

MODERN TRENDS IN CARDIAC SURGERY

Edited by H. R. S. HARLEY



BUTTERWORTHS MODERN TRENDS SERIES

MODERN TRENDS
IN
CARDIAC SURGERY,

Edited by

H. R. S. HARLEY

M.S., F.R.C.S.

**CONSULTANT THORACIC SURGEON
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INTRODUCTION

THIS VOLUME in which all the contributors are British, was produced because it was felt that the time was propitious for an expression of British thought and practice in cardiac surgery.

The subject titles were selected by the editor, but the views expressed are those of the various contributors. The book consists of a series of chapters which should be read separately, for they represent the personal opinions of the several writers, and their placing bears no relationship to their importance.

The subject matter has been chosen to cover aspects of current interest, and to point the way to the future. Full weight has been given to new techniques such as hypothermia, deep hypothermia, and extracorporeal circulation. The volume is not a text book, and it makes no attempt to discuss the whole field of the surgery of the heart and great vessels. Such would be impossible in a book of this size, and would not be appropriate to the title of *Modern Trends*. Such subjects as the surgery of the pericardium, of coronary heart disease, and of injuries of the heart and great vessels, although of interest and importance, have had to be omitted. A chapter on history has been included for two reasons; first, because advances in the surgery of the heart and great vessels have been so rapid and so dramatic in the last few decades that they seem worthy of recording; and secondly, because this is the first book on the subject that has been published in Britain. As a complement to the chapter on history, which starts this book, there is a final one on the future of cardiovascular surgery. The editor hopes that both these chapters will be enjoyed.

It is hoped that the consultant, the trainee, and the general practitioner, will all find the account of current practice and future possibilities in the pages of this book presented in such a way as to stimulate his interest and further his knowledge. Views and techniques are advancing with such rapidity that many of the opinions put forward in these pages may require modification in the light of further experience and future advances.

The editor takes great pleasure in expressing his thanks to Sir Clement Price Thomas for graciously writing the Foreword, to all the contributors for the time, thought and trouble they have taken, to Miss P. Morse for her invaluable secretarial help, to Mr. Ralph Marshall and Mrs. June Jones for illustrations, and to the members of the Medical Department of Messrs. Butterworth's for their expert and kindly advice and assistance.

Cardiff
April, 1960

H. R. S. HARLEY

FOREWORD

NOTHING is truer than that the innovation of today becomes the commonplace of tomorrow.

To those of us who have, to a very large extent, occupied the place of onlookers in the development of cardiac surgery during the last twelve years, a new process of thought seems to have arisen, and, in fact, almost a new language, one which mainly resolves itself into linked groups of capital letters, yet to the young surgeons and physicians employed in this field these are but the commonplace implements of their daily task.

It is for this reason that we should be grateful to the editor and the contributors to this book. Called *Modern Trends in Cardiac Surgery*, it starts with near fundamentals and then takes the reader through the intricate paths of specific pathology. As pointed out in the introduction, the progress in this field has been so rapid that, unless one is immersed in this subject daily, it is almost impossible to keep fully abreast of the times.

This book will be of interest to all those who are actively engaged in this work, for the Editor has drawn together a team of contributors representative of surgical and medical thought in all parts of the country, and people who are specifically interested in the problems they treat. This is the first book on this subject to be produced in Great Britain and will certainly satisfy a long-felt want in the members of the medical public at large, who are anxious to share the up-to-date knowledge in this field. Without doubt, it also will be invaluable to the young man, be he physician or surgeon, who considers embarking on a career in this fascinating sphere of study.

Unquestionably there will be further advances in our knowledge, and in the not too distant future, and who is to set a limit to it? Although many of the conditions, which are today amenable only to surgery, will doubtless come in the future into the realm of preventive medicine, without doubt there will still be problems to be solved.

In the immediate future, one feels assured that there will be considerable interest in such problems as the regurgitant valve and the inadequate coronary blood supply, and that this interest will be followed to a successful conclusion.

Finally, I should like to congratulate the editor, the contributors and the publishers for making available such a book at such an appropriate time in the development of Cardiac Surgery.

