OPEN HEART SURGERY*

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Open Heart Surgery is being performed in many centres in the United States today. The thoracic surgeon who intends to study these modern methods must of necessity limit his visits to the best known of the Clinics.

Accordingly, for reasons which I shall discuss later, I divided the precious time at my disposal between Philadelphia, where Charles Bailey was in charge of the surgery, Minneapolis, under the aegis of Lillehei and Varco, and the Mayo Clinic at Rochester where Kirklin was the presiding genius.

My main interest naturally was in watching the surgical techniques and the special anaesthetics they required, but I had hoped to glean some information on the diagnostic methods. Unfortunately I was not able to see many of the pre-operative investiga-

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tions, nor the post-operative 'follow-up', as I could not spend longer than 14 days at each of the selected centres.

We have witnessed wonderful progress in heart surgery during the last 10 years. Many patients, for years under medical treatment alone, are now being helped and even cured by surgical techniques.

The exploration of the interior of the heart had always been the deterrent to further advances. Conditions such as patent ductus arteriosus, coarctation of the aorta, constrictive pericarditis, mitral stenosis, and some of the congenital abnormalities of the aortic arch had all proved amenable to surgery, but opening and inspection of the heart was not necessary in these cases. Disease processes inside the heart, such as mitral stenosis, aortic stenosis, and pulmonary stenosis, valvular and infundibular, were treated by blind measures, i.e. instruments were inserted into the heart and the surgery was performed while the heart was in action.

The latest and most exciting advance was the so-called 'Open Heart' surgery, which allows the surgeon to operate under direct vision. This necessitates alteration of the heart function in some way, so that the normal circulation and oxygenation of the blood can be maintained during the operation.

BAILEY'S CLINIC AT PHILADELPHIA

The name of Dr. Charles Bailey is associated with every branch and facet of cardiac surgery, and in Philadelphia I learned that not only is he an extremely able surgeon but a man whose nimble and original mind has devised many instruments used for the different aspects of heart operations. My first introduction to heart surgery was thus the profitable period I spent with Bailey and his assistants at the Hahneman Hospital in Philadelphia, and I shall tell you of a few of my experiences there. I was surprised at Bailey's operating theatres, as I had always believed that most of the American specialist hospitals were wonderfully equipped, more or less as depicted in the cinema operating theatre scenes. This was certainly not at all the case here, where Bailey performed wonderful work with the primitive and inadequate facilities offered by this old hospital.

As most of you are aware, the operation for mitral valvotomy is carried out through the left side of the chest. Bailey, however, operates through the right side, his reasons being that not only do his patients suffer from mitral stenosis, but 30% of all his cases with mitral stenosis also have some degree of tricuspid stenosis. In order to reach both the mitral and tricuspid valves, he considers that the right side offers the best approach. Naturally I quote Bailey's own statement that 30% of his cases have tricuspid stenosis as well as mitral stenosis, and he adds—to strengthen his case—that there are cases in which there is co-existing aortic stenosis, so that the patients require what is referred to as a 'three-valve-job'.

I should like to describe Bailey's right-sided approach for mitral valvotomy. A plane is found between the right and left atrial walls, and when the tissue has been incised for a short distance between these two walls, the left atrial cavity is entered from behind the heart. He maintains that this access gives him a good opportunity to feel the entire mitral valve. In my opinion this is not only a more dangerous but also a more difficult procedure, although it does not appear to be so in his hands. Having carried out the mitral valvotomy, a variety of valvotomes designed either by his assistant or himself are used, and he then explores the right atrial cavity. If necessary, the aortic valvotomy is then performed by means of a trans-aortic approach. His operative results are good, and he is perfectly satisfied by this technique, which I believe he is using as a routine approach for all his mitral valve surgery.

Operations on the aortic valve were also performed using pump-oxygenator procedures. The type of pump oxygenator used by Bailey is the bubble type of oxygenator, where oxygen is bubbled through the blood while simultaneously the blood passes over certain baffles or discs, so as to increase the oxygenation, and the blood, after being filtered, passes through the special pumps into the patient's circulation.

I feel at this stage that a word should be said about the principles underlying the pump oxygenator apparatus, as many of you will not be acquainted with this very specialized type of work. Catheters are inserted into the superior and inferior vena cavae through the right atrial chamber. These catheters drain most of the blood returning to the heart. This blood is then passed through the pump oxygenator system, and returns through a single catheter introduced into the left sub-clavian artery. As a result of this by-pass, the heart is relatively dry. The term 'relatively' is correct, because blood will still flow through the coronary vessels into the heart, and thence back into the right atrium through the coronary sinus. This blood must be aspirated away even though the by-pass system is in operation. The pressure of blood in the aorta keeps the aortic valves closed, so that the blood can circulate through the systemic system without actually circulating through the heart, except for that blood which passes through the coronaries, and the blood which reaches the heart through the bronchial system. This means that the bronchial arteries coming off the aorta will return blood through the pulmonary veins, which enter the left auricle, thus coming into the field of operation. This blood must also be aspirated away during the by-pass procedure.

At Bailey's Clinic I saw for the first time operations for the repair of ventricular septal defects and for the repair or correction of aortic stenosis using open heart surgery. The first point that comes to mind is the question of the nourishment of the heart. Bailey makes use of retrograde perfusion of the heart muscle through a coronary sinus catheter. The aortic valve is approached through the aorta under direct vision, and repaired.

The correction of transposition of the great vessels of the heart is also performed by means of this by-pass method. At this same clinic I witnessed the Vineburg operation, devised to improve the blood supply of the myocardium in coronary artery disease. I shall describe this procedure later, as I was fortunate enough to see much of the surgical experimental work in connection with coronary disease in New York.

One of the few pre-operative investigations that I was able to see was the examination of both the right and left ventricles, using opaque dye. This is carried out as an out-patient procedure in the X-ray Department of the Hahneman Hospital. The patient is lightly sedated, and under local anaesthesia a needle is introduced through the skin in the region of the xiphisternum in an upward direction. It is passed upwards and outwards through the right venticle, and the dye which will outline the ventricle is then injected. The needle as it is advanced will pass through the septum into the left ventricle, which can then be outlined with the dye, which will then pass up into the aorta. If mitral incompetence is present the dye will then pass into the left auricle. Great care must be taken to ensure that no dye is injected into the ventricular septum, as this will result in a permanent heart block, and may even cause the death of the patient.

This examination of ventriculography is believed to be one of the only reliable methods of determining the presence and degree of mitral and tricuspid incompetence. Pictures are exposed rapidly by means of a special cassette changer, and the degree of contrast shown by the dye was better than anything I have seen. The reason for this may be partly due to the fact that 90% hypaque was used. This opaque medium is not at present available in South Africa.

LILLEHEI AND VARCO, MINNEAPOLIS

From Philadelphia to Minneapolis, to see the work of Lillehei and Varco, who — with DeWaal — had developed the pump oxygenator apparatus. A few words first about the surgical department at the University of Minnesota in Minneapolis, under the control of Dr. Wangensteen. A great deal of the renown of this school of medicine is due to the personality and drive of this great surgeon. Many surgeons will have heard of Dr. Wangensteen's views on carcinoma of the colon, and the 'second look' operation which he has advocated. This second look operation is usually done about 6 to 9 months after the first operation, and patients—irrespective of their financial status—return to the hospital for a re-examination operation carried out at the expense of the hospital. A great deal of information about the spread of cancer of the colon has been gleaned, as well as knowledge of the efficacy of modern surgery.

A special type of operation is practised in Dr. Wangensteen's department for the treatment of malignant disease of the breast. The surgical pathology department found that the glands along the internal mammary artery were involved in a large number of cases in whom the carcinoma appeared to be localized to one quadrant of the breast. Consequently a super-radical mastectomy is now performed, which is really 'super' and 'radical'. An ordinary radical removal of the breast and axillary lymphatics is followed by dissection of the supraclavicular glands and a sternum-splitting

operation to remove the glands of the internal mammary artery inside the pleural cavity. This extensive operation is, in Dr. Wangensteen's opinion, justified, because almost 30% of cases show the presence of involvement of these regional lymphatics.

