ASSISTED CIRCULATION*

VERNON WILSON, M.D. (CAMB.), M.R.C.P. (EDIN.)

Department of Surgery, University of the Witwatersrand, Johannesburg

Dr. Wilson represented the Cardiac Surgical Research Unit attached to the Department of Surgery of the University of the Witwatersrand. This Unit was formed 3 years ago with Mr. G. R. Crawshaw, thoracic surgeon, Dr. K. B. Vetten, anaesthetist and Dr. V. H. Wilson, physician, and has been supported by the Nuffield Foundation. He reported that Mr. L. Fatti had been closely associated with this work; Dr. K. H. Foord, anaesthetist, had studied the problems connected with the artificial circulation; Dr. P. A. H. Knocker has been associated during experiments with refrigeration, Dr. L. Kreel with electrocardiography, and Dr. H. Rudinsky with the estimation of blood-oxygen saturation and the CO_2 combining power of the blood; and Dr. W. J. Pepler, pathologist and Dr. W. M. Politzer, biochemist, had also given their services.

The ultimate purpose of the Unit's investigation was to explore the possibilities of correcting incompetence of the mitral valve surgically. For this a dry left ventricular cardiotomy was required to allow detailed study of the chordal attachments of the mitral valve and the mobility of the cusps. These requirements demanded that cardiac surgery could be performed without time restriction and with the same confidence as other well-established operations upon the chest, such as pulmonary resection, and with an operative mortality of less than 10%.

In addition therefore to the study of the anatomical and functional disturbance of the incompetent mitral valve, 50 dogs had been specifically used to study the control of heart action and the behaviour of the circulation during attenuation and arrest in relation to ventricular cardiotomy, with and without artificial forms of circulatory maintenance. Studies in pharmacology, pressure and ECG recordings, the O_2 saturation and CO_2 combining power of the blood, and other forms of biochemistry and pathology had been undertaken.[1–5]

Two forms of artificial circulatory maintenance had been studied:

1. Cross perfusion between two living organisms.
2. The artificial heart-lung pump.

In these the arterial system of the subject was perfused with blood at sufficient pressure to close the aortic valve and to maintain viability of tissue, whilst venous blood was withdrawn from the subject by catheters in the vena cava to prevent blood entering the heart and lungs. The Unit had found that the two main difficulties in applying the extracorporeal circulation had been (*a*) the use of heparin to prevent clotting of blood in the artificial system and its connections, and (*b*) the difficulties in withdrawing blood artificially from the veins.

CROSS PERFUSION

To offer hope for heart surgery unrestricted by time, an experiment in the cross perfusion between two dogs was presented. The photograph of the operating theatre was shown, illustrating the organization required, with the junction machine between the two animals consisting of catheters, venous and arterial booster pumps, and a 4-channel apparatus for recording pressure and ECG to control the general condition of the animals. During the experiment the Donor maintained the general condition of the Recipient, who had a thoracotomy and left ventricular cardiotomy. The Donor supplied blood by a polythene catheter from one femoral artery to the subclavian artery of the Recipient, which returned blood from its femoral vein to the same vein of the Donor. In the Plate (Fig. 1) a series of records of the ECG and systemic arterial pressures of the Recipient and the Donor illustrated the progress of the experiment. Tracing 1 showed the ECG and systemic arterial pressure of the Recipient before thoracic surgery was started and before perfusion by the Donor. Tracing 2 showed the Recipient's records during the cross perfusion and illustrated the serious fall in the carotid pressure soon after the inferior vena cava was clamped. Tracing 3 showed the ventricular fibrillation which occurred soon after, and also the carotid pressure of the Recipient supplied by the Donor. Dr. Wilson considered that ventricular fibrillation remained a serious complication. The Unit had found that the most important single factor in the causation of ventricular fibrillation was a serious fall in the systemic arterial pressure, whatever its cause, be it loss of blood volume, refrigeration, neurogenic shock, or rotation of the heart upon its venous return. Ventricular fibrillation can be suppressed—and suppressed it must be before heart beat can be re-established—by electrical defibrillation and chemical means in 75% of cases and, if controlled soon enough, the patient's life saved in some. In this experiment the electrical defibrillator and various poisonous quantities of potassium, magnesium and quinine dyhydrochloride, failed to stop the ventricular fibrillation of the Recipient, which continued for 52 minutes. During this period, left ventricular cardiotomy upon the Recipient showed a dry left ventricle without evidence of clot. Finally 20 c.c. of ½ mEq potassium chloride injected directly into the coronary system of the Recipient arrested the ventricular fibrillation, soon after which the heart action returned spontaneously (Tracing 5). Later, sinus rhythm and a good systemic blood pressure was established with the Donor disconnected (Tracing 6). Tracing 4 showed the Donor's records during perfusion. The recovery of the Recipient's heart to provide a carotid pressure and maintain breathing and corneal and gag reflexes after 52 minutes of ventricular fibrillation, in spite of poisonous substances injected into the coronary system, encouraged belief in artificial circulatory methods and hope for heart surgery without time restriction. Further experiments on cross perfusion, however, demonstrated some serious dangers for the Donor dogs, so as to make the team feel that this method was prohibitive at present for human application.

