The CENTRAL AFRICAN JOURNAL OF MEDICINE

Dr. DAVID LIVINGSTONE

Vol. 4. No. 9.

CONTENTS

SEPTEMBER, 1958.

ORIGINAL ARTICLES

EDITORIALS

PUBLISHED MONTHLY, ANNUAL SUBSCRIPTION £2 2s. 0d.
Registered at the General Post Office as a Newspaper.

Vol. 4. No. 9. September, 1958

The Central African Journal of Medicine

The Artificial Heart*

BY

DENIS H. THOMPSON, O.B.E., F.R.C.S.

Honorary Consultant Surgeon, Bulawayo General Hospital.

Recently Research Assistant, University of Minnesota.

In 1896 Paget wrote, "Surgery of the heart has probably reached the limits set by nature to all surgery; no new method and no new discovery can overcome the natural difficulties that attend a wound of the heart."

Since that time there have been two world wars. During the last of these it became obvious that injuries to the heart were not necessarily fatal and could be repaired. Since the second world war certain "blind" intracardiac procedures have been performed on the heart with great success, the most satisfactory of these being the attack on mitral stenosis.

Surgeons have always been anxious to attack lesions of the heart under direct vision, but this has necessitated a heart which is dry. In order to do this one of two things had to be done. Either the circulation of the heart had to be stopped completely or it had to be by-passed with extra-corporeal circulation.

In 1952 the principle of hypothermia was introduced to cardiac surgery. In this method the patient lay in a bath packed with ice, the temperature being reduced to 30° C. or less. With the low temperature it was found possible to stop the circulation for a period of up to eight minutes without severe damage to the brain. On its first use an atrial septal defect was repaired. The operation took six minutes, but because of air trapped in the heart the patient died. History's first open heart operation in a dry field looked like a failure.

Four days later, Lewis *et al.* (1953), working in the department of Professor Wangensteen at the University of Minnesota, did an identical operation on a five-year-old girl who survived.

The difficulty of hypothermia lies in the short period of time which is available and the dangerous complication of ventricular fibrillation which is liable to occur.

In 1953 an oxygenator of the stainless steel screen type was used. The patient was a university student of 18 with an atrial septal defect. The circulation was by-passed for 26 minutes. The operation was a complete success, but, despite this hopeful start, the heart-lung machine

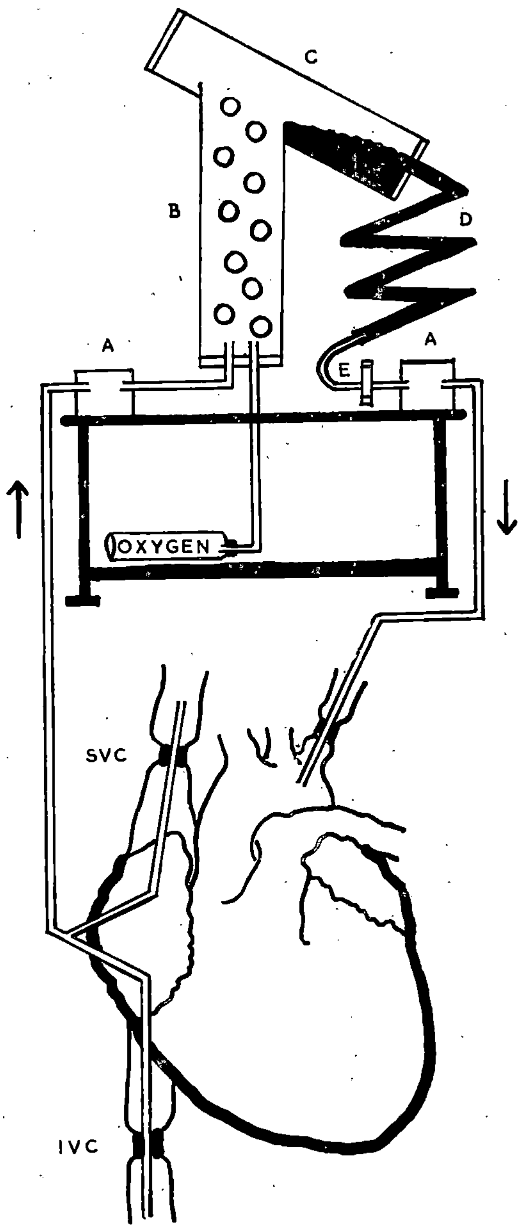

Fig. 1—Basic principles of the bubble oxygenator. A. Pumps. B. Oxygenator. C. Debubbling chamber containing antifoam. D. Helix (reservoir). E. Filter.

