Cold reperfusion after circulatory arrest

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In this issue of the Journal, Di Mauro and associates report an outstanding series of patients with acute and elective aortic arch operations, with different cerebral protection methods [1]. The authors are to be congratulated for their excellent results in this mostly elderly, high-risk population and for providing new information in this complex field of aortic surgery.

In the hands of most aortic surgeons, the results of aortic arch surgery have been improving gradually over the last decades. Nevertheless, neurological injury is still a frequent cause of death and complications, as a result either of focal thromboembolic episodes or of global ischaemia during the arrest of antegrade cerebral circulation.

Various approaches have been used throughout the world to try to reduce the incidence of both kinds of neurological complications. In addition to clinical studies, laboratory investigations have also contributed to an understanding of how best to protect the brain during surgery that requires the interruption of normal cerebral perfusion.

HYPOTHERMIC CIRCULATORY ARREST

The exact mechanism of cerebral protection during hypothermia is not well understood. It is widely assumed that at least a portion of the protection afforded by hypothermia is secondary to metabolic suppression. Interestingly, it has been demonstrated that metabolic suppression due to hypothermia is still 24% of baseline values at 20°C and 16% of baseline at 15°C [2]. Deep hypothermia at low temperatures provides ample protection of the brain and other important organs, such as the kidneys. Circulatory arrest provides the possibility of performing operations on the aortic arch without placing a clamp on the aortic wall, thus avoiding clamp injury of fragile dissected aortic tissue. The major drawback of hypothermic circulatory arrest (HCA) is the time limitation. Studies suggest the ‘safe period’ of circulatory arrest at an oesophageal temperature of 10°C to be 40 min [2].

ANTEGRADE CEREBRAL PERFUSION

As mentioned before, the major drawback of HCA is the limited duration of a safe cerebral circulatory arrest. For this reason, new techniques have been developed over the last decades. One of these is the use of antegrade cerebral perfusion. The basic concept of this technique is to perfuse the cerebral arteries with blood cooled to between 10 and 25°C without cooling the patient to profound hypothermic temperatures. Therefore, cardiopulmonary bypass times can be shortened without losing the benefit of carrying out an open distal anastomosis. One of the largest antegrade cerebral perfusion (ACP) series was studied by Bachet et al. [3]. Within a time frame of 15 years, 171 patients aged between 25 and 83 years underwent replacement of the transverse aortic arch with the aid of cold blood antegrade selective perfusion. The mean duration of cerebral perfusion was 60 min. All but seven patients (4%) in this series showed signs of normal awakening within 8 h postoperatively. Six patients (3.5%) had fatal neurological complications, and 16 patients (9.3%) had non-fatal neurological complications. Twenty-nine patients (16.9%) died during the hospital stay. One of a recent large studies performed by Leshnower et al. from the Emory University School of Medicine included 500 patients. Hospital mortality was 4%, and permanent neurological complications occurred in 5% of patients [4]. It seems that ACP provides excellent protection, avoiding the use of deep HCA and prolonged cardiopulmonary bypass time.

RETROGRADE CEREBRAL PERFUSION

Around 25 years ago, a number of surgeons enthusiastically adopted the use of retrograde cerebral perfusion (RCP) as a means of improving the neurological outcome following complex cardiovascular and aortic surgery, even though considerable uncertainty existed regarding both the efficacy and the safety of this technique [5]. The appeal of RCP lies in its possible benefit both in reducing embolic injury and in prolonging the safe duration of HCA. Regarding the results of RCP, there is a discrepancy between clinical and experimental results. The Japanese experience with RCP performed in 3 different medical centres included 249 patients with a median age of 65 years [6]. Hospital mortality in this study was 10%, and stroke rate was 4%. Our own experience with RCP includes a cohort of 54 patients [7]. Multiple regression revealed the lack of RCP to be the only significant independent risk factor for permanent neurological dysfunction. Several experimental studies have clearly demonstrated, however, that RCP does not perfuse the brain in pigs [8]. Only a minimal amount of blood entering the superior vena cava passes through the brain capillaries. Most of the blood is...
shunted into the inferior vena cava or passes though the venous head vessels. We strongly believe that the apparent superiority of RCP over profound hypothermic circulatory arrest in general can be explained by the sustained intracranial cooling during HCA made possible by RCP, and may therefore enhance the topical cooling effect of icepacks around the head.

COLD REPERFUSION

As mentioned above, the mechanism of cerebral injury following HCA remains unclear. The extent to which postischaemic cerebral damage is affected by events during reperfusion is not known. The idea that cold reperfusion (CR) after HCA might improve cerebral recovery has some intrinsic appeal. The hypothesis that this modification in the technique of implementing HCA might be beneficial was reinforced by the independent observations of investigations studying the cerebral blood flow following HCA in infants recovering from operations to correct congenital heart defects. Both reported that the postoperative velocity of flow in the middle cerebral artery was much better in patients in whom rewarming was preceded by an interval of CR following HCA [9, 10]. Ehrlich et al. from the Mount Sinai School of Medicine explored the possibility of an interval of reperfusion (CR) improving cerebral outcome following prolonged HCA [11]. Cold reperfusion failed to improve electrophysiological recovery or reduce brain weight, but median intracranial pressure (ICP) increased significantly less after CR than in the control group. They concluded that cold reperfusion significantly inhibited the rise in ICP seen in controls after HCA, suggesting that CR may decrease cerebral oedema, and thereby improve outcome following prolonged HCA.

In summary, the series of arch aneurysms presented in this issue of the Journal is a demonstration of the excellent results possible with elective as well as urgent surgery of aortic arch aneurysms or dissection. When more complex aortic reconstruction is anticipated with prolonged circulatory arrest times, ACP has to be instituted. A 10-min period of CR before the rewarming phase seems to reduce the incidence of neurological events and perhaps extends the safety period of HCA up to 40 min.

Conflict of interest: none declared.

REFERENCES