Preparing and Managing Deep Hypothermic Circulatory Arrest
Marc Kanchuger, MD
Annette Mizuguchi, MD, PhD

Learning Objectives:

The participant will become familiar with;
   a. the various neurologic monitoring modalities that can be used during DHCA
   b. the various perfusion modalities (antegrade and retrograde cerebral perfusion) that can be used to provide cerebral blood flow during DHCA

Case Presentation:

A 55-year old male with a recent history of a TIA was noted on further evaluation to have a 6x6 cm aortic aneurysm involving the aortic arch. He is now scheduled for aortic arch graft replacement with DHCA. He is a former smoker and was otherwise healthy until his TIA. He has not had any recurrent neurological events and has no residual symptoms. Carotid Doppler studies at that time showed mild to moderate bilateral internal carotid disease but surgery was not indicated. He was also diagnosed with hypertension at that time and was started on metoprolol and aspirin. The preoperative TTE showed an EF of 60%, mild AR, mild MR and trace TR. He is a busy executive director of an internet advertising company and is not ready to retire.

Questions:
1. What preoperative risk factors does this patient have?
2. How will you monitor his neurologic function during the case?
3. What pharmacologic adjuncts will you use to increase the safety of deep hypothermic circulatory arrest (DHCA)?
4. His intra-operative blood glucose is 200. Will you treat this? What affect does hyperglycemia have on cerebral function?
5. How will you manage this patient’s blood gas status (pH stat vs alpha stat) and does it matter?
6. How low should his body temperature be lowered to before the extracorporeal circulation can be stopped? Where should the temperature be measured?
7. Is it safe to perform arch repair with DHCA alone?
8. What impact does the addition of antegrade or retrograde cerebral perfusion have?
9. How are antegrade and retrograde cerebral perfusion performed?
10. What are alternative cannulation sites and techniques?
11. 15 minutes after DHCA, the NIRS (cerebral oximetry) monitor shows a dramatic decrease on the left side (>40% from baseline). What do you think is happening and what will you do?
12. How will you re-warm this patient and to what temperature?
Discussion:

Aneurysms involving the aortic arch require a period of circulatory arrest or low-flow selective perfusion. Therefore, there have been multiple innovations introduced to monitor cerebral function to minimize neurologic dysfunction and to alert us of potential hazards.

Neuromonitoring:

The electroencephalogram (EEG) records spontaneous electrical activity originating from the cerebral cortex (1). Three practical approaches to monitor intraoperative brain activity include the bispectral index (BIS), spectral entropy (Entropy) and the patient state index (PSI). In aortic arch surgery, the main benefit of EEG monitoring is in confirming electrical silence prior to turning the pump off.

Jugular bulb oxygen saturation (SjVO$_2$) allows measurement of mixed venous sampling of the brain, which is thought to reflect the global balance of cerebral oxygen supply and demand (2). A value above 95% is thought to represent sufficient suppression of metabolism to allow circulatory arrest for a period of 50 minutes (3).

Transcranial Doppler Ultrasound is a noninvasive method of monitoring cerebral blood flow and the middle cerebral artery is usually monitored. It may be useful in monitoring the adequacy of retrograde cerebral perfusion and may determine the optimal retrograde cerebral perfusion pressure (4).

Near-infrared spectroscopy (cerebral oximetry) is based on absorption of light similar to pulse oximetry except that it uses two receptors instead of one (5,6). The superficial receptor is located 3 cm from transmitter and captures saturation level from extracerebral tissue (skin, bone, dura). Another receptor is placed 4 cm laterally from light source and this analyzes total brain tissue signal. The deeper brain signal is calculated by subtracting the superficial signal from the total signal (normal range 47% to 83%). The advantage of this monitor is that it provides data on local oxygenation and perfusion not possible with jugular bulb saturation and does not require pulsatile blood flow making it useful during cardiopulmonary bypass and circulatory arrest. In the US, cerebral oximetry is

Cerebral Protection:

Neurologic injury occurs when cerebral oxygen delivery does not meet cerebral oxygen consumption. Therefore, neurologic insult may be decreased by optimizing cerebral blood flow and cerebral oxygen consumption during the period of reduced or absent cerebral perfusion as in the case of complex aortic arch surgery.
Currently, hypothermia is the principal method of brain protection for aortic arch surgery. Although hypothermia is thought to reduce the electrophysiologic and cellular homeostatic components of brain energy expenditure, there seems to be a limit to the reduction of metabolism. At 25°C cerebral metabolic rate decreases to 37% of baseline and at 15°C the cerebral metabolism is decreased to 16% (7). As the temperature decreases, metabolic demand falls exponentially but cerebral blood flow falls more linearly. Therefore, cooling below 22°C causes “uncoupling” of flow and metabolism (8,9).

Four hypothermic techniques are commonplace during aortic surgery:
1. Deep hypothermic circulatory arrest alone
2. Deep hypothermic circulatory arrest with antegrade cerebral perfusion
3. Deep hypothermic circulatory arrest with retrograde cerebral perfusion
4. Deep hypothermic circulatory arrest with a combination of antegrade and retrograde cerebral perfusion

Deep Hypothermic Circulatory Arrest (DHCA):

DHCA is based on the primary concept that temperature reduction will sufficiently inhibit cerebral metabolism to allow the period of “safe” circulatory standstill to be proportionately prolonged in parallel with depth of hypothermia (8). However, there are many unanswered questions. The optimal temperature to cool before the pump is stopped is debated with most cooling to 15-25°C. The total time required to cool to electrical silence on EEG monitoring is dependant on many factors. Stecker et al. noted that electrical silence could be assured if cooling time were greater than 50 minutes (10). The safe duration of DHCA is another question. In a clinical study in humans, McCullough et al. noted that the predicted safe duration of DHCA at 13°C is only 29 minutes (7). Recently, a retrospective analysis of 394 patients undergoing straight DHCA noted that the incidence of stroke was acceptable if the DHCA time was less than 40 minutes (11).

Retrograde Cerebral Perfusion:

Retrograde cerebral perfusion was first reported by Mills and Oschner for the management of massive arterial air embolism in 1980(12) and was used as an adjunct to DHCA by Ueda et al. in 1990 (13). The technique involves interruption of antegrade perfusion followed by perfusion through a SVC cannula. Retrograde cerebral perfusion is monitored by a superior vena cava or a jugular bulb catheter and flow is adjusted to maintain a pressure of approximately 20 mmHg (14). The benefits of retrograde cerebral perfusion include the ability to maintain intracranial hypothermia, to flush out embolic debris and to deliver metabolic substrate. On the other hand, there is evidence that retrograde cerebral perfusion may worsen neurologic outcome by inducing cerebral edema. The efficacy of retrograde cerebral perfusion has been widely studied. A case series in humans by Cheung et al., suggests oxygen consumption by tissues perfused with retrograde cerebral perfusion(15). However, whether the oxygen consumed is sufficient to support cellular metabolism and prevent neuronal injury is not known (16).
Antegrade Cerebral Perfusion:

Antegrade cerebral perfusion is more physiologic compared to the “no flow” or retrograde approach and seems to reduce the subtle global cerebral injury seen with inadequate cerebral protection during DHCA. Animal studies have demonstrated that antegrade cerebral perfusion is more effective compared to DHCA with or without retrograde cerebral perfusion. However, antegrade cerebral perfusion often requires complicated cannulation techniques and risks embolization of atheromatous debris (17). As an alternative cannulation site, the right axillary artery has become popular because of the lower rate of atherosclerotic changes compared to the aortic arch and the ability to provide antegrade cerebral perfusion without cannula repositioning. There is concern that axillary artery perfusion will be insufficient in the 15% of patients with incomplete Circle of Willis and a second selective antegrade cerebral perfusion cannula may then be used (8).

References:


