SPECIAL ARTICLE: SURGICAL OPINION AND REVIEW

A Current View of Cerebral Protection in Aortic Arch Repair

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SOME ISSUES REMAIN controversial among surgeons concerning aortic arch surgery. One of the most important is the cerebral protection method. Many techniques have been offered including antegrade cerebral perfusion (ACP), deep hypothermic circulatory arrest (DHCA), and retrograde cerebral perfusion (RCP), but which method is the best for cerebral protection remains a dilemma.

DEEP HYPOTHERMIC CIRCULATORY ARREST AND RETROGRADE CEREBRAL PERFUSION

The major objective in arch surgery is to supply the basic metabolic needs of the brain during the anastomosis. Many advances have been introduced into aortic arch surgery since Griepp et al[1] used the DHCA technique. Svensson et al[2] reported the safe DHCA period as 40 minutes. However, Ergin et al[3] reported this duration as 30 minutes. The safe DHCA period also was reported to be 30 minutes under 15 °C and 40 minutes under 10°C.[4]

Michenfelder et al[5] reported that the complete arrest of the cerebral circulation for as long as 30 minutes at 18°C would not result in any permanent neurologic injury, and they provided evidence indicating that periods of DHCA as long as 60 minutes should be safe. Neuropsychologic tests after DHCA showed that DHCA duration of more than 25 minutes and advanced age were significant predictors of poor performance in examinations of memory and fine-motor function.[6]

Ueda et al[7,8] described an RCP technique through the superior vena cava cannula under DHCA. RCP may accomplish neuroprotection by flushing embolic material from the cerebral circulation,[9] providing cerebral flow sufficient to support cerebral metabolism,[10] and maintaining cerebral hypothermia.[11] Although RCP was reported to expel air emboli, it is now well known that the pressure necessary for this causes brain edema.[12] Another point is that the blood returning to the aortic arch was less than 5% of the amount given through the retrograde perfusion cannula. ACP was reported to afford the best cerebral protection, but RCP was reported to provide clear improvement compared to DHCA.[13]

RCP, especially at high pressures, although successful in removing some emboli, may aggravate cerebral injury.[14] Besides, it was not able to decrease the incidence of stroke.[15] Recently, RCP has lost its popularity because it did not sufficiently prolong the safe period of DHCA. Less than 60 minutes of RCP was reported to be tolerated with a minimal risk of brain complication.[16] DHCA also has been found to be associated with excellent organ protection with an RCP time less than 45 minutes.[17]

ANTEGRADE CEREBRAL PERFUSION

DHCA revealed some limitations, especially when longer durations were required. Therefore, a combination of hypothermia and circulatory arrest with selective ACP may allow clinicians to take optimal advantage of the benefits of both cerebral protection strategies. A combination of selective cerebral perfusion with hypothermia allowed the use of much lower flow rates and hypothermic-selective ACP afforded better cerebral protection from global ischemia than DHCA alone or DHCA and RCP.[18,19]

In 1995, Sabik et al[20] popularized the technique of using the right subclavian/axillary artery for arterial inflow for complex cardiac operations. ACP through the right axillary artery has been proven to be a safe and effective method for cerebral protection in aortic surgery since then. It has become the preferred site for cannulation and is indicated in wider areas.[20] Selective cerebral perfusion (SCP) allowed increased ease of performance of total arch replacement and reduced periprocedural mortality and morbidity in patients with aortic arch aneurysm and those with acute aortic dissection.[21]

Kazui et al,[22] perfusing both the innominate and left common carotid arteries with flows of 10 mL/kg/min at 22°C, obtained 50% of physiologic levels. They also found that selective cerebral perfusion time had no significant impact on outcome.[22]

Ergin et al[3] used ACP under deep hypothermia, whereas Tasdemir et al[23] used the technique under moderate-degree hypothermia (26°C). Jacobs et al[24] in their series with selective ACP under moderate hypothermia (28°-30°C) found the transient neurologic deficit (TND) rate to be 4% and concluded that there was no correlation between long SCP duration and neurologic injury.

ACP became the preferred technique of cerebral protection in recent years because the other techniques did not provide satisfactory cerebral protection and they were associated with harmful effects of profound hypothermia.[25-28] This cerebral protection method depends on bihemispheric perfusion of the brain through the Circle of Willis. The brain is supplied by the 2 internal carotid arteries and the 2 vertebral arteries. The 4 arteries anastomose on

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the inferior surface of the brain and form the Circle of Willis. Therefore, perfusion of one or more arch branches would perfuse the brain.

On the other hand, ACP under moderate hypothermia was reported to poorly protect visceral organs like the liver when compared with deep hypothermia.[29] To overcome this, ACP through the right axillary or the brachial artery in addition to descending aortic perfusion through the femoral artery with the aid of descending aortic occlusion was studied.[30,31]

