Papers and Originals

The Genesis of Heart Surgery*

Sir THOMAS HOLMES SELLORS,† D.M., M.CH., F.R.C.P., F.R.C.S.

[WITH SPECIAL PLATE]

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The development of surgery of the heart has placed a therapeutic weapon of the highest potency in the hands of the cardiologist, and one of which he readily avails himself. This branch has emerged with almost explosive violence, and has made its impact on many aspects of science and medicine within the period of a few years.

In being invited to deliver this St. Cyres Lecture I am only the second surgeon to do so, and I have chosen a title suitable for discussing the early stages of development and evolution rather than to consider the growing fringes represented by valve replacement, correction of the transposition of great vessels, complex haemodynamics, and so on. It is difficult to realize that the practice of cardiac surgery was virtually unknown 25 years ago (see Chart 1).

The definition of "genesis" that I have taken is one given by that remarkable scientist, philosopher, and divine, Teilhard de

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† Surgeon, National Heart Hospital, London W.1; Thoracic Surgeon, Middlesex Hospital, London W.1.

Chardin: "Now every genesis presupposes interconnexions, mutual and reciprocal, dependent without any break." It emphasizes that evolution is not an isolated spontaneous technical exercise, but has its ramifications and influences in many fields. Every advance has been facilitated by parallel steps in allied disciplines.

In the history of medicine cardiac surgery is a late arrival, but once it started it made up for lost time. Not only has it established new procedures, but at every stage it has stimulated advances in fields of technology as well as in medicine. These are the "interconnexions, mutual and reciprocal," and may be illustrated by a whole series of subjects—advances in anaesthesia; cardiac catheterization and angiography; methods of measurement; haematology and studies on coagulation of the blood; hypothermia; perfusion techniques; pace-making of the heart and deliberate changes of rhythm; the use of plastics; new design of instruments; immune reaction studies in relation to tissue transplantation. These are just some of the facets that impinge on each other in present-day cardiology, and they illustrate the necessity of "teamwork"—that hackneyed term

	GENERAL	LUNG	HEART	HISTORICAL
1933	Special chest hospitals start surgery.	CLOSED DRAINAGE of PLEURA.	Empyema. Phrenicectomy. Thoracoplasty.	Brunn & Shennstone & James tourniquet lobectomy.
1937		Efficient collapse therapy	Constrictive pericarditis.	Graham-pneumonectomy.
1939	PHYSIOTHERAPY. Blood transfusions.	LUNG RESECTION BY TOURNIQUET. Drainage lung abscess.		Gross-ductus.
	MODERN ENDOTRACHEAL ANAESTHESIA.	SEMB THORACOPLASTY. Extra pleural pneumolysis.		
1941	Pre-operative preparation.	DISSECTION LOBECTOMY & PNEUMONECTOMY.	DUCTUS	
1943	Early ambulations.	Return of decortication.		Crafoord-coarctation.
1945	ANTIBIOTICS.	Penicillin controls infection.		Blalock.
1947	Heart & lung investigation.	DISAPPEARANCE OF LUNG ABSCESS. RESECTION for PUL. TUB.	Coarctation.	Sellers } Pulmonary Brock } Valvotomy
1949	Increase in carcinoma.	Vascular anastomosis.	BLALOCK'S OPERATION	
	DECREASE IN LUNG SUPPURATION.	Segmental resection of lung. BRONCHIAL FISTULA CONTROLLED.	Pulmonary valvotomy.	
1951	DECREASE IN PUL. TUB.	Suction drainage of pleura.		Harken } Mitral Bailey } Stenosis. Brock }
1953	Increase in heart surgery.	Intracardiac surgery.	MITRAL VALVOTOMY. Hypothermia.	Lewis's open heart.
1955	Angiography.	Limited excision for carcinoma. BILATERAL THORACOTOMY. Plastic repair bronchus.	A.S.D.	Heart-lung machines.
1957		Artificial heart-lung.	Open pul. valvotomy. V.S.D., etc.	

Chart 1, indicating significant developments in thoracic surgery. Given at an address to the 10th Meeting of the Netherlands Thoracic Society in 1957.

which covers many aspects of collaboration and co-operation in addition to a full understanding of one another's problems. A surgeon working in isolation in this field is a mere technician or operator; a physician without adequate knowledge of the possibilities (and difficulties) of surgery is an imperfect therapist.

