THE DEVELOPMENT OF THORACIC SURGERY[1]

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An English text-book of thoracic surgery published in 1933 does not mention the word *physiotherapy,* but Mr. D'Abreu's book the "Practice of Thoracic Surgery", published in England in 1953, apart from frequent references in the text, contains a whole section on physiotherapy in relationship to thoracic diseases. So somewhere in this period of twenty years the advantages of physiotherapy became apparent to an enlightened somebody (almost certainly at the Brompton Hospital) and those of us who follow the British line of thought in the management of thoracic diseases would not be prepared to run a thoracic surgical unit without a trained chest physiotherapist as part of the team.

Furthermore, Mr. D'Abreu states in his book that "As Physiotherapy is a profession in itself requiring a long study and training in technique, it is not possible for a surgical writer to do justice to the subject". Since accepting the honour of addressing you, I agree with him heartily in this matter of physiotherapy for physiotherapists. As a result of this firm conviction, I have chosen a surgical subject for today, but I hope it is not too disproportionately so. I am salving my conscience with the fact that the development of chest physiotherapy must have been strictly parallel with the advance in the management of thoracic disease, and with this slender thread is my subject tied to physiotherapy. Nevertheless, the thread is strengthened by the fact that the practice of both physiotherapy and thoracic surgery has this very much in common—they both depend for their success on constant attention to the physiological principles of function.

Hearts and lungs cannot be put in plaster of Paris for weeks while they heal or be fixed with nuts and bolts; therefore, thoracic surgical treatment is carried out strictly on the basis of "running repairs". It is in this problem of maintaining maximal cardiorespiratory function throughout treatment that physiotherapy has become an integral part of management.

When, in the second half of the last century, the introduction of anæsthesia, antisepsis, and asepsis, new discoveries in anatomy and physiology, and developments in pathological anatomy, finally ushered in the "Golden Age of Surgery", operative technique rapidly became established on a reasonably sound basis. Only the thoracic region was an area of which surgeons still felt shy. Isolated cases were reported by surgeons in the Middle Ages and in the Renaissance in which removal of lung tissue was carried out. Even as far back as the thirteenth century, Rollando of Salerno removed a gangrenous piece of lung which had prolapsed through an injury in the chest wall; and other isolated examples of what were then considered to be heroic measures have been recorded over the years. In point of fact, much of the medical literature of those times consisted of reports of the management of injuries sustained in the never-ending wars. As far as the chest is concerned, in spite of the numerous descriptions of chest wall and lung injuries in the literature of the Ancients and of the Middle Ages, there is not one mention of pneumothorax and there are but few references to subcutaneous emphysema. It is obvious from this that in spite of their knowledge of anatomy the surgeons of those days had no conception of the physiological function of the respiratory system. This is not to be wondered at when one realizes that it was not until long after the time of Harvey, who discovered the circulation of the blood, that the true function of the lung was understood. Harvey realized that the blood flowed through the lungs, but, as oxygen was not discovered and oxidation not thought of, he concluded

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that the lungs were in some way associated with the heating of the blood. If the essential function could not be understood, how were the clinicians of those days to realize the fact that collapse of the lung from pneumothorax following a penetrating wound was a factor of vital importance? Until the beginning of the twentieth century the approach to the problem of traumatic open pneumothorax was not really different from what it had been at the Battle of Mantinea (362 B.C.), when Epaminondas, fully aware of the fate, if not the physiology, of open pneumothorax, refused to remove the spear point from his breast until he learned that the Thebans had won the day. Even in the early days of World War I, the rule was not to intervene in such cases and to hope for the best. The realization that it was enough to transform an open pneumothorax into a closed one to remove all immediate danger only slowly found acceptance.

It must have been realized before this century that the movement of the diaphragm and movement of the intact chest wall were the essential parts of respiratory function. However, as soon as this function became disordered by alterations of pressure within the chest or damage to the functioning parts, the thinking or reasoning of the clinicians apparently became chaotic. It was not until 1876 that a Hamburg physician introduced the method of underwater seal drainage into the treatment of empyema in children; a practice which he was induced to do by his unfavourable experience in the performing of open thoracotomy drainage in children. His work shows that he had a clear conception and understanding of the danger of pneumothorax, and of the fact that any air leaking into the pleural cavity must be allowed to escape without re-entry to prevent any formation of positive pressure which would interfere with lung function.