The University of Minnesota, situated in Minneapolis, is in one of the wealthiest areas of the United States. Minnesota is, in fact, referred to as 'the bread-basket of the nation'. Dr. Wangensteen has collected large sums of money for the research work carried out by his Department. The operating theatres, which are not very large, are certainly some of the most magnificent I have ever seen. Visitors are shown to a room immediately above the theatre, in the floor of which is a dome-shaped projection made of thick glass. The visitor is thus able to sit in comfort, placed immediately over the operating table, and is given opera glasses to ensure a close-up view of what is going on in the theatre below. I was told that at one time a two-way inter-communication system existed, which was discontinued because of some of the adverse comments heard by the operating surgeons from a group of visiting surgical authorities. I cannot vouch for the truth of this, but I am sure that a two-way inter-communication system would be extremely distracting to the surgeon.

This University Hospital has an impressive heart hospital attached to it, with at least fifty beds for surgical cases. It has been donated entirely by the efforts of the Variety Performers Guild, and houses the patients on whom operations have been performed. There is communication with the main hospital by a most complicated system of passages, and interestingly enough, at many vantage points in the passages, there are special machines, from which one can buy hot coffee or tea, with or without milk, and with or without sugar, according to one's taste.

Drs. Lillehei, Varco and DeWaal have their names associated with a special type of pump oxygenator, and it will be recalled that they were the first group of workers to use human donors. The mother or father of a child suffering from Fallot's Tetralogy would act as a donor supplying the blood and the oxygenation system for the child patient. I was told that no parent was ever lost, but some cerebral damage had been suffered by one of them. The development of an artificial oxygenator and pump was inevitable, and Drs. DeWaal, Lillehei and Varco then perfected the pump oxygenator, which is used in many parts of the States. The pump oxygenator is a Sigmamotor pump, which consists of various finger-like projections, which massage the tubing in which the blood circulates. This machine gives the blood projectile force resembling the stream issuing from an ordinary heart, i.e. there is a systolic and diastolic ejection from the machine. The blood, however, which comes from the patient must also pass through an oxygenator. The type of oxygenator used in this department is the bubble type, i.e. blood is collected in a tube, and oxygen is bubbled through it. The blood then overflows into a reservoir or de-foaming chamber, following on which it is collected in a special coiled tube called the Helix, and having passed through filters, is pumped into the patient.

A team of workers is necessary to work this type of pump oxygenator. This team consists essentially of three people—a technician and two doctors, one of whom must be trained to regulate the blood flow. The apparatus is assembled in the theatre just before the commencement of an operation, and one must remember of course that the machine itself must be primed with blood, and this may require as much as five pints per patient. Also the blood must be heparinised immediately before use. Heparinised blood cannot be kept longer than an hour or two at the most, and it would be extremely dangerous to use it if it had been left standing for several hours.

The assembling of five pints of blood may require the testing of 50 or 60 donors before the correct blood is found, and careful attention must be paid to the cross-matching and compatibility of the blood for each patient. It can thus be seen that the actual preparation of the apparatus for use involves considerable expense.

Many cases with a pure ventricular septal defect have shown evidence of pulmonary hypertension, and Drs. Lillehei and Varco believe that it is this pulmonary hypertension which has been responsible for some of the post-operative fatalities. Secretions in the bronchial tree may become uncontrollable, so they perform a routine tracheotomy on their patients a week or so before the operation.

I saw the pump oxygenator in use for cases of ventricular septal defect, cases of Fallot's Tetralogy, cases of aortic aneurysm resection, and also for transposition of large vessels. Its actual use at the time of operation is very much the same in all cases. At this hospital the operations were done by two senior surgeons with two assistant surgeons. Two junior surgeons stood by, and they were washed-up merely in order to get acquainted with the nature of the operation. The pump oxygenator was connected to the patient firstly through the vena cavae, the venous blood was drained into a sump, which was then pumped through the pump oxygenator system, and returned to the subclavian artery.

Some of the cases of Fallot's Tetralogy which I saw treated required not only a plastic repair of the ventricular septal defect, but also a plastic widening of a hypoplastic pulmonary artery. This requires a small insertion of Ivalon into the myocardium in the region of the pulmonary artery so as to increase its size.