Beginnings of Heart Surgery

Of the beginnings of heart surgery there is little to be said: they were isolated attempts, starting with pericardial aspiration, which was first carried out successfully 150 years ago, and suturing wounds of the heart. The weight of surgical opinion at the turn of the century was that surgery of the heart was out of the question and Billroth's and Stephen Paget's remarks were often quoted somewhat unkindly in this context. Up to the time of the second world war little had been achieved apart from the repair of some injuries, a few pericardial resections, and some attempts at valve surgery. Beck (1935) and O'Shaughnessy (1936) were exploring methods of revascularizing ischaemic heart muscle, but, most important of all, thoracotomy was becoming a safe and routine procedure.

It was safe thoracotomy or, more correctly, the control of the open chest that paved the way for heart surgery. This advance owed much to the anaesthetists, and in this country it was the influence of Ivan Magill that inspired our present school of thoracic anaesthetists. Crafoord, in his Leriche Lecture in Philadelphia in 1965, devoted considerable time to a description of the control of respiration during operation as an essential part of the development of the surgery of the heart and great vessels. It is not unexpected to find that the early cardiac surgeons nearly all graduated from general thoracic surgery.

Having established safe access, it was only a matter of time before operations on the great vessels and the heart would be possible. Barrett (1960) has described surgery as going through three phases in its evolution—trial, adjustment, and consolidation. *Trial* covers the introduction of new operations and techniques. This is the spirit of adventure with a high mortality and morbidity—and many mistakes. *Adjustment* is more critical, where limitations are defined and diagnosis has to be more accurate and the whole approach is critical rather than experimental. *Consolidation* is the period of follow-up and analysis, assessing the plan and value of the procedure while introducing it into routine surgery. Heart operations have exactly followed this pattern, but with this qualification—the period of trial has been unexpectedly less dangerous than might have been expected. For example, I think that some of us would have been prepared to accept a 10 or 12% mortality in the early stages of mitral valvotomy, whereas the actual figure was only a third of this. Experimental work has undoubtedly made for safer surgery and helped to anticipate and overcome hazards, foreseen and unexpected (Special Plate, Fig. 1).

Diagnosis and Assessment

Before the introduction of surgery diagnosis and the interpretation of physical signs were matters of careful observation and deduction supported by the necropsy findings. The "pathology of the living" was not possible until surgery made direct, as opposed to indirect, observation possible, and this helped to elucidate the origin and cause of many physical signs. For example, early on we showed by direct auscultation that the maximum intensity of the Gibson murmur in a patent or persistent ductus arteriosus was several centimetres away from the ductus and towards the base of the common pulmonary artery. Similarly in mitral surgery it was easy to demonstrate that the "opening snap" could be abolished by light pressure or damping the aortic cusp of the valve. Again, in exploration of the diseased valve it became apparent that a small regurgitant jet

impinging on the wall of the left atrium could be much more noisy than a more significant but relatively silent reflux. These are small illustrative points which emphasize the importance of every cardiologist being able on occasion to observe and listen directly to the exposed heart.

With the introduction of surgery more accurate diagnosis and assessment were called for and rapid development in ancillary techniques followed. The progress that has been made since 1929, when Forssmann passed a catheter into his own heart, has been remarkable. Pressure records and samples can be taken from all chambers of the heart, and with associated angiography it is possible to visualize the whole process of the circulation. It is a far cry but not many years from the time when the x-ray films were changed by hand to current angiography with its image intensifiers, television screens, cinematography, and so on.

Methods of Measurement

Parallel with radiological techniques are methods of measurement which record pressures, estimate flows, and analyse blood gases. Haemodynamic studies involve elaborate recording systems, and the pure expense of these in equipment and manpower coupled with the necessary radiological equipment has led as much as anything to the concentration of heart surgery in centres which can afford these facilities.

In spite of the great advances made in this field, a great deal of relatively elementary knowledge is still lacking. When we started heart surgery there was little reference in existing textbooks to the physical factors in the circulation. Was the blood flow laminar or turbulent? What was the cause of a murmur? Could the second heart sounds be due to a water-hammer effect? Could "cavitation" (liberation of gases from the circulation) occur beyond a stenosis? Reference to and application of the Reynolds factor and the Venturi principle to different circumstances of the circulation, are recent introductions in the field of cardiology.

Another essential study, especially now that perfusion techniques are safely established, is that of the physical properties of the blood—its viscosity, its stickiness, and so on. To this must be added the vast problem of coagulation, with its allied subjects of anticoagulants and blood replacement and the whole question of biochemical changes, each one of these a special subject in itself but with direct reference to the actual surgery.

A great deal of the experimental work that has been carried out cannot be directly applied to man. For example, most careful observations can be made concerning the viability of animal tissues under varying conditions of ischaemia, but these can only broadly be applied to man. Actual operative experience and observation have had to determine how long the heart or the brain or the kidneys can survive without damage under varying circumstances, such as anoxia, cold, or hyperbaric conditions.