From this time onwards, surgeons realized the need to reduce and eliminate the positive pressure inside the chest during and after intrathoracic operations. In point of fact, the immediate effect of this understanding was to hamper rather than to assist, because the dangers of the open pleura were grossly over-estimated, and even though, as early as 1884, a Swiss surgeon performed a resection of a lung, many years went by before others followed suit, and it was not until the turn of the century that other isolated instances were reported.

A turning point in the history of intrathoracic surgery was marked by the publication, in 1904, of Sauerbruch's experimental work on the management of open pneumothorax. This work was done when Sauerbruch was assistant to Von Mikulicz in Breslau. The latter had set himself the aim of performing a radical operation for cancer of the gullet; and the first important step in this direction was to perfect a technique for opening the chest which would prevent collapse of the lungs once the chest wall had been opened. Sauerbruch tried to introduce increased pressure within the bronchial tree by means of a tightly fitting mask and thus to keep the lungs inflated; however, he considered that this method was unphysiological. When he tried the method, he found that secretions in the mouth and bronchi could not be controlled with the cumbersome technique used in those days and the patient literally drowned in his own secretions, or, if the mask was removed during the operation with the chest still open to clear the secretions, the lung collapsed and the patient died from that cause. He realized that a negative pressure was necessary to keep the lung expanded in the normal person; and, in order to maintain this pressure relationship and to provide the normal conditions of pulmonary function with the chest open, he experimented with an apparatus we would now recognize as an "iron lung". He operated on the chests of dogs and rabbits by placing the animal's body in a sealed box with the head protruding at one end through a rubber diaphragm. Open ether or chloroform was administered. The pressure was reduced to a suitable level inside the box. He then introduced his arms through airtight openings in the side of the box. When the chest was opened, the negative pressure inside kept the lungs expanded. He next enlarged this apparatus to allow the surgeon and the assistant to get inside the box. After many experiments an even larger box was made and the technique was tried on

a human patient with cancer of the gullet. Unfortunately, the valve failed and the patient died. However, the second attempt was successful.

As you can see, this hopelessly cumbersome, impractical contraption had in spite of all its drawbacks made history by allowing the first elective thoracotomy to be performed. Sauerbruch's pneumatic chamber, as this was called, solved the problem from the physiological point of view. However, it broke down in practice because it was impossible to change the patient's position during an operation without endangering the pressure differential; and if this altered, the patient died. The surgeon and his assistants had very little room to move, the heat was unbearable and, finally, it was found to be extremely difficult to communicate satisfactorily with the anæsthetist, who was outside the chamber. For all these reasons, the pneumatic chamber was abandoned and today is nothing more than an historical milestone; but it is of interest to note that it has since been resurrected in a miniature form as the "iron lung" of today. The technique of anæsthesia using higher concentrations of oxygen improved, and anæsthetists became more skilled with their appliances, thereby making positive pressure with a mask or endotracheal tube safer. However, Sauerbruch pig-headedly refused to realize that his method had been superseded and, such was his influence on the Continent, that in many ways he hindered the development he had begun.

The method of positive pressure in the bronchial tree is now the standard method of anæsthesia for open thoracotomy with the exception that a cuffed or airtight endotracheal tube is inserted in preference to the cumbersome face mask. It should be mentioned in the interests of historical accuracy that inflation of the lungs during operations had already been performed in animal experiments by means of an endotracheal tube for some years before Sauerbruch's work; but in such cases the tube was introduced in the form of a tracheotomy through the neck, and it was not until 1909 that the proposal to introduce the endotracheal tube via the mouth was first made. Today, since controlled respiration through the medium of the endotracheal tube has become a normal part of everyday general anæsthesia, it is hard to realize the air of mystery that still enshrouded it as recently as twenty years ago.