DISCUSSION

The cerebral protection methods in arch surgery have been well defined with their advantages and disadvantages in recent reports. ACP gained popularity in recent years due to its favorable postoperative outcomes. Svensson et al[32] reported that the brain was incompletely perfused by the RCP method. The incidence of TND was reported to be significantly higher in patients with RCP than in patients with ACP.[33] Hagl et al[15] concluded that the method of cerebral protection did not influence the occurrence of stroke, but ACP resulted in a significant reduction in the incidence of TND. Most of the series suggest ACP for patients who need longer cerebral protection because it could provide the luxury of time, allowing for the appropriate repair of complicated arch aneurysms. However, ACP was thought to have a potential disadvantage of requiring manipulation of cerebral vessels, which carried the risk of dislodging atherosclerotic debris.[34] ACP has been reported to attenuate the metabolic changes seen after DHCA.[35] Cerebral autoregulation in the postoperative period after hypothermic circulatory arrest procedures is altered, and ACP has been found to have a beneficial role on cerebral autoregulation.[36] On the other hand, DHCA/selective cerebral perfusion has been found to be superior to DHCA alone for preventing cerebral injury during operations on the aortic arch.[37]

Transverse aortic arch repair is a technically demanding and time-consuming operation. It may be more troublesome, especially in acute type-A dissection. For this reason, many authors have switched to selective ACP. Kucuker et al[31] reported a unilateral antegrade ACP perfusion technique via the right brachial artery in conjunction with moderate hypothermia under 26°C with excellent neurologic outcomes. To show the effect of unilateral perfusion, neurocognitive functions of both the right and left hemispheres preoperatively and postoperatively in the first week and second month postoperatively were reported to be normal, and the flow patterns of both middle cerebral arteries before, during, and after low-flow antegrade selective cerebral perfusion with transcranial Doppler measurements showed a reduction of blood flow on the left side after the onset of ACP.[38] Transcranial Doppler also revealed that the blood flow never stopped, and this reduced flow was satisfactory to maintain the metabolism of the left hemisphere.[39] ACP provided nutritive cerebral blood flow during brain exclusion and enabled the authors to perform appropriate arch repair without compromising the extent of replacement for fear of exceeding the "safe" period of circulatory arrest.[34]

Most of the studies in the literature concentrated on cerebral perfusion. Spielvogel et al[40] concluded that the optimal cerebral protection strategy for total arch replacement would seem to be one relying on hypothermic antegrade selective cerebral perfusion. Some authors prefer moderate hypothermia during the cerebral perfusion. However, what the effect of moderate hypothermia on the visceral organs will be remains a problem. Novitzky et al[30] and Kucuker et al[31] suggested additional femoral artery cannulation as an option for acute dissection cases with renal, visceral, or lower-extremity malperfusion, especially when the surgeon expects a long arch repair time. To prevent further ischemia during the selective antegrade perfusion period, distal perfusion can be provided with femoral artery cannulation after the insertion of an intra-aortic balloon occluder to the proximal descending aorta. Novitzky et al[30] reported a case of type-A aortic dissection using this technique. Tagaki et al[41] used the technique under 25°C with an aortic balloon occlusion catheter with a perfusion lumen for the protection of the lower body during distal anastomosis in aortic arch repair. Klodell et al[42] perfused the distal aorta at a bladder temperature of 18°C. They suggested that the technique allowed the continuation of the cerebral protection, with the added benefit of maintaining antegrade flow to the distal aorta, spinal cord, viscera, and lower extremities. The distal aortic perfusion of the spinal cord, viscera, and lower extremities avoids the need for deep hypothermia.[43] The present authors used similar perfusion techniques but with a nasopharyngeal temperature of 28°C. The present results suggest the safety of moderate hypothermia for cerebral and visceral perfusion. Moreover, ACP at physiologic pressures with systemic circulatory arrest at moderate hypothermia of 22°C was reported to provide superior cerebral protection by combining the protective effects of reduced metabolic demand secondary to moderate hypothermia, and avoiding the negative cerebrovascular effects of deep hypothermia.[44] There is not a prospective and randomized study concerning this technique. In cases of a severe calcification or ectasia, tight occlusion of the descending aorta may not be possible. The balloon of the aortic occluder should not be located distally in the descending aorta and should be optimally inflated in order not to cause damage in the aortic wall. This will make the intra-aortic balloon occluder stay in the right position and not dislocate; meanwhile, the spinal cord and the visceral perfusion will not be disturbed. With the utilization of an additional cannulation site, as in the present cases, the femoral artery is a potential site for further morbidity. This may be overcome via a perfusion balloon cannula inserted from above. This might avoid the retrograde perfusion of the descending aorta via the femoral artery and might further avoid atheroembolism in aortic disease.

Shimazaki et al[45] reported a 2.5% incidence of mild renal dysfunction versus a 2.5% incidence of liver dysfunction with a mean of 50 minutes' cessation of distal aortic perfusion under 28°C. In the study by Kucuker et al,[31] postoperative renal and hepatic function tests showed significant difference when compared with the preoperative values but these were reported to be within normal limits for routine cardiac operations.

Increasingly, mildly hypothermic or normothermic cerebral perfusion in addition to perfusing the descending aorta are used. Panos et al[46] replaced the aortic arch using continuous antegrade perfusion of the brain and lower body, under 30°C mild hypothermia by direct cannulation of the right axillary artery and the descending aorta with a venous cannula. Moreover, in a limited study population in whom normothermic cardiopulmonary bypass was used, Touati et al[47] reported successful outcomes by selectively perfusing the right femoral artery, the truncus brachiocephalicus, and the left common carotid artery.

In conclusion, cerebral and body perfusion through axillary and femoral artery combined cannulation may provide more time for the surgeon and better protection for the brain and visceral organs, which is especially important for surgical teams during the learning curve.

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