* Paper presented at a meeting of the Consultants and Specialists' Society of Matabeleland.

was far from perfected. As a temporary expedient, while difficulties were being corrected, Walton Lillehei *et al.* (1954) of Minnesota developed a method called "Cross Circulation." For this method he used a donor, usually the father if the patient was a child. He connected their circulatory systems, so making the donor's heart and lungs do the work of the patient during the operation. The grave disadvantage was that it risked two lives instead of one. Nevertheless, some 45 operations were done in this way. To avoid the risk to the donor, another method was tried by Lillehei. For this, a freshly removed dog's lung was used as the oxygenator, and some 15 operations were performed. This method fell away when reports were received from the laboratories about a better oxygenator. Extensive research had been carried out on the bubble

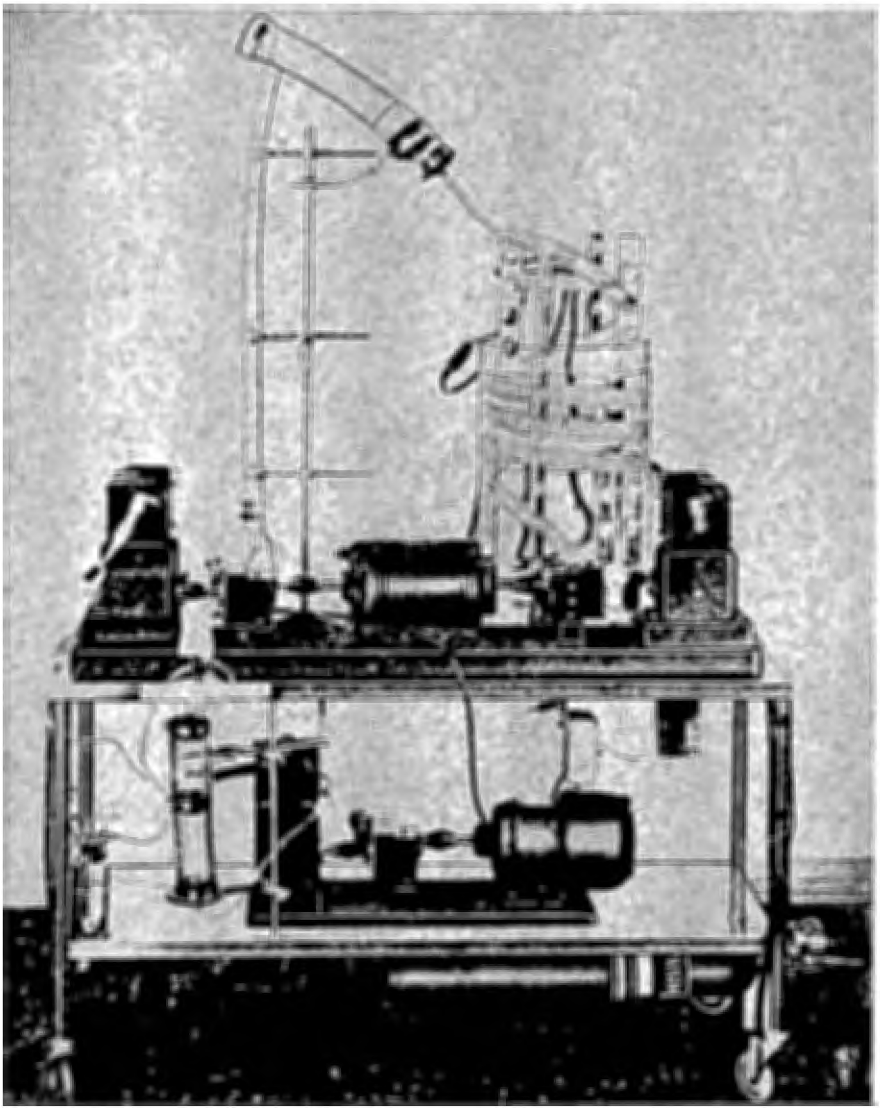

Fig. 2—De Wall bubble oxygenator, utilising a sigmamotor pump. In addition, a small pump is shown on the lower shelf for the coronary sinus return.

oxygenator, which had been used by other research workers for some time without success. De Wall and Lillehei were confident of its advantages and managed to perfect the technique of using bubbles to oxygenate the blood (Lillehei *et al.*, 1956). It is now the basic principle of many oxygenators. A large number of cases have undergone intracardiac surgery utilising the bubble oxygenator, nearly 400 having been performed in Minneapolis alone. Not long after Lillehei began this method, Kirklin *et al.* (1956) and his assistants at the Mayo Clinic demonstrated a pump-oxygenator of the Gibbon type with stainless steel screens. This machine has been used on large numbers of patients with success. Although there is still controversy about the best type of oxygenator, all workers are agreed that certain basic requirements are necessary for an efficient machine. These are as follows:—

1. Arterial blood must be adequately oxygenated up to 95 per cent. saturation.
2. Venous oxygen saturation should approximate to 70 per cent.
3. Trauma to the blood corpuscles must be minimal. Plasma haemoglobin should not be raised unduly at the end of the perfusion.
4. The P.H. of the blood should not be altered by the perfusion.
5. The apparatus should be easy to sterilise.
6. The machine should not be unnecessarily complicated and there should be an alternative method of working the machine should a power failure occur.