London
April, 1960

CLEMENT PRICE THOMAS

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CHAPTER 1

HISTORICAL INTRODUCTION

ROBERT G. RICHARDSON

HISTORY is the record of fact, and the facts in the operative story of the heart are dramatic enough without embellishment; yet a breath of philosophy brings substance and perspective. Intrathoracic surgery was retarded for many years by a failure to appreciate the benefits of endotracheal anaesthesia and this despite the work of men such as Tuffier in France, Milton from Cairo, and Matas in New Orleans in the closing years of the nineteenth century. The negative pressure cabinet, introduced a few years later by Ferdinand Sauerbruch whose influence was keenly felt, and the uncertain views about the open pneumothorax did little to improve the situation. But over all the climate of contemporary opinion was unfavourable, and only after World War II was the stage properly prepared.

THE FORMATIVE YEARS

Wounds of the heart

From the earliest days of mankind a superstitious awe surrounded the heart; Galen stated that if a wound penetrated a ventricle the man must immediately die, and this belief was fostered until the seventeenth century. Medical opinion in 1651 was summarized by Paulus Zacchias as "... lethalia vulnera de necessitate sunt, quae Cor quomodocunque laeserint, cum viscus hoc nobilissimum continui solutionem non patiatur", so it was with interest that he then related the following singular case. Having castrated himself, a mad priest proceeded to jab a stout needle many times below his breast; the necropsy showed that these wounds had all involved the heart, yet despite this the priest had survived 5 or 6 days. The literature of subsequent years recorded post-mortem observations of healed wounds in man and animals, but there was perplexity as to why some wounds were rapidly fatal and others were not. In general the view persisted that if the substance only of the heart was injured and the wound did not penetrate the ventricles, the patient might survive even for some days; the obliquity and site of the wound were also considered possible factors. However, Théophile Bonet in 1679, and Morgagni nearly a hundred years later, were groping in the right direction when they inferred that the pressure of the blood in the pericardium could stop the heart beating. The term "Herztamponade" was coined and explained by Edmund Rose in 1884.

Georg Fischer's analysis in 1868 of 452 heart and pericardial wounds, showing a survival rate of 10 per cent, and the arrival of antiseptic surgery stimulated a practical interest. In 1873 George Callender of St. Bartholomew's Hospital recorded the first successful removal of a needle from the heart in a 31-year-old man; other reports followed. Block in 1882 inserted sutures into rabbit hearts with ease and suggested the surgical repair of heart wounds in man. Simplicio

HISTORICAL INTRODUCTION

Del Vecchio in 1895 successfully sutured experimental wounds in dogs, and detailed a technique suitable for human use.

The first two attempts to suture stab wounds, by the Norwegian, Axel Cappelen, on September 4, 1895, and by Guido Farina in March 1896 were magnificent failures. Later, in September 1896, Ludwig Rehn achieved the first success. On October 10, 1903, Tuffier localized by radiography and removed a bullet that was intrapericardial and bound by adhesions to the left atrium. The young officer recovered.

This experimental and clinical work must be set against a background of current opinion scarcely encouraging. Block committed suicide after an unsuccessful lung operation. Theodor Billroth is reputed to have said in 1883 that any surgeon who wished to preserve the respect of his colleagues would never attempt to suture the heart (in view of the date, this may be considered timely advice). Stephen Paget, in 1896, wrote that "Surgery of the heart has probably reached the limits set by Nature to all surgery", and thus showed that he held the same views as a number of persons at the top of the profession. Specialization was frowned upon, yet without the formulation of new principles general surgery was approaching its own limits. Paget did not appreciate this and by recording yet ignoring the significance of the advances that had already been made, implied that his book represented the ultimate pinnacle of thoracic surgery.

The pericardium

Jean Riolan, professor of anatomy at Paris, suggested in 1653 that a pericardial effusion could be drained through a trephine opening an inch above the xiphisternum. This was done by Skielderup in 1818. Jean Baptiste de Sénac in 1794 advocated the use of a trochar introduced obliquely in the third left interspace, and in about 1814 Francisco Romero of Barcelona, aware of the difficulties of diagnosis, made his incision in the fifth interspace and opened the pericardium with scissors when he found an effusion.

In 1810, Dominique-Jean Larrey incised the pericardium for an effusion consequent upon a stab wound. About 3 pounds of fluid came away and the patient's condition was improved, but unfortunately infection developed and 10 days later Larrey released 3-4 ounces of sero-purulent matter with a bistoury. After a further improvement Bernard Saint-Ogne died of vomiting and dysenteric flux. In 1824, Larrey performed débridement of another stab wound and inserted a gum-elastic catheter into the pericardial cavity. The 22-year-old soldier recovered.