ARTIFICIAL HEART-LUNG PUMP

With regard to the artificial heart-lung pump, the Unit had studied the Jongbloed and Brinkman machines. The demonstrations in which Dr. Wilson and Mr. Crawshaw assisted in the laboratory of Professor Jongbloed in Holland encouraged them to accept his machine as practical. Dry heart-surgery was possible with a well-maintained intermittent arterial pressure and cardiac output of 4 litres per minute by a compact and simple machine without biochemical problems or difficulties in maintaining venous return from the body. Its disadvantage was the heparinization required of the animal's blood volume and the 4 pints of blood needed to fill the dead-space of the machine. Dr. Wilson considered that as the effects of heparin are unpredictable and its neutralization uncertain its acceptance by the surgeon was difficult at present. The Unit had found, for instance, that whereas one animal had bled to death in ½ hour with 10,000 units of heparin during thoracotomy, another showed no signs of bleeding with 50,000 units. Furthermore the effects of heparin had been found sometimes to be delayed so that during operation, even though no signs of bleeding had been observed, the animal had died some hours later from a fatal haemorrhage unrelated to surgical technique. On account of this and the expense of the Jongbloed machine the Brinkman machine was purchased. The Brinkman theoretically overcame the heparin difficulty by siliconization of its surface; in practice this was not found to be fool-proof. Furthermore the vibration pumps, although most ingenious, were subject to break down and were difficult to adjust; venous return was also difficult to maintain.

In the experience of the Unit the extracorporeal circulation cannot yet provide ideal conditions for open cardiotomy, namely surgery unrestricted by time, with an immediate mortality of less than 10%. When the mechanism of bleeding and clotting was fully understood and controllable, the Jongbloed machine, which imitates physiological condition by intermittent pumping, would provide satisfactory conditions.

The purpose of Dr. Wilson's paper was to show that a sincere attempt was being made to understand the basic principles and difficulties of the artificial and arrested circulations; to explain why the extracorporeal circulation was still considered to be

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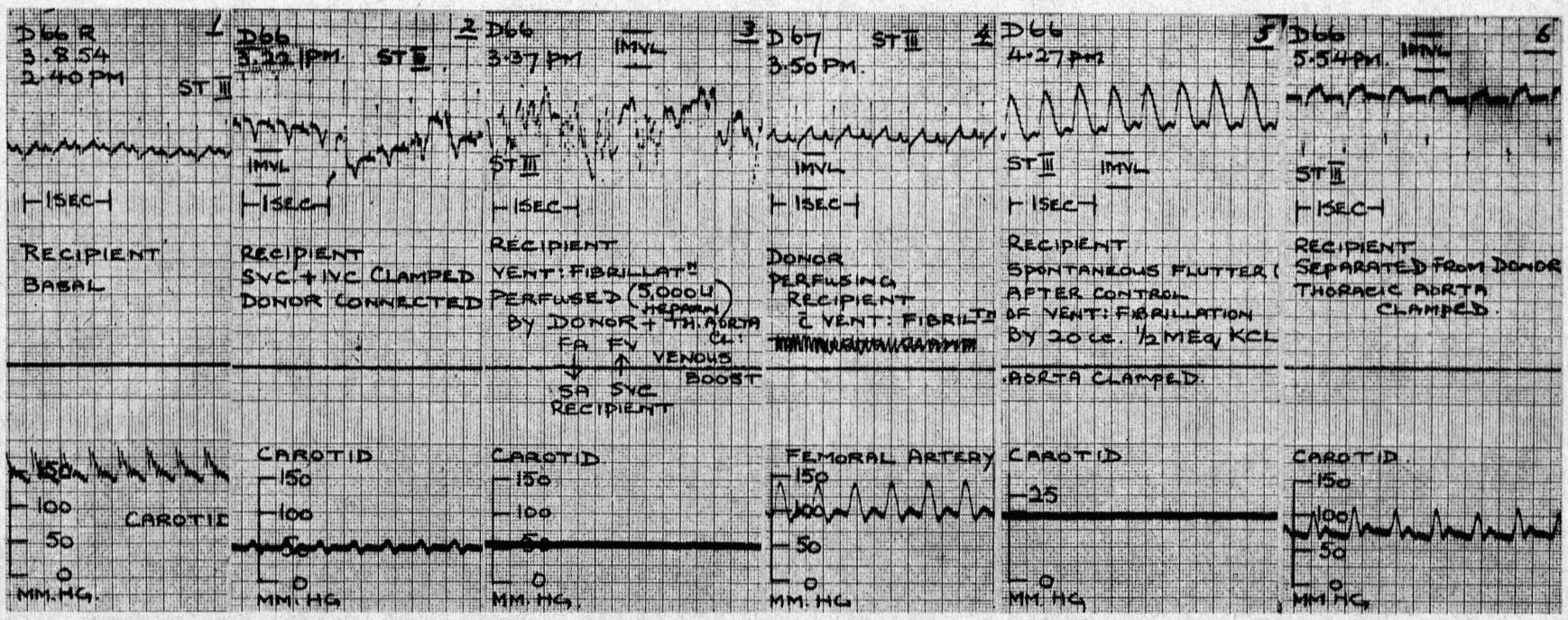

Fig. 1. Serial ECG and carotid pressures of the Recipient and Donor dog during an experiment in cross perfusion of the Recipient undergoing open left ventricular cardiotomy. During the cardiotomy the Recipient's mean blood pressure of 25-50 mm. Hg is recorded in tracings 3 and 5, and was maintained for over 50 minutes until the venrticular fibrillation of the Recipient was suppressed. Tracing 6 shows the final circulatory state of the Recipient disconnected from the circulation of the Donor.

experimental, and to give hope that the ideal would be realized, so that major surgery one day would be possible upon the heart, which potentially was very good material for this work.

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