THE DIFFICULTIES AND DANGERS OF CARDIOVASCULAR SURGERY WITH AN ARRESTED CIRCULATION*

A Preliminary Communication

PAUL MARCHAND, CH.M. (RAND), F.R.C.S.
and
J. C. ALLAN, CH.M. (RAND), F.R.C.S. (EDIN.)

Thoracic Surgery Unit and Department of Surgery, University of the Witwatersrand, Johannesburg

Within the space of 10 years, surgery for stenosis of mitral, pulmonary and aortic valves has become commonplace. With increasing familiarity with the vagaries and difficulties of this type of surgery the surgeon, teamed with the anaesthetist and cardiologist, has so reduced the dangers of operation that today the risks are comparable with those of any other accepted major surgical procedure. These cardiac operations are however restricted to stenotic lesions, which are corrected by methods such as valvotomy or shunt procedures that do not require direct visualization of the lesion. During the past 3 or 4 years attention has become focussed upon a large group of cardiac diseases that could be treated by open cardiotomy. This procedure necessitates the arrest of the circulation so that the operative field may be clearly visualized, and carries obvious anoxic dangers to the heart, brain, spinal cord, liver and kidneys. Many operations have already been successfully performed throughout the world under conditions of hypothermia, but the scope of the operations are seriously limited by time. It is generally agreed that at body temperatures of 27°C the surgeon has from 8 to 10 minutes of comparative safety in which to complete his manipulations.

In the Department of Surgery of the University of the Witwatersrand, in common with other centres in many parts of the world, experimental work is in progress designed towards lessening the dangers of present techniques and extending the time of safe open cardiotomy.

The Indications for Operation with an Arrested Circulation These include such intracardiac anomalies as interatrial septal defect, intervertricular defect, infundibular stenosis, and myxoma of auricle. The only extracardiac anomalies which could possibly justify the procedure at the present time are those which imminently jeopardize life and which cannot be dealt with in any other way. These are aorto-pulmonary septal defects and certain aneurisms of the thoracic aorta.

EXPERIMENTAL WORK

Essentially the problems of the arrested circulation are (*a*) the conservation of the integrity of the brain, spinal cord, liver and kidneys, and (*b*) the conservation of cardiac function and the application of efficient methods of restoring the heart's action should ventricular fibrillation supervene.

(*a*) *The Integrity of the Brain, Spinal Cord, Kidney and Liver*

There are two possible approaches to this problem—either a supply of oxygenated blood must be maintained or the demands for oxygen should be so reduced as to make it possible to exclude the blood supply to the brain, spinal cord, kidneys and liver for a period of some 20 minutes without producing irreversible changes.

The first method entails the development of an efficient extracorporeal heart-lung machine or some efficient form of cross-perfusion in which a donor supplies oxygenated blood to the brain, spinal cord, kidneys and liver of the individual being operated on. (*The problems presented by these methods were presented by Dr. Vernon Wilson—(see page 000 of this issue).*

The second possibility may be achieved by lowering the body temperature to levels where the oxygen uptake is so reduced that the brain and spinal cord may be depleted of a fresh source of oxygen for appreciably longer periods than would otherwise be possible and yet survive intact. A series of experiments on dogs, designed to test the efficiency of hypothermia, have been performed in the Department of Surgery, University of the Witwatersrand and it has been established that at normal temperatures the dog can endure total circulatory arrest for periods up to 8-10 minutes and recover completely. Circulatory arrest lasting between 10 and 15 minutes always produces changes as evidenced by coma, paraplegia etc., which may however be temporary. Beyond 15 minutes profound irreversible damage results.

Similar experiments have been repeated at varying degrees of hypothermia and it is established that at temperatures below which 28°C the brain and spinal cord survive total circulatory arrest for periods of up to 15 minutes.

Hypothermia is not without danger. Changes have been produced in the kidneys and liver at low body-temperature. These changes would appear to be caused by the hypothermia itself and may well account for deaths which occur after re-warming has been successfully accomplished.[1]

(*b*) *The Conservation of Cardiac Function*

In order to operate upon the interior of the heart it is necessary to empty the heart of blood so that the operation field shall be clearly visible. It is possible to achieve this by clamping the superior vena cava, inferior vena cava and azygos veins, whilst the blood entering the heart *via* the coronary sinus can be removed by suction. If this procedure is carried out without any ancillary aid the heart may continue beating for many minutes, but recovery of function after the release of the inlet clamps is most unusual if the isolation has continued for more than a few minutes. We have established that the period of time during which clamping can be safely applied to the otherwise normal dog heart is directly dependent upon the number of times the heart beats once the source of oxygenated blood has been removed. On an average 800-1,200 beats represent the limit of tolerance of the anoxic heart and beyond this recovery is most unusual. Therefore in the presence of bradycardia comparatively long periods of occlusion are possible, whereas with tachycardia the safe period of cardiac isolation is diminished.

Under conditions of hypothermia the heart rate is considerably slowed and fairly prolonged periods of isolation are tolerated by the heart. At 27°C, however, the heart rate is seldom reduced to below 80 beats per minute and theoretically this rate will only allow a safe period of about 10 minutes of occlusion. At lower temperatures the heart rate is still further slowed, but the incidence of deaths due to cooling and the irritability of the heart with the tendency to ventricular fibrilation on manipulation progressively increases with lower temperatures. Ideally, therefore, a temperature of 27°C to protect the brain and spinal cord, together with some method of slowing the heart further, would seem to be required. This ideal has been accomplished experimentally by stimulating the right vagus nerve in the neck; but the possibility of permanent injury to the nerve and possible side-effects on the gastro-intestinal tract are theoretical objections to its use in humans. Accordingly slowing of the heart has also been attempted by other means and perfusion of the coronary vessels with acetylcholine has been used successfully.

The paper was illustrated by a film showing the various experiments which the authors had performed.

CONCLUSION

Open cardiotomy is already a practical procedure under conditions of hypothermia. The time restriction is not due to adverse effects upon neural tissue, for these will survive much longer than the heart at 27°C. If hypothermia is combined with slowing of the heart it is possible to arrest the circulation for appreciably longer periods than with hypothermia alone.

1. Knocker, P. (1955): Lancet, **2**, 837.

* Address given at the South African Medical Congress, Pretoria, October 1955.