Friedrich Joseph Hilsmann on July 20, 1844, treated a suppurative pericarditis by incision and drainage (this was reported by his son 35 years later). The patient, Mathias Huser, aged 25 years, was seriously ill, having been treated medically, at other hands, for 8 months, but he made a perfect recovery. In 1850 Bernhard von Langenbeck also incised for suppurative pericarditis, with successful healing by second intention. He said that incision was neither difficult nor dangerous. However, in 1866 his pupil, Billroth, took the opposite view, holding it to be the next best thing to a frivolity, although he believed that later generations would feel differently. (This remark is often dated incorrectly to 1882 and commented upon rather scathingly; in fact it was a fair assessment for the true date of 1866.)

Difficulties in diagnosis seriously retarded adequate treatment of both suppurative and serous pericarditis. A number of paracenteses for serous pericardial

effusion were reported in the first half of the nineteenth century, and in the second half there were heated arguments over aspiration or incision, with Georges Dieulafoy leading the aspirationists. Gradually, the inadequacies and dangers of aspiration became apparent, largely due to the work of Rosenstein, of Leiden, John Roberts in Philadelphia, Samuel West in England and Delorme and Mignon in France.

Pericardial adhesions and constrictive pericarditis

Great confusion surrounded pericardial adhesions and the effects they produced. Operations were devised for particular conditions, but were applied indiscriminately and without any clear idea of the underlying pathology. The true picture only began to appear in the 1930s. This state of affairs accounted for some of the poor results in the early days.

Constrictive pericarditis.—Two Frenchmen, Edmond Weill and Edmond Delorme in 1895 independently suggested removal of the pericardium for constrictive pericarditis. Delorme had shown the technique to be feasible in cadavers and advocated operation early in the disease. However, it was a major undertaking and was not put into practice until 1910, when Paul Hallopeau at the Necker Hospital removed the anterior pericardium in a 16-year-old boy, with complete success and to his great surprise. Nevertheless, it was the later work of Rehn and of Sauerbruch that drew attention to the operation.

Cardiolysis.—Ludolph Brauer, a Heidelberg physician, proposed the operation of cardiolysis for chronic adhesive mediastino-pericarditis. This was first done by Petersen on April 1, 1902. Simon performed the second on May 20 of that year and included part of the sternum in his resection. A much later addition to the operation was the removal of the antero-lateral part of the pericardium.

Mackenzie's operation.—William Mackenzie, an Australian physician, independently devised Brauer's operation, but his faulty reasoning reflected the incorrect views held at that time. The operation was first performed about 2 years before his report in 1906, but, as he himself admitted, the case was really unsuitable.

Morison's operation.—Alexander Morison, another physician, recommended a thoracostomy for cardiac pain and enlarged heart in a 19-year-old youth. The aim of removing part of the anterior chest wall was to give the heart more freedom. Ewen Stabb performed the operation on May 1, 1908 and the patient was pleased with the result.

The performance of the thoracostomy was the same as that of Brauer's operation, but the underlying principles were different. This contributed to the confusion and Morison's principles failed to gain acceptance.

Cardiac arrest

In the early 1870s Moritz Schiff, professor of physiology at Geneva, performed cardiac massage in dogs during his studies on death due to chloroform and ether. Then in 1880 Neihaus, of Berne, was confronted with cardiac arrest in a 40-year-old man whose goitre he was about to remove; he immediately exposed the heart and began rhythmical compression, but to no avail. At this time most attention was directed to heart puncture and intracardiac injection; and the next adequately documented account of an attempt at massage was that of Tuffier in 1898, the patient being a man convalescing from drainage of an appendix abscess. A transthoracic approach was again used. The reason for failure became apparent

HISTORICAL INTRODUCTION

when post-mortem examination disclosed a pulmonary embolus. Other French surgeons followed enthusiastically in Tuffier's footsteps, but without success.

The first successful cardiac massage was performed, probably in 1901, by Kristian Igelsrud of Tromsø, after rib resection in a woman of 43 years. The next was in 1902 when Arbuthnot Lane gave an arrested heart "a squeeze or two" through the diaphragm and felt it start re-beating. Artificial respiration was continued for about 12 minutes. This happened during abdominal section for adhesion about the colon in a 65-year-old man. The appendix was incidentally removed.

Lack of artificial respiration undoubtedly accounted for many of the early failures of cardiac massage, and the importance of this additional manoeuvre was emphasized by George Crile.