These requirements are met by most of the oxygenators in use to-day. The bubble and the steel screen oxygenators are the two types most widely used. The rotating disc, over which blood is filmed in an atmosphere of oxygen, is used by Gross in Boston. There is yet another type which is still being developed. It consists of a system of thin polythene bags through which blood is pumped. These are surrounded by oxygen which enters the blood by diffusion. It appears to be the ideal method, but in order to achieve an adequate flow the machine has to be enormous, which is a disadvantage.

The conditions which are amenable to surgery with the use of an extra-corporeal circulation will be the subject of a later paper in which details of clinical cases will be discussed.

It is hoped that in the near future a start will be made in the Federation with extra-corporeal circulation. Before this is undertaken some laboratory and research facilities must be made available in order to train a team and to overcome the inherent difficulties in this procedure, so avoiding the tragedies that have occurred in some centres. If intracardiac surgery using the artificial heart is contemplated, an adequate supply of fresh blood is essential. This throws a great strain on the blood transfusion service unless adequate plans have been made for this development.

I think we should be guided by Kirklin, of the Mayo Clinic, who stated, "The maintenance of life by whole body perfusion for one hour, during which time open intracardiac operation is performed, can be accomplished at a very low risk provided all details are properly managed. While sporadically satisfactory results can be obtained otherwise, uniformly excellent results demand a thorough knowledge of the myriad of factors affecting the adequacy of the procedure, a carefully trained team and proper equipment" (Kirklin *et al.*, 1957).

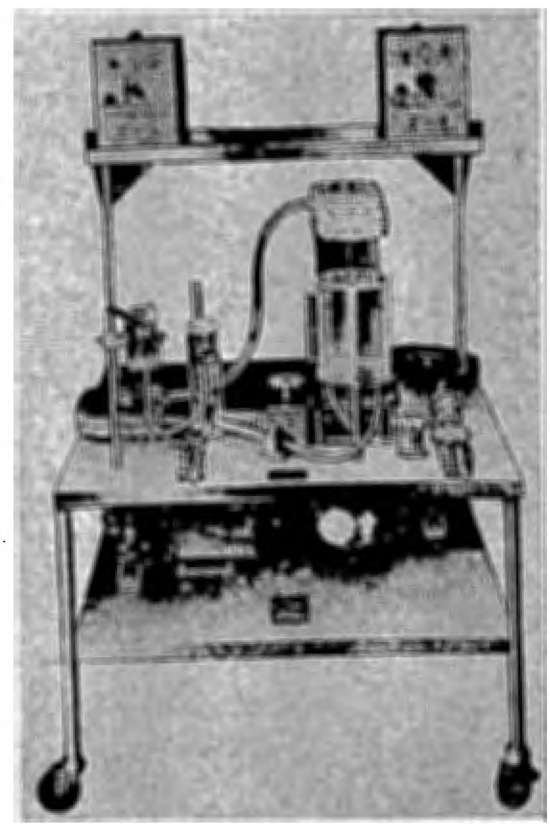

Fig. 3—The Gibbon type machine, using stainless steel screens for oxygenation of the blood. This machine is marketed by the Mark Company.

Whereas it may still be possible for some patients to make the long journey to America, the vast majority of cases requiring intracardiac surgery will not be in a position to do this and will have to be treated in this country.

While perfection should be our aim, it will not be necessary at the outset to have the intricate and expensive equipment found in the large American centres. In many of the smaller centres adequate intracardiac surgery is performed with equipment on a less lavish scale.

REFERENCES

1. LEWIS, F. J. & TAUFIC, M. (1953). *Surgery*, 33, 52-59.
2. WARDEN, H. E., COHEN, M., READ, R. C. & LILLEHEI, C. W. (1954). *J. Thoracic Surgery*, 28, 331.
3. LILLEHEI, C. W., DE WALL, R. A., READ, R. C., WARDEN, H. E. & VARCO, R. L. (1956). *Dis. Chest*, 29, 1.
4. KIRKLIN, J. W., DONALD, D. E., HARSHBARGER, H. G., HETZEL, P. S., PATRICK, R. T., SWAN, H. J. C. and WOOD, E. H. (1956). *Ann. Surgery*, 144, 2.
5. KIRKLIN, J. W., PATRICK, R. T. & THEYE, R. A. (1957). *Thorax*, 12, 93.