

DISTAL AORTIC PERFUSION : PREVENTION OF ORGAN INJURY IN THORACOABDOMINAL AORTIC SURGERY

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Most widely accepted preventive methods in thoracoabdominal aortic surgery are active distal perfusion, hypothermia and perioperative use of steroids. The critical duration for aortic cross-clamping is 25-30 minutes. As a result of reperfusion, local inflammatory response causes hyperemia and increased permeability leading ultimately to edema. The rationale for distal aortic perfusion is to prevent spinal cord and other distal organs during cross clamping of the aorta by increasing distal aortic pressure and perfusion. Most commonly applied method is atrial-femoral by-pass. Depending on other factors, neurologic complication rates differ between 0.5-38%. The increase in CSF pressure can be corrected by drainage which is also useful to remove neurotoxic mediators. Hypothermia is one of the most efficient methods for protection. In order to increase durability of nervous tissue to ischemia, several pharmacologic agents have been studied. Protective methods provide surgeon time for the operation and decrease the gravid complications of thoracoabdominal surgery.

Key words: Distal aortic perfusion, thoracoabdominal aorta, surgery, protection

Neurologic losses and vital organ damage have been sine qua non of the surgical treatment of thoracoabdominal aortic aneurysms for years.

In the early 1900s, Alexis Carrel performed experiments about descending and thoracic aorta on animal models. He noticed that paraplegia was seen following long durations of cross-clamping and he suggested and used techniques for perfusion of the clamped segment of the aorta to prevent this severe complication. In late 60s and early 70s, Vincent Gott, applied his new method