One of the more recent and dramatic aspects in cardiology has been the influence of electrical stimulation. The myocardium's own electrical reactions have provided us with the basis for electrocardiography. It is now possible not only to "pace" the heart, but to fibrillate it or defibrillate it at will and even to revert a long-standing arrhythmia.

The actual instruments in heart surgery have no special features that distinguish them apart from their adaptation to special sites or circumstances. Clamps that can be applied to large vessels without slipping and without causing damage have been evolved on the pattern introduced by Potts *et al.* (1946). Suturing is still largely done by hand in spite of the promise offered by stapling machines. The principal mechanical advances have been in the form of artificial valves used for replacement. In spite of many surgeons' ingrained objection

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(A)

(B)

FIG. 1.—A and B. A “deflated” heart after too rapid loss of blood during the course of right atriotomy being inflated by direct intravenous transfusion.

FIG. 2

FIG. 2.—Oblique radiograph of chest showing a reticulated band of calcium lying in the region of the A-V junction in a case of long-standing constrictive pericarditis (1943).

FIG. 3

FIG. 3.—Infected patent ductus arteriosus (1941). High fever, rigors, a large spleen, haematuria, and haemoptysis characterized the clinical picture. Complete and immediate relief after ligation of the ductus.

FIG. 4. — A and B. Postero-anterior and lateral angiographs of right ventricular catheter filling in Fallot's tetrad. The stenosis in the right outflow tract is shown, and in the lateral view the filling of the left ventricle through a large septal defect is easily seen. Note that the aorta has not filled simultaneously with the pulmonary artery, which it should have done if “overriding” had been present (1958).

(A)

(B)

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(A)

(B)

FIG. 5.—A and B. Radiographs taken before and after mitral valvotomy (1950). The venous congestion has been considerably reduced and the size of the heart is smaller.

(A)

(B)

FIG. 6.—A and B. Aneurysm of the sinus of Valsalva. The aneurysm, which in this instance has ruptured into the right atrium, is of the "wind-sock" type.

FIG. 7.—Forceps passed through a recurrent ventricular septal defect. The sutures that have given way are just visible to the side of the forceps.

to the burying of foreign material these valves have functioned satisfactorily for a number of years and the replacement of blood vessels by plastic tubes has proved preferable to vascular homografts. Currently the use of homograft aortic valves has offered considerable promise, and it is only a step to considering the feasibility of other transplants. When the rejection mechanism of a tissue transplant can be overcome immense possibilities are opened out in cardiology. Many research workers are engaged in this field, preparing the ground for opportunities of whole-organ transplantation.

Development of Heart Surgery

Having considered the interconnexions, we can turn to the development of heart surgery and its history from its inception. Pericardial aspiration and successful heart suture (Rehn, 1897) have already been mentioned and isolated operations on various conditions have also been attempted, but few of these were the direct initiators of current procedures.

During the years between the world wars spasmodic attention was given to "adherent pericardium," but, oblivious of Lower's (1669) classic description of constriction of the heart, confusion arose in distinguishing between the enormous heart with valve disease and with pleuropericardial adhesions for which Brauer's operation was performed, and constricting or constrictive pericarditis, which limits the diastolic phase of the heart, and for which Weill's (1895) and Delorme's (1898) decortication operation is suitable. I recall seeing Denk carry out two decortication operations in one week in Graz in 1930. Some 10 years later my immediate predecessor as the St. Cyres lecturer, Sir George Pickering, and I traced the natural history of constriction from a serous tuberculous effusion to full fibrotic constriction which was not amenable for excision for 18 months to two years from the onset. The principle of excising both layers of pericardium has not changed, though the current operation is a good deal more extensive than it was 20 years ago (Special Plate, Fig. 2).

From another angle came the practice of vascular surgery, in which the names of Carrel (1910), Guthrie (1912), Ballance (1920), and Makins are associated with ligation and suture of large vessels and with simple vascular anastomoses. Though the surgery of peripheral aneurysm dates back to antiquity, the work of Matas in reconstruction or obliteration constituted a great advance and remained accepted practice until excision and replacement by homografts or prostheses were introduced. Historically the ligation of innominate aneurysm was pioneered in 1832 by Valentine Mott, whose portrait hangs in the Presbyterian Hospital, New York. The story of this particular aneurysm was brought up to date by Gordon-Taylor (1950).