After the pressure differentials were fully understood, as so often happens with a new discovery, undue emphasis was placed on the need for complete closure of the pleural cavity to prevent any air getting in after the chest had been opened for any reason. This policy was correct for operations on the chest wall or other intrathoracic viscera, but, in the early days of lung surgery patients subjected to operation sometimes leaked air from the surface of the lung, and many patients died from pneumothorax and tension pneumothorax, showing that in point of fact even though the principles were understood the practical application was lacking. If the surgeons of those days had paid as much attention to the closure of the bronchus after operation as they did to closure of the chest, and thereby prevented any leak of air into the chest cavity, many of the disasters would not have occurred.

Most of the operations in the first part of this century were performed for gross suppurative diseases of the lung, such as bronchiectasis or lung abscess; hence the patient ran a great risk of drowning in his own secretions during the operation in addition to the risks he had to face in the postoperative period from mismanaged pressure adjustment. Preparation of the patient by postural drainage and breathing exercises, which is the province of the physiotherapist today, was not appreciated. Hence secretions far in excess of those encountered today were present, and the method of controlling these during operation was by mass ligation of the whole lung root by means of an elaborate mechanical tourniquet. This controlled the vessels at the lung root and also obstructed the main bronchus and thus controlled the secretions. At that stage the operative risk of lung resection was between 15% and 20% in the best hands, and in many series the results were very much worse.

The first successful pneumonectomy was performed in 1931. Even though ligation of the individual structures in the root of

the lung was attempted in 1930, it was not until 1933 that a truly successful case resulted; this was in fact the first case in which the bronchus was adequately closed by a series of sutures, and it was performed by Rienhoff at Baltimore. This technique of individual ligation of artery, vein, and bronchus of the segment, lobe, or lung, according to how much lung tissue is being removed, is the basis of the technique for surgical lung resection today. From 1933 to 1943, even though an understanding of management of secretions, and of differential air pressures, and perfection of the "individual ligations" technique was fully established, the postoperative management of these patients was plagued by infection and it was almost an invariable rule that an empyema developed after a chest operation. The empyema would then have to be treated by prolonged drainage, making the whole performance a prolonged and debilitating affair even if the end result proved to be successful.

The next major step to place lung resection on the safe basis which exists today came in the form of the discovery of penicillin. Now, with adequate preparation of patients before operation with penicillin and other antibiotics to control infection, the use of penicillin during operation to kill organisms that may be scattered during the actual surgical technique, and follow-up antibiotic therapy, the control of infection has been made so efficient that the occurrence of an empyema, which was previously accepted as routine, is now looked upon as a disastrous and avoidable complication.

Added to this control of infection, today we have the vast improvements in methods of resuscitation and anæsthesia, together with better overall team work, including physiotherapy, rendering the resection of lung tissues no more hazardous than any other major surgical procedure; and the mortality rate of 20% to 50% of twenty years ago has now been reduced to the region of 1%.

For the most part, cardiac surgery as such only began after all these vicissitudes had been conquered. With one notable exception, all the earlier reports of surgery of the heart related to isolated examples of removing foreign bodies from the heart or pericardium, or such procedures as the drainage of the pericardial sac. Operations of this kind in their day were regarded as both heroic and rare and, considering the conditions of operating within the chest at that time, this was certainly the case.

A real advance in cardiac surgery has only come in the last ten years, and it has been my privilege to meet personally and to see the work of a number of men who have made world history in cardiac surgery, and, in spite of being the pioneers of the development of this surgery, they are men still in their forties and fifties.

I think at this stage we should differentiate between operations involving the surface of the heart or the great vessels which arise from the heart, and the surgery of intracardiac abnormalities. As I mentioned before, the removal of foreign bodies from the pericardium, drainage of abscesses in the pericardium, and the removal of constricting fibrous tissue from the surface of the heart have been practised for many years.

The first operation on the great vessels was in 1938, by Gross, of Boston, who ligated a patent *ductus arteriosus*. This was indeed a memorable occasion. We have to remember that when this operation was performed penicillin had not been discovered and the sulphonamides were the only agents we had to control the infection.