Pulmonary embolism

After successfully removing an experimental pulmonary embolus from a calf, Friedrich Trendelenburg in 1908 twice attempted pulmonary embolectomy, though in fact it was his assistant, Sievers, who operated on the first patient. In both instances the patient died, the second after 37 hours from a damaged internal mammary artery. In the following years other surgeons tried their hand without success, but on March 18, 1924, at his eleventh attempt, Martin Kirschner of Königsberg was triumphant. The patient was 38-year-old Johanna Kempf. Other successes have since been recorded, but the number still is only about a dozen. The performances of Crafoord with 3 successes, Arthur Meyer with 3, and Gunnar Nystrom with 2 (all concluded before 1933), are therefore quite outstanding. The only British success has been that of Ivor Lewis, achieved after a stormy post-operative course in 1938.

At one time it appeared that the operation might be abandoned owing to difficulties of diagnosis and timing as well as to the arrival of the anticoagulant drugs; but in clinics where there is enthusiasm and preparedness there are signs of a renewed interest.

Disease of the heart

Experimental and clinical phases

Experimental studies on the heart valves were initially undertaken with no thought of application to human surgery. For instance the earliest experiments were those of Otto Becker, a German ophthalmologist, who in 1872 produced aortic incompetence in dogs to prove that the fundal changes were not due to eye disease.

Milton, in 1897, and Samways, in 1898, foresaw the relief of valvular lesions by operation and in 1902 Sir Lauder Brunton seriously suggested the possibility of treating mitral stenosis surgically; this the *Lancet* viewed with disapprobation. The subsequent correspondence included letters from Samways, and from Arbuthnot Lane who said that Dr. Lauriston Shaw had suggested the idea to him "some years ago". But it was Fisher who summed up the prevailing attitude by stating his belief that fibrosis of the heart muscle was the important factor.

In 1907, John Cummings Munro of Boston advocated ligation of a patent ductus, having "long ago" shown its possibility in the cadaver, but he was unable

to inspire the co-operation of his paediatric colleague owing to the latter's doubt about making the diagnosis during life.

The following years saw some serious experimental work, notably by workers at Johns Hopkins who, in 1905, were the first to produce valvular lesions by a thoracic approach, and by Tuffier, Alexis Carrel and Ernst Jeger, all of whom showed a remarkable grasp of the issues involved. Eventually on July 13, 1912, came a clinical achievement when Théodore Tuffier operated on a 26-year-old man suffering from severe and progressive aortic stenosis. With his little finger he invaginated the aortic wall and slowly dilated the stenosed ring. Carrel was present and when he and Tuffier reviewed the case in 1920 they were able to record a temporary improvement. In January 1913, Eugene Doyen introduced a special tenotome through the right ventricle in an attempt to relieve a stenosis of the infundibulum of the pulmonary artery in a 20-year-old girl. When she died on the next day an interventricular septal defect was found to be an associated anomaly. Doyen had also worked out a precise technique for the surgery of mitral stenosis.

After World War I, Duff Allen and Evarts Graham in America devised a cardioscope and in dogs they obtained good results in operations on the mitral valve. Their first patient, a 31-year-old woman operated upon in August 1923, died on the table before the instrument could be used and they were unable to get another case. In 1923 Elliott Cutler and Samuel Levine treated 5 patients with mitral stenosis, but only the first of these, a 12-year-old girl, survived. Her operation took place on May 20, 1923, and a modified tenotome was inserted through the left ventricle. One reason contributing to the failures was the mode of handling the heart, which was liable to cause disturbances of rate and rhythm.

In England, Strickland Goodall had been working on the problem of mitral stenosis for some years, and in 1924 he and Lambert Rogers detailed the relative merits of the atrial and ventricular approaches, concluding that the former was superior. On a number of occasions they operated on the cadaver, using their specially designed double-edged knife, and saw quite clearly that mitral stenosis could be relieved surgically.

Then on May 26, 1925, Henry Souttar operated through the left atrium and digitally dilated the stenosed mitral valve of 19-year-old Lily Hine; she survived for 5 years in very fair health, before dying from a cerebral embolus. Owing to the steadfast belief of physicians in the significance of the state of the heart muscle, Souttar was not given the opportunity to repeat his performance. Later the same year, on November 14, Bruno Pribram, in Germany, followed Cutler's technique and excised part of the fibrosed mitral ring with a cardiovalvulotome. The 38-year-old woman died 6 days later and the post-mortem examination disclosed a severe aortic stenosis, affected by an active endocarditis.