Arterial embolectomy was established as the result of Einar Key's (1929) classic paper, and, though Trendelenburg's (1908) heroic attempt to remove a pulmonary embolism was thwarted by internal mammary artery haemorrhage, the first successes were achieved by Kirschner (1924) and by Meyer (1930). These were followed by two successes in Crafoord's hands and two in Nyström's (1930). I saw both the latter's patients within a few hours of operation and realized what could be achieved with enterprise and initiative on the part of the surgeon.

Cardiac massage has been practised spasmodically as a matter of urgency over the years. Many failures to restart the heart resulted from ineffective massage and too long an interval between the arrest and starting treatment. The difference between standstill and ventricular fibrillation has only recently been recognized and the general surgeon of 10 or 15 years ago would find the modern concept of external cardiac massage and defibrillation a far cry from what he practised. But it is not only in surgery that restarting the heart is indicated: ischaemic heart disease provides sufficient material to keep the drill of cardiac resuscitation well practised in any large hospital.

Modern Cardiac Surgery

The curtain rose on modern cardiac surgery in 1939, when Gross successfully ligated a patent or persistent ductus arteriosus. Previously Graham, when performing the first pneumonectomy, had demonstrated that ligation of one pulmonary artery did not cause a circulatory upset, and it was assumed that occlusion of an open ductus could only benefit the circulation. The operation was originally conceived by Munro of Boston in 1907 and was practised on cadavers about the same time as Gibson in Edinburgh was describing the signs of the condition. Munro did not have the opportunity of performing the actual operation, probably because the diagnosis of the condition at that time was too uncertain. Though the first success was to Gross, Streider two years previously operated on a child who had persistent ductus and infective endocarditis, but who unfortunately died four days later.

That the time was ripe for the practice of operations on the heart and great vessels was shown by the number that were carried out almost within months of Gross and Hubbard's (1939) publications. In this country Tudor Edwards and Tubbs had successes, and I well recall my first case in 1941. The patient was a girl with signs of a ductus and bacterial endocarditis (Special Plate, Fig. 3). She had a high swinging fever, a large spleen, haematuria, and haemoptysis. Blood cultures were persistently positive for *Streptococcus viridans*. The operation was not easy, as the ductus was friable with marked inflammatory changes around it. After the duct was ligated a blood culture was taken, and for the first time in a fortnight this was negative. The temperature fell to normal in 24 hours and the embolic shadows in the lung fields rapidly cleared. This was the type of case that stimulated the imagination and made surgeons consider what other possibilities there were. The safety of the operation, with a mortality of 1% or less, has made it obvious that every patient with a patent ductus should be regarded as a candidate for operation.

Vascular Anastomosis

After ligation the next step was the practical application of vascular anastomosis. Blalock, while endeavouring to produce experimental pulmonary hypertension, anastomosed systemic arteries and pulmonary vessels. This failed, but the idea was transferred to the field of aortic coarctation, where the left subclavian was to be turned down and joined to the descending aorta below the stricture. The first actual operation of this type was probably done by Clagett.

Having established that the pulmonary and systemic circulation could be anastomosed, Blalock and Taussig used this procedure as a method for shunting unsaturated blood in a patient with cyanotic heart disease into the lung field, where it would become fully oxygenated. The operation that bears their names initiated treatment in patients with cyanotic heart disease, and the first successes of the "blue baby" operation (Blalock and Taussig, 1945) firmly established cardiac surgery as a branch of medicine in its own right and many children derived benefit from the procedure.

Artificial Ductus

The principle of providing an artificial ductus is still maintained in such modifications as were introduced by Potts. Though the operation was in no way "curative," it has provided palliation for many incapacitated children over a period of many years. Of the considerable number of patients I operated on between 1947 and 1954 about a quarter or a third are capable of leading normal lives with minimal inconvenience. Of the remainder some have died and others are in need of more definitive corrective surgery. But this shunt operation, which added yet one more deformity to the complex of Fallot's tetrad

(Special Plate, Fig. 4), still has a place in the treatment of babies and small children not yet suitable for total correction. In this country we owe much to Blalock personally, particularly when he worked at Guy's Hospital. Some of us will recall the lecture he gave at that time in the old museum at the Royal College of Surgeons. The hall was packed, and so many were left outside that with characteristic generosity he gave a repeat performance within the hour to an equally full hall and enthusiastic audience.

Coarctation

Still holding to the theme of great vessels, coarctation was chronologically the next lesion to be treated. The descriptions given of the condition by Abbott (1936) and James Brown (1939) had demonstrated the different sites and forms of the narrowing, and many surgeons were aware that the problem of excision and end-to-end suture was solely a technical one. The immense collateral system bypassing the coarctation would be able to maintain the circulation in such essential organs as the kidneys during the period of aortic occlusion. The first successful operation is attributed to Crafoord in 1944, and acknowledgment is due to Gross's experimental and clinical work about the same time. In this country the operation was pioneered by Price Thomas, but for some years there was no marked general enthusiasm for this difficult and potentially dangerous procedure. When, however, hypotensive drugs were introduced the problem was simplified, and when arterial homografts became available surgeons felt that they had additional security in being able to bridge a long gap rather than try to perform an anastomosis under marked tension. It was still not easy to convince doctors (and patients) that cut ends of the main artery to the body could be united and secured by a single row of fine sutures.

It is also difficult on occasion to make these extremely fit-looking hypertensive subjects realize that they are not suited to competitive boxing or the like and that they should undergo major surgery. The operation is safe—in over 140 patients we have operated on there were one early death and two fatalities considerably later. In all cases there has been a satisfactory reduction in blood pressure, if not to normal limits, to a reduced figure that does not expose the patient to the hazards of persistent and progressive hypertension.

Pulmonary Valve Stenosis

In 1913 Doyen operated on a patient with pulmonary valve stenosis, but without success. Access to this valve is comparatively easy, but in spite of the considerable numbers of patients with pulmonary stenosis the problem was not tackled until patients with Fallot's tetrad were being operated on by Blalock's procedure. During these anastomotic operations a comparatively high incidence of pulmonary valve stenosis was recognized, and it was clear that sooner or later a formal operative approach to this valve would materialize.

In 1947, while attempting to perform a left-sided Blalock operation in a patient with long-standing pulmonary tuberculosis, it was not possible to expose the subclavian artery because of vascular adhesions. The pericardium was opened, and proximal to a grossly dilated pulmonary artery trunk the hard dome of the narrowed valve could be palpated. With the assistance of Mullard and the late Paul Chin, two rows of control sutures were placed in the infundibulum away from obvious coronary arteries while an angled meniscotomy knife was sterilized. This was passed through the ventricle wall and up to the tough valve, which was divided in two places (Fig. A). The patient recovered and improved considerably, though he died from spread of the tuberculous process nine years later.

At the same time Brock had designed valvotomes and dilators, which he used for valvotomy, and elaborated the blind trans-

ventricular approach into a "punch" operation in which obstructions within the infundibular position of the outflow tract could be cut away (Fig. B). This form of procedure was eminently suitable for septal-like obstructions in this area, and his experience and views were ably given in his St. Cyres lecture (Brock, 1960).

FIG. A.—The first successful pulmonary valvotomy (1947). An angled meniscotomy knife introduced through an incision in the right ventricle divided the valve in two places.

FIG. B.—Transventricular dilatation of pulmonary valve using a bi-fin dilator. Valvotomes, dilators, and punches can be used similarly.

Though the pulmonary valve was originally approached along the direction of the blood flow—that is, through the ventricle—it was also possible to carry out a valvotomy through the left pulmonary artery, a retrograde valvotomy (Fig. C). This operation had considerable personal appeal, since it gave

an alternative or supplement to the Blalock procedure if a left thoracotomy was used to expose the left pulmonary artery. The same valvotomes and dilators could be used, and if satisfactory enlargement of the narrowed valve or outflow was not obtained the incision in the pulmonary artery was available for a Blalock anastomosis.

FIG. C.—Retrograde pulmonary valvotomy (1955). The valvotome or dilators are introduced into the left pulmonary artery and guided through the stenosis into the left ventricle.

In the absence of open heart surgery these anastomotic and punch operations were all that could be used on children and adults with this type of congenital heart disease, but they did provide a measure of very considerable relief in a high proportion of patients.

Mitral Stenosis

Another form of valve obstruction that had actively been considered over the years was mitral stenosis. Lauder Brunton (1902) is credited with making the first published suggestion that mitral stenosis could be treated surgically, but there was an interval of over 20 years before research work by Cutler and Levine (1923) and Allen and Graham (1922) showed how the valve could be approached. After several attempts the first success was accredited to Cutler and Levine (1924), who partly divided the stenosed valve with a tenotome passed through the ventricular wall. In this country we recognize the transatrial exploration carried out by Souttar in 1925 as the great pioneer step in this field. The operation was not strictly a valvotomy, since the patient had predominant regurgitation, but it showed that the interior of the heart could be explored by the surgeon's finger. The patient survived a number of years, but, with the perversity of circumstances that dogs the pioneer, no further attempts were made for almost a quarter of a century.

When, however, early experiences had demonstrated the possibilities of going further in the intracardiac field the operation of transatrial commissurotomy, as it was called, exploded simultaneously on both sides of the Atlantic. Bailey, Brock, Harken, and Smithy (the names are in alphabetical order) achieved successes about the same time, and their example was followed by a spate of operations undertaken safely and with good results (Special Plate, Fig. 5). To illustrate the speed of progress and

state of readiness to develop this new concept, I recall that in 1952, at the European Congress of Cardiology, Bedford and I reported 64 patients operated on without a death, and at the same time we demonstrated the cause of the "opening snap" (Fig. D) and the significance of the mobile diaphragm type of stenosis.

FIG. D.—Diagram to demonstrate the cause of the "opening snap" in mitral stenosis (1952). Damping of the mobile part of the aortic cusp abolishes this sound. Note the inaccuracy of depiction of the size and shape of the valve cusps.

FIG. E. (A).

FIG. E. (B).

FIG. E.—(A) and (B). Cardioscope (1951-2) for use through the left atrial appendix so as to perform mitral valvotomy under direct vision. The knife is projected by pressing on the wire and emerges through the perspex rod, which is transilluminated by a powerful water-cooled light.

The operation that started with the finger as the disrupting agent was quickly supplemented by dilators, special knives, and valvotomes, which improved the extent of the valvotomy. Some of us attempted to use cardioscopes (Fig. E), but did not persist when it was found that the finger which guided instruments was adequate and effective.

The technical results of mitral valvotomy have more recently been greatly improved by the simultaneous use of a transventricular dilator guided through the orifice and checked for position by the index finger introduced through the left atrial appendix. This procedure was introduced and popularized by Logan, though the first actual transventricular operation of this type was probably performed by Oeconomos (Fig. F).

FIG. F.—Approach to the mitral valve in cases in which the atrial appendix is small or fibrosed and the left atrium is too small to use a purse-string (1953).

The principle on which mitral valvotomy has succeeded so well is that lines of pathological fusion are more easily separated than those of normal anatomy. The site of disruption occurs more readily along a plane of adhesion than into a normal structure. Recurrence or restenosis can and does occur in less than 5% over five years and may require a repeat operation, but often it is an ineffective original operation that has to be supplemented or a fresh rheumatic exacerbation leading to adhesion rather than straightforward cicatrization. A second operation can give great benefit so long as regurgitation is not an important factor in the disorder of the valve.

There is an increasing and, in my opinion, an unnecessary tendency to treat mitral stenoses by open operation, but in the uncomplicated case I am convinced that indirect and closed methods give at the present time results that cannot be bettered by open heart surgery. When regurgitation is a major factor the whole situation is altered and open operations to repair or replace the leaking valve are almost obligatory.

Early attempts to relieve aortic stenosis followed the closed or "blind" principle of approach. Transventricular dilatation (Fig. G) was popularized by Bailey, who used a large tri-fin dilator with a swivel head to enlarge the valve orifice. This was succeeded by an operation in which a pouch or sleeve was sewn on to the aorta (Fig. H), and through this the finger and/or instruments were passed into the stenosis. This form of surgery was never as successful as it was in the case of other valves: the pathological state of the valve often precluded a

good result, and cases of calcific stenosis offer a rock-like resistance to this form of treatment. Even if the orifice is enlarged

FIG. G.—Semidiagrammatic illustration to show transventricular approach to a stenosed aortic valve (1952-3).

FIG. H.—Transaortic approach to aortic stenosis. The valvotome was passed through the stenosis. The blade of the instrument was then opened and pulled through the valve. (1954).

regurgitation sometimes proves to be an insoluble problem. Baker and Campbell (1956) have shown how good results can be obtained in properly selected cases, but at the present time the term "valve replacement" is more often heard in connexion with aortic valve disease than "valvotomy."

Foreign Bodies in Heart

The story of closed as opposed to open or direct-vision surgery cannot be completed without reference to foreign bodies in the heart. The first world war produced few successes in this field apart from Duval's (1918) intriguing case of a soldier who had a "bullet embolus" successfully removed from the vena cava. Grey Turner (1940) illustrated the tolerance of the heart by publishing the story of a soldier on whom he operated in 1917 and who had a bullet lodged firmly in the wall of the ventricle. Though it was not possible then to remove the missile, the patient remained in good health for more than 20 years.

During the second world war many surgeons were familiar with foreign bodies of one sort or another buried in vessel wall or in the heart muscle. These were removed with considerable apprehension and anxiety but with little difficulty. Nothing comes up to Harken's 14 removals of foreign bodies from the heart chambers without a fatality. I remember him lecturing to a large Services audience on the subject in the Royal Society of Medicine to the close accompaniment of exploding V2's. The heart is a tolerant organ willing to support considerable interference, and this was an object-lesson in surgical courage and expertise.