Patent *ductus arteriosus* is a congenital abnormality and, even though most sufferers from this anomaly are able to live a normal life in youth, the expectation of life is reduced to somewhere between thirty and forty years. One of the chief causes of death in this condition used to be bacterial endocarditis with infection of the blood stream, which was, and still is, commonly associated with any of the congenital cardiac abnormalities; in 1938, before penicillin, this was an invariably fatal disease. Gross showed that dissection and ligation of the abnormal vessel were possible, and that if the operation was successful the patient was quite cured and would expect to live a normal life. What was more important, there was no further risk of the dreaded bacterial endocarditis. The mor-

tality in this operation even in those days was relatively low, and the operation soon became an established surgical procedure. A further advance, however, was that Mr. Tubbs, a surgeon at the Brompton Hospital, London, showed that, when a patient was diagnosed as suffering from bacterial endocarditis superimposed on a patent *ductus arteriosus,* if the operation was undertaken in the presence of the infection (a really heroic step in those days) the infection could be controlled and the patient would recover instead of dying. His fame for developing this step in cardiac surgery was short-lived, because with the advent of penicillin a few years later bacterial endocarditis could be cured, and the operation could be performed as an operation of election after recovery; and that is the standard management today.

By 1944, during World War II, the control of infection by penicillin was established, and it was in this year that Gross, at Boston, and Crafoord, in Sweden, separately succeeded in dissecting a coarctation of the aorta and performing an end-to-end anastomosis to restore continuity. This advance was only made possible by the extensive use of animal experimentation. By that I mean the operation was planned and then tried on anæsthetized animals before performing it on a human being, to perfect the technique as far as possible and thus to reduce the operative risk of the first patients. This application of animal experimentation has been one of the major factors in the development of cardiac and cardiovascular surgery, as it is impossible to develop a safe surgical technique on the heart and great vessels without the opportunity to practise it and to develop it in the animal laboratory. Animal experimentation forms a part of the training in all large American centres and, almost without exception, the training of surgeons in that country demands the spending of a period of time in the animal laboratory. Last year, when I visited the Mayo Clinic, I found that the animal experimental theatre there was of a standard equal to or above that of many operating theatres for human subjects in this country today.

Another milestone in the development of cardiovascular surgery was the development of the so-called 'blue baby' operation by Blalock and Tausig. Dr. Tausig is a pædiatric physician with a particular interest in congenital cardiac abnormalities. Dr. Blalock is a surgeon at Johns Hopkins Hospital in Baltimore. The 'blue baby' condition is one in which a number of abnormalities in the heart and great vessels occur together. These abnormalities affect the heart in such a way that the blood flow is obstructed from its normal passage into the lungs and the relatively unoxygenated blood is shunted through a defect in the heart out into the general circulation. The blood which should be passing through the lungs is being passed around the body in an unoxygenated condition, and therefore the patient is cyanosed at all times—hence the expression 'blue baby'. Tausig and Blalock conceived the idea that the blood flow to the lungs could be increased by attaching one of the systemic arteries in the vicinity of the lung root to the pulmonary artery and thereby more blood would be carried to the lungs. They reasoned that by doing this there would be better oxygenation of the circulating blood and improvement in the patient's condition. Their operation consists of anastomosing the subclavian artery to one of the pulmonary arteries. The operation brought relief to many children and, as this is one of the commonest congenital lesions, there was a huge supply of patients waiting to be done in the world, and for several years after the war this was one of the commonest cardiac operations performed. In spite of the improvement it brings, it is a palliative operation only and not a curative one such as we have discussed for coarctation of the aorta and for patent *ductus arteriosus.*

The lesion I have been describing is an intracardiac abnormality, but the operation is only compensatory and does not tackle the actual abnormality; to effect a cure would require an operation within the chambers of the heart. This very problem of operating inside the heart is the basis of one of the biggest research programmes in the world today. The first step in the direction of actual intracardiac technique was the development of the surgical treatment for mitral stenosis, which makes an interesting story in itself.

In the *British Medical Journal*, in 1923, there is a short reference to work that was being performed in America by Cutler and Levine, of Boston, in an attempt to relieve the obstruction caused in the mitral valve as a result of rheumatic carditis or rheumatic fever. Their work at that time was confined to animal experiments, using instruments passed blindly through the heart wall, and, even though they paved the way for further developments, they never actually operated on a human being.

In 1925, Mr. Souter, from the London Hospital, described an operation for the treatment of mitral stenosis by approaching the mitral valve through the auricular appendage of the left atrium. This article is of particular historical interest because the technique he devised for entering the heart and approaching the mitral valve from above is almost identical with the method used today. It is even more interesting to study the article because the conclusions he drew from this one attempt on the mitral valve show that he virtually predicted most of the facts and conclusions that we accept in the modern treatment of this condition. For some reason which has never been explained, he did not repeat the operation, although the original patient survived.

It was Bailey and Harken, in America, and Brock, in London, in the years immediately after World War II who developed the surgery of the mitral valve in its present form. The operation for mitral stenosis is one which has become quite humdrum, and it carries a mortality of less than 5%. It is now a standardized unglamorous routine procedure but, when one reads articles as recently as those of ten years ago, the mortality was in the region of 30%, and the hair-raising descriptions of colossal blood loss and death on the table make real blood-and-thunder reading. It is encouraging for the future to think of the advance that has been made in this one branch of cardiac surgery in the short period of ten years.

Whilst the surgery of mitral stenosis is an intracardiac surgical procedure, it is nevertheless blind, inasmuch as it is done with the heart closed, except for the finger and knife which are introduced through a suitable opening. However, there are other intracardiac lesions which are now coming within the range of surgical treatment which can only be dealt with by an open technique; by that I mean the heart has to be opened and the lesion actually seen and handled. Obviously this cannot be done with blood still flowing through the heart; and the techniques which are being developed to overcome this problem involve the use of pump oxygenators by means of which the blood flow through the heart is completely bypassed through an external pumping apparatus, leaving the cavities of the heart free of blood, to allow the surgical procedure to be carried out. The same result can be achieved, but for a shorter time, by cooling the patient to low temperatures before beginning the operation; then the body tissues do not deteriorate from oxygen lack during the period of complete obstruction of the blood supply. With the patient cooled, the main vessels to and from the heart are completely occluded, the heart is opened, and the repair is made. The heart is closed in as short a time as is possible and the circulation is re-established.

Another method which has been used in Minneapolis is, instead of using a pump oxygenator, the circulation of a suitable relative of the same blood group is connected through plastic tubing to the patient in such a way that the patient's heart is bypassed through the donor's circulation, leaving it free for surgical intervention as outlined above. This method is now, however, losing favour because of the risks to the donor as well as the great hazard to the patient himself.

Evolving from the surgery of coarctation as introduced by Gross and Crafoord for direct anastomosis, it became necessary in certain cases to insert grafts to bridge gaps in the aorta, if the abnormality was such that two ends could not be brought together. A further development allowed other abnormalities of the aorta to be resected and the diseased vessel to be replaced by grafts. The conditions to which I refer are: clots obstructing the abdominal aorta, damaged areas in the aorta from injury, and aneurysmal dilatations of the aorta. The material that can be grafted into place can either be an aorta from a suitable person recently deceased, the aorta being taken in an aseptic manner from the body and stored

in a deep freeze; or, alternatively, by the use of suitable plastic material formed into tubes of required sizes. The method we have used here has been by moulding a plastic substance (Ivalon) into a tube and sterilizing it by boiling; but there are many others. While in England last year, I saw Professor Robb at St. Mary's Hospital in Paddington, using ordinary orlon shirting which could be bought in Oxford Street for about ten shillings a yard. This was simply sewn into a double thickness tube by a suitable fine suturing technique and used instead of a piece of human aorta from a deceased person.

Far more elaborate operations than these have been attempted for lesions in the arch of the aorta, and there are some descriptions in the recent thoracic surgical literature of operations, taking up to twenty hours, where most ambitious undertakings have been embarked on for the replacement of the whole arch of the aorta with a complicated graft. In such cases, apart from the replacement of the aorta itself, the blood has to be bypassed from the diseased area to maintain the body circulation; this means many suture-lines and many anastomoses before the actual operation of replacement can begin. There are isolated cases of success in this type of surgery, but one requires a number of surgeons to perform an operation of this nature, as it is physically impossible for one person to continue the surgery for longer than six or seven hours at a time.

Thoracic surgery has been rightly described as the growing edge of surgery today, and, even in the ten years during which I have been associated with it, the changes in technique and the advances made in diagnosis and management have been phenomenal. The advances are being made so rapidly that it is almost necessary to travel overseas every year to keep pace with the work of others.