The surgery that I saw in Minneapolis was of a very high standard. I was able to watch a number of the cases in the immediate post-operative period. For the first few days the patients were kept in a resuscitation ward, which in itself was extremely interesting. As one would expect, not all cases go according to plan—e.g. during the repair of a ventricular septal defect, the bundle of His was caught up in the sutures, as a result of which the patient developed complete heart block. The post-operative management of all cases naturally calls for continuous attention from the medical staff. At one time I saw three patients in the post-operative recovery room, each with the following equipment attached to him—a tracheotomy tube with oxygen supply, and a suction tube available in case secretions became excessive. Two drainage tubes had been inserted lower down on each side of the chest, while stitched over the front part of the chest was one electrode of a special pace-maker, the other electrode being attached to the myocardium. The patients also had catheters in position in order to collect all urine, and intravenous cannulae were in position in both the antecubital and the femoral veins. All patients require oxygen, and cases with heart-block require a pace-maker together with its mechanical signal in operation. The whole collection of patient and apparatus was placed on a special rocking bed, in order to assist respiration.

Obviously such careful post-operative care is only available in these very highly specialized centres. I must mention that careful investigations were made in all cases to try and determine the cause of the development of complete heart block. Several operations had been done while the patient's heart was actually contracting, so it was decided to try several of them under a-systole; potassium citrate is injected into the aorta and renders the heart completely immobile.

This was of particular interest to me, because there was no electrocardiographic evidence that the patient was alive, as there was no heart beat. The circulation, of course, was maintained by the pump oxygenator system, and one knew that that was still working because one could see and hear the motors, and the blood being pumped through the circuit. The electro-encephalographic readings taken from electrodes pinned into the patient's scalp provided the only evidence that the patient was alive. The special curves on the E.E.G. show very clearly whether the patient is suffering from any anoxia or not.

Magnificent research and experimental laboratories are attached to this hospital. Operations are carried out on dogs regularly, and the experimental work is carefully controlled and recorded. I also visited several of the combined clinics where cases are discussed before being sent for surgical treatment, and I was impressed to see that where cardiac catheterization or angiocardiography had been done cine records were kept, so that all the staff could see a 16 mm. cine film showing the flow of dye through the heart chambers during the process of angio-cardiography. These records were kept of all their patients, and could be repeatedly shown until the combined committee had finally come to a diagnosis as to the type of lesion.

The team of workers at Minneapolis are not yet certain whether their pump oxygenator is the final answer to the problem of artificial circulation. Unfortunately one of the complications is the cerebral damage which the patient may suffer as a result of this form of artificial circulation. They are not certain whether micro-bubbles, 'anti-foam', the temperature or the biochemical changes in the blood are the cause of cerebral damage. Undoubtedly the fact that a percentage of cases suffer cerebral damage as a result of a successful by-pass operatiom must make all workers realize that there is yet room for improvement in the pump oxygenator field.

KIRKLIN, THE MAYO CLINIC, ROCHESTER

I had learned a great deal at Minneapolis, and most regretfully had to carry on to my third stop, namely the Mayo Clinic at Rochester, which I had always wished to see. I had decided to watch Kirklin and Ellis operate, as they employed a different type of oxygenator. I have already described two types of oxygenator, namely the bubble oxygenator used by Lillehei and Varco, and the revolving disc oxygenator used in conjunction with the bubble oxygenator as employed by Bailey. At the Mayo Clinic they used the type of oxygenator which had been initially described and built by Gibbon. It consists essentially of a series of frames of stainless steel. The blood is allowed to run over these frames rather like the battery plates in an accumulator, and while the blood runs over these steel mesh-work frames, a thin layer is exposed to an atmosphere of oxygen, CO_2, and ether, so that the gas content of the blood is altered and made suitable not only for oxygenation but also for anaesthesia of the patient. The de Bakey pump is also greatly modified and is of the revolving type which causes occlusion of a rubber tube without actually producing a wave similar to that produced by a Sigmamotor. This wave of the Sigmamotor, it will be remembered, resembles the pulse pressure wave in a normal person. This whole pump oxygenator machine is a very beautifully built piece of equipment. It is calibrated, and there are electronic devices arranged so that any increase in pressure on one side or one part of the circuit automatically speeds up or slows down the pump when necessary. An electronic device on the opposite side will also regulate the amount of blood being pumped into the patient's circulation. The blood is kept at a given temperature, and there is an intermediate circuit which allows the blood to circulate and be oxygenated without actually passing through the patient.

This special pump oxygenator machine is wheeled into the operating theatre at the commencement of operation, and is prepared by the technicians. The surgeon connects it up when the by-pass assistance is required.

The Gibbon pump oxygenator machine has undergone numerous modifications and the final apparatus is a shining, chromium-plated unit. Many hundreds of thousands of dollars have been spent in its perfection and construction, and once again we see how the amazing financial resources of the Mayo Clinic have been responsible for the development of new medical instruments. I saw the machine-tool workshops, where all the mechanical apparatus is prepared in blue prints before the final construction.

The problem of the sterilization of the apparatus must immediately come to the mind of the reader. All the tubing is autoclaved, and the stainless steel screens in the plastic containers must be sterilised by immersion in sterilising solutions as well as special autoclaving. The Bubble Oxygenator of DeWaal has the advantage of being sterilizable by autoclaving, whereas the Mayo machine can only be partly autoclaved. The DeWaal Oxygenator has the disadvantage of being open to the atmosphere, while the May machine is relatively closely sealed.

Contaminating organisms can enter these machines, so that very great care must be exercised with the sterilizing before the machines are used. I was informed that Pseudomonas septicaemias have been encountered in all centres using pump oxygenators, so that the hazard is a very real one.

The surgical technique I saw at the Mayo Clinic was of an extraordinarily high standard. The cases were mainly either pure ventricular septal defects, or ventricular septal defects associated with Fallot's Tetralogy. I also witnessed the operations for several cases of mitral stenosis, and also a few cases of aortic aneurysm. My main interest, however, was in the repair of septal defects.

I was impressed by several other things at the Mayo Clinic. Firstly, an operating theatre session was held every day in the dog laboratory in the Medical Sciences Building, and operations on dogs were performed. This building housed approximately 200 dogs, as well as numerous cats, rabbits, and other animals which were used for experimental procedures. One would have anticipated both noise and smell in such a place, but neither were present owing to the magnificent air-conditioning and sound-proofing of the whole surgical area.

The recording system at the Mayo Clinic is worthy of note. During all the major heart operations continuous recording is done, outside the theatre, by technicians who record on moving photographic film. It is possible for example to have an immediate venous pressure, arterial pressure, blood oxygen examination, or E.C.G. report issued to the surgeon through a two-way intercommunication system. Furthermore there is a two-way intercommunication system between the anaesthetist and the pump team, so that if any acceleration or deceleration is required, the surgeon need not be interrupted.

The theatre staff were extremely skilful, one theatre sister doing all the work at the operating table, threading needles with the thinnest thread in an almost miraculous fashion, and also collecting sterile instruments from a trolley placed in the theatre. These instruments presumably were placed in the trolley at the beginning of the day, and removed and replaced throughout the day's work.

I left the Mayo Clinic and travelled through Chicago, where I saw the experimental plastic oxygenator being made by the Baxter Laboratories. This curtain or envelope oxygenator is disposable, and has been used in a few human cases. It has great possibilities, though at present its use is restricted by the size of the patient. The use of this apparatus is still in the experimental stage, and it is only large enough for an average sized dog, so can only be used for small children.

I was advised to see it as used by Dr. A. Bakst in New York, but instead was shown Dr. Bakst's experimental work on revascularisation of the coronary arteries. This work is based on Vineburg's original operation, and I am convinced that in the future this will have a great effect on the management of cases with coronary ischaemia. I was greatly impressed with the specimens in which good cross-vascularization had occurred after internal mammary implantation.

I had gone to the States to see open heart surgery, and had visited three major centres. My visit was not only instructive but exciting, and I was deeply impressed with the standard of the surgery that I witnessed and the kindness and hospitality that I met everywhere.

The cardiac surgeon has travelled far in his chosen field and there remain but few fields left for him to conquer in his domain. It is left to the physiologist to uncover the numerous mysteries of the circulation under pump oxygenator conditions.