University of Berlin, not a circus ringmaster, thus forever bringing to a close Forssmann's academic career. Forssmann left the university, devoted himself to urology and in the following years worked in hospitals in Dresden and Berlin. At the beginning of the Second World War, Forssmann was drafted into the German Army as a surgeon. In 1944 he was taken prisoner by the Allies and interned in a prison camp. After being released in 1945, he worked for several years as a general practitioner and later as a urologist in small provincial hospitals.

Meanwhile, his experiences had not been completely ignored and by the beginning of the 1930s, in Lisbon, Paris and Buenos Aires, some researchers had already obtained radiological visualization of the pulmonary artery through the injection of contrast medium through a catheter placed in the right atrium. In Prague, with a methodology still used today, the cardiac output – or the amount of blood ejected from the heart per unit time – was measured. The most important studies derived from his experiences were those done by André Cournand and Dickinson Richards who, from the early 1940s to the mid-1960s at Bellevue Hospital, an affiliated hospital of New York University, conducted fundamental research on the heart's physiology and pulmonary circulation. In 1956, they were awarded the Nobel Prize in Physiology or Medicine for these studies.

When André Cournand learned of being awarded the prize, he immediately phoned Stockholm and informed the Nobel Committee of the Royal Swedish Academy of Sciences that when he started using cardiac catheterization in 1940, he had simply adapted the procedure from experiments already published by a German doctor, a certain Werner Forssmann. He urged the committee to investigate if this person had survived the war and declared that if they managed to find him, he would accept the Nobel Prize on condition that it was also awarded to him. The committee found Werner Forssmann at the hospital in the small town of Bad Kreuznach in Rhineland-Palatinate, where he worked as a urologist. He had abandoned his research on cardiac catheterization 26 years before and the news of the Nobel came as a bolt out of the blue. He stated that he felt like a country priest who had suddenly been appointed bishop.[18]

Following the award of the Nobel Prize Werner Forssmann, who had been completely forgotten for many years, was appointed chief of surgery of the Evangelical Hospital in Dusseldorf and honorary professor of many universities. He became a member of the steering committee of the German Society of Surgery as well as an honorary member of many international professional societies. Forssmann's story is similar to that of other protagonists in the pioneering history of cardiac surgery, those individuals who proposed innovative procedures that were ignored at the time of their conception only to be rediscovered and utilized decades later. Like them, it may affirm that Werner Forssmann was just too far ahead of his time.

Paediatric cardiology. Maude Abbott and Helen Taussig

At this stage, studies of the anatomical features of congenital heart diseases were crucial. Correlating these studies with the physiopathological characteristics and clinical signs and symptoms of the diseases, made it possible to identify and classify the various congenital anomalies. Further, by clarifying many aspects of the physiopathology of these anomalies they provided the scientific bases for their surgical correction. Research into congenital heart diseases and the inception of paediatric cardiology by two great scientists was fundamentally important in the evolution of cardiology. These two pioneers were the Canadian Maude Abbott and the American Helen Taussig.

Maude Elizabeth Seymour Abbott (Fig. 1-12) was born in a town in Quebec in 1869. Despite the fact that she had shown herself to be a student of exceptional talent she was denied admission to the Faculty of Medicine at McGill University in Montreal because, at that time, women were barred from admission to that university's Faculty of Medicine. She was instead admitted to Bishop's College of Medicine in Sherbrooke, which was also in Canada, where she graduated with full honours in 1894. Soon her interest focused on the study of the pathologic anatomy of congenital heart diseases. Her enthusiasm and competence were noticed and well received by the Medical Faculty of McGill University. Within a short time, she was appointed curator of the Museum of Pathological Anatomy at the university. It is ironic that the same university that had refused to admit her in 1890, would award her an Honoris Causa doctorate in 1910.

Over the years, Maude Abbott studied hundreds of hearts, analyzing and classifying the morphology of congenital malformations. Her work was esteemed by Sir William Osler, (Fig. 1-13) the great clinician generally considered the father of modern medicine, who in 1905 entrusted her to write the chapter on congenital heart diseases to be included in his fundamental treatise: *A System of Modern Medicine*. This chapter, that was based on the analysis of 412 cases, formed the basis of the systematic work that Maude Abbott was to pursue over the following decades and that culminated in 1936 with the publication of her monumental *Atlas of Congenital Heart Diseases*.[19] In this treatise, that was founded on the analysis that she had personally performed on over 1,000