In 1931 Sauerbruch was attempting aspiration of a "mediastinal tumour" in a 28-year-old woman but when this produced an alarming jet of blood he realized that he was dealing with a cardiac aneurysm. With superb skill he resected the wall and sutured the edges. The patient recovered.

At the end of the 1930s it was becoming apparent that cardiac surgery did indeed have a future. On March 16, 1937, John Strieder of Boston closed (partially) a patent ductus in an heroic attempt to treat a bacterial endocarditis, since medical measures had nothing to offer. The 22-year-old girl died from acute dilatation of the stomach on the fifth day after operation. On August 26, 1938, Robert Gross, also

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of Boston, ligated a patent ductus in a 7½-year-old girl as an end in itself, an event that proved to be the inauguration of modern heart surgery. In the same year the introduction of angiocardiology by George Robb and Israel Steinberg was an important diagnostic advance.

War surgery

A few instances of successful removal of missiles from the heart wall were recorded by French surgeons in World War I. The most memorable operation of this nature was the extraction of a bullet from the inferior vena cava by Pierre Duval. In World War II Dwight Harken, working in Southern England, achieved the incredible record of removing 134 missiles from the mediastinum with no deaths. Of these, 13 were in the heart chambers. He emphasized the difficulty of exact localization unless the patient came to operation, or necropsy.

THE POST-WAR PERIOD

Experimental work in the closing years of the 1930s and the intense stimulation of World War II prepared the way for rapid progress in heart surgery. The important factors were the realization that certain types of heart disease were amenable to surgery, the improved diagnostic facilities, and the development of anaesthesia and the blood transfusion service. The road ahead was still hard, but it was now ready for travelling.

In the immediate post-war years there was great activity and a strictly chronological account would be a confusion. However, the first successes to emerge were for those congenital defects amenable to extracardiac or anastomotic procedures. The direct attack on the valves was attended by a high mortality, owing partly to the selection of seriously ill patients, but as experience was gained operation was undertaken earlier and the results improved. In some instances palliative procedures were introduced as interim measures until the definitive technique could be perfected. In others, disease demanded an open heart for its treatment and until this was obtainable operations had to be devised within the limitations currently imposed. Among the most difficult problems were those presented by valvular regurgitation and disease of the aortic valve.

Angina pectoris and coronary occlusion

The search for a surgical treatment of angina pectoris provides a convenient link between the past and the present. It is a search that still continues for, despite reports of undoubted success, there are so many variables that accurate assessment of the procedures is extremely difficult. The operations for angina have been directed to interference with the nerve supply, improving the blood supply or lowering the metabolic needs of the heart muscle.

Sympathectomy for angina was tentatively suggested in 1899 by Charles-Émile François-Franck, professor of physiology at Paris, and on April 2, 1916, Thomas Jonnesco of Bucharest put the idea into practice in a 28-year-old man with syphilitic aortitis and angina; during the subsequent 4 years the patient had complete relief of pain. Charles Mayo had performed a similar and successful operation on an American Army major in 1913 but did not make his report until 1925. The great variety of operations advocated reflected ignorance of the anatomy of the sympathetic nervous system.

THE POST-WAR PERIOD

Thyroidectomy was next on the scene; its vogue lasted for a decade and its passing was not lamented. In 1927 subtotal thyroidectomy was performed on a 61-year-old woman with congestive heart failure because of a suspicion of latent hyperthyroidism; the thyroid was normal histologically but the patient was greatly improved. This operation was reported by Levine, Cutler and Eppinger in 1933. In the same paper they also recorded the first subtotal thyroidectomy for angina pectoris *per se* performed on a 53-year-old man on June 15, 1932. Herrman Blumgart then suggested total thyroidectomy and this was carried out by Cutler on a man of 43 years in December of that year. Alcohol injections of the thyroid gland have also been used.

The thiouracil drugs were employed for a short period but for a number of reasons were abandoned. Then in 1947, Blumgart began the use of radioactive iodine ablation of the thyroid.

The surgical approach to the heart itself began in 1932 with the experiments of Claude Beck to improve the blood supply to the myocardium. Three years later he operated on his first patient by roughening the pericardium with a burr and grafting pectoral muscle to the heart. At this stage he did not favour the omentum as a graft, but Laurence O'Shaughnessy, who had been working on this subject in England since 1933, used the omentum on a 64-year-old man on January 4, 1936. As a result of observations by Lezius in 1937, the lung was also employed as the graft.