Further examples of closed surgery can be instanced in Sauerbruch's (1936) successful excision of a ventricular aneurysm in 1929 and in more recent attempts to deal with intracardiac defects. In 1948 Gordon Murray operated on four patients with septal defect, passing slings of fascia lata across the defect in the plane of the septum. Various attempts were made by invagination methods to close atrial septal defects, but of these Bailey's "doughnut" atriopexy was the only method at all effective. In 1954 Sndergaard introduced an operation in which a plicating suture was passed in the substance of the septum round the margin of the defect. This procedure was developed and became popular in Scandinavia, but it anticipated the advent of open heart surgery only by a short time. Gross and Watkins's (1953) "well" technique was an ingenious operation which, though "blind," was more accurate than most indirect methods, but it still lacked direct vision.

Hypothermia

The goal of the heart surgeon started to be realized when hypothermia made it possible for the heart to be excluded from the circulation for a limited period. The name of Bigelow is rightly associated with the early development of this first attempt to reduce the oxygen and metabolic requirements of the body. It was found experimentally that a temperature of about 30° C. allowed the circulation to be arrested for a period of 10 minutes. The first figures were not as precise as this, but it was recognized early on that too marked a depression of temperature led to ventricular fibrillation and arrest, which could be embarrassing, to put it mildly, for the surgeon.

The first success in man was achieved by Lewis and Taufic (1953), who closed an atrial septal defect under direct vision, using conventional or 30° C. hypothermia. The methods of body cooling have varied: taking blood from an artery and cooling it through a coil before returning it to the venous side of the circulation; veno-venous cooling; and what is the most popular method, surface cooling, usually by immersion in a bath of cold water.

Our interest in conventional (30° C.) hypothermia was stimulated by visits to Swan and Virtue, who were among the early

advocates of surface cooling. Bedford had a considerable list of well-documented and assessed patients with atrial septal defects (see Chart 2 for classification) which required attention. Up to the present time Sellick and I have dealt with 450 patients with the secundum type of defect. The overall mortality has been 3.5% and in good-risk cases there have been no fatalities. Somerville (1966) has recently made a detailed computer study of just under 400 of these cases—an exercise which may well pioneer the use of this technique in assessing and evaluating surgical procedures.

CLASSIFICATION OF ATRIAL SEPTAL DEFECTS
(212 Cases)

OSTIUM PRIMUM 11		
Normal valves	2	
Cleft valves	9	
OSTIUM SECUNDUM 201		
Fossa ovalis	136	67.7%
Inferior caval	53	26.4%
Superior caval or sinus venosus	11	5.5%
Cor triatriatum	1	

CHART 2, classifying atrial septal defects (1958-9).

There were several lessons to be learned from our initial approach in this field. A secundum defect is a well-defined hole that simply requires suturing, and for this the 10-minute circulatory arrest at 30° C. is ample; but if the diagnosis is in error, and, for example, a primum defect or another defect (Fig. 1) is found, the time allowance is inadequate. In our series, with all credit to the diagnosticians, only one mistake has been made. Consequently we have not been faced with the uncomfortable position of having to switch to perfusion at short notice or to abandon the operation and start afresh another day.

FIG. 1.—Atrio-ventricular canal and ostium secundum atrial septal defect. The crescent of the primum defect is shown, and to the left lie two large secundum defects. The cleft in the mitral valve extends to divide the septal leaf of the tricuspid, and in the gap the top of the ventricular septum is just visible.

In addition to the closure of atrial septal defects (Fig. J) we have undertaken valvotomies and a number of other procedures under hypothermia, and before perfusion techniques became satisfactory aneurysm of the sinuses of Valsalva (Special Plate,

Fig. 6), aortic stenosis, myxoma, and ventricular defects (Special Plate, Fig. 7) were dealt with. One case of aortic regurgitation in a small child was treated and relieved to the extent of raising the diastolic pressure from zero to 60 to 70 mm. Hg.

Proceeding with the concept of hypothermia as a means of reducing metabolic requirements, Drew *et al.* (1959) developed and practised profound hypothermia—a temperature range of 10–20° C.—at which level heart arrest for a period of at least 45–60 minutes is feasible. The method is a good deal more complex than surface cooling required for 30° C. hypothermia

FIG. J.—Ostium primum atrial septal defect. The crescentic edge of the defect is visible to the right of the coronary sinus. Through the defect the cleft septal cusp of the mitral valve is to be seen. The stitch to the right passes through the top of the ventricular septum.

and involves cannulation of both pulmonary and systemic circuits and the use of heparin. But it does produce a completely still and dry heart, which is of great advantage in many intricate procedures. As one American surgeon stated, "It is a very elegant procedure" and is an alternative to the more formal heart-lung machines.