In order to develop the coronary anastomoses still further a sterile inflammation was set up in the pericardium by the introduction of various substances, either at the time of grafting or as a procedure on its own account. Beck initially used powdered beef bone and later asbestos dust; Thompson and Raisbeck of New York used sterile talc powder. and Harken, 95 per cent carbolic acid and a powdering of sterile talc.

The Beck I operation developed with experience and by 1954 consisted of pericardial abrasion, the application of an inflammatory agent, partial occlusion of the coronary sinus (*see below*) and grafting of parietal pericardium and mediastinal fat.

Louis Gross of New York in 1937 showed that occlusion of the coronary sinus in dogs increased the blood supply to the heart. Mercier Fauteux of Montreal and Boston began his experimental studies in 1935 and between 1940 and 1946 had ligated the great cardiac vein in 16 patients with satisfactory results; in most instances he also performed a pericoronary neurectomy. Then on January 27, 1948, Beck anastomosed the brachial artery to the coronary sinus and ligated the latter structure. This was the Beck II operation which, as such, was short lived—even though an autogenous vein was later employed as a graft—owing to the need for a two-stage operation, the high operative mortality and other factors.

Arthur Vineberg of McGill University, after 5 years of experimental work, first implanted the bleeding end of the internal mammary artery into the heart muscle in 1950. The fate and effects of the implant have been the subject of much controversy.

Bilateral ligation of the internal mammary artery below the origin of the cardiaco-phrenic branch was originally suggested by the Italian, Fieschi, in 1939. and applied clinically in the same year by Zoja and Cesa-Bianchi.

Treatment of occlusive coronary artery disease

Monroe Schlesinger in 1940 demonstrated on post-mortem material that

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coronary occlusive disease is usually localized and limited in extent—a view that has recently been challenged by Alan Thal on the basis of arteriographic studies. Nevertheless Schlesinger's work has been the starting point for much research and in 1953 Gordon Murray of Toronto reported on 5 patients in whom he had resected the diseased portion of the coronary artery replacing it with a vascular graft. The next year he anastomosed, in experimental animals, a systemic artery, either attached or as a free graft between the aorta and the peripheral end of the left coronary artery. However, in 1910, Carrel had performed similar and successful experiments using a free vascular graft, and had speculated on the possibilities of the technique in the treatment of angina when the mouths of the coronary arteries were calcified.

Congenital lesions

Coarctation of the aorta

Clarence Crafoord in Sweden successfully resected a coarctation in a 12-year-old boy on October 19, 1944, and on July 6, 1945, Gross and Hufnagel at their second attempt brought to fulfilment the experiments started in 1938. Gross in 1948 first used a preserved homologous arterial graft to bridge the resulting gap. Blalock and Park in 1944 had suggested by-passing the coarctation by means of the left subclavian artery and this was performed clinically at the Mayo Clinic by Theron Clagett on a 34-year-old man on August 6, 1946. At operation he found that the planned resection would be impracticable, so he joined the subclavian artery to the aorta by an end-to-end anastomosis. In the period before arterial grafts were introduced, other surgeons, for instance Murray, used the by-pass operation as a routine in cases where the ends of the aorta could not be approximated.

Fallot's tetralogy and pulmonary stenosis

Helen Taussig's observation that cases of Fallot's tetralogy fared better if there was an associated patent ductus led to the anastomosis of the left subclavian artery to the left pulmonary artery in a 14-month-old girl on November 29, 1944. Alfred Blalock of Johns Hopkins was the surgeon and in the next 2 cases he used the innominate artery. In their paper Blalock and Taussig mentioned the possibility of anastomosing the aorta to the pulmonary artery and had done this experimentally. But it was Willis Potts of Chicago who first performed this operation clinically on September 13, 1946. Some of the children who had undergone anastomotic operations subsequently lost all or part of their improvement and later had a direct operation performed; this latter has since tended to replace the anastomotic operations.

On December 4, 1947 Holmes Sellors of the Middlesex Hospital successfully operated on a youth of 20 years with pulmonary stenosis by inserting a long tenotomy knife through the infundibular region of the right ventricle. Russell Brock of Guy's Hospital had considered approaching the valve through the left pulmonary artery, but abandoned it as unsatisfactory. On February 16, 1948, he introduced dilating forceps through the right ventricle and dilated the valve in an 18-year-old girl. In 1949 he treated infundibular stenosis successfully in 5 cases with a special punch passed through the right ventricle, although in one instance a finger dilatation alone proved sufficient.