Perfusion

The concept of extracorporeal circulation or perfusion dates back a good many years. Many surgeons and investigators wondered how an artificial circuit could be devised to overcome the immediate problem posed by loss of vitality in some part of the body. Gibbon was originally stimulated to develop a method of maintaining the circulation artificially in patients where arrest was produced by massive pulmonary embolism. He was the first surgeon to carry out a successful whole-body perfusion in 1953, when he closed an atrial septal defect in 26 minutes' perfusion time.

This was the initial success and it was followed up by Crafoord, who used a disc or cylinder oxygenator in the removal of an atrial myxoma. At the same time many teams were designing their own heart-lung machines. Lillehei, who had brilliantly used crossed-circulation in eight patients for closure of ventricular septal defects, developed with de Wahl a bubble oxygenator which has been used successfully in many hundreds of cases and is currently popular for short perfusions. The disc principle of oxygenator has appeared in many forms under various names, of which Kay-Cross, Melrose, and Aga-Senning are familiar. The Gibbon vertical screen pattern of oxygenator

has its current counterpart in the streamlined Mayo-Gibbon machine which is used so efficiently by Kirklin and his colleagues at the Mayo Clinic. There must be many surgeons in this country and elsewhere who owe much to the courtesy, teaching, and help received from this unit. I certainly count myself one of them.

The choice or selection of apparatus is one for the individual surgeon and his team. It is often influenced by opportunity and expense, and it is up to the team to know their machine and its capabilities. Perfusion methods have stretched the scope of intracardiac surgery during the past few years from the more simple measures such as closure of ventricular and atrial septal primum defects, total repair of Fallot's tetrad, up

FIG. K. (A).

FIG. K. (B).

FIG. K.—(A) and (B). Coarctation (post-ductal) with a mycotic aneurysm and a patent ductus (1955). Treated by excision and restoration of continuity by a homograft.

to the more complex concept of valve replacements requiring coronary perfusion.

Conclusion

At this point the subject of this address comes towards its close, for there is no intention of continuing into the growing fringes where excitement and achievement go hand in hand as one difficulty after another is overcome. Where advances in cardiac surgery will end cannot be foretold. Those comparatively few who were in at the start have given up being surprised as one vision after another has become real. In the present skilled and polished state of heart surgery it is perhaps difficult to understand the early hazards and problems; though only a few years away, they seem far distant.

To summarize the present position: certain procedures can be routinely and safely practised. They are "consolidated"—patent ductus, secundum atrial septal defects, pulmonary stenosis, and coarctation (Fig. K). These are congenital in origin and with a myocardium undamaged by disease. To this group we must add mitral stenosis as a safe and satisfactory operation, so long as we remember the extent of damage that the heart muscle has suffered. The risks are small and the results are good.

Other routine operations such as closure of ventricular septal defect and ostium primum defects have a higher mortality, particularly if complicated by pulmonary hypertension or valve insufficiency. In the same category we should put Fallot's tetrad, where the results vary widely according to the degree of disability.

Beyond this, our interest is centring on valve repair and valve replacement, where the factor of myocardial efficiency can be of vital importance. Individual teams with gathering experience are passing from the period of "trial" to that of "adjustment," and I would mention Ross and Barrett Boyes, who, from opposite sides of the globe, are pioneering homograft transplantation of valves and obtaining increasingly good results. Their work and that of Waterston and Aberdeen from Great Ormond Street, and of Mustard from Toronto on the correction of transposition, are good examples of the growing fringes.

This is not a complete history of the origins of cardiac surgery. The detailed account has been far better annotated by Richard Meade (1961), the historian of thoracic surgery. I am indebted to him for his great knowledge and verification of certain facts.

Let us not forget that each project is only possible with full co-operation of the various sections of the team. Diagnosticians, anaesthetists, haematologists, biochemists, engineers, technicians, blood donors, and nursing staff are all essential. Man—the surgeon—is no longer a demi-god in complete control. He is the leader and co-ordinator of a complex. No one unit, no one country, has the sole credit for the evolution of this fascinating branch of surgery. It is a summation of multiple efforts and observations.

The unending inquiries and researches, the trials, the disappointments and successes, are shared by the team, but they

have given a tremendous stimulus not only to cardiology but to the whole of medicine. The methods of investigation, the techniques, and the nursing requirements have spread into other branches, and the stimulus and challenge offered by new horizons could well be expressed by a quotation from a letter of Keats: "The imagination may be compared to Adam's dream—he awoke and found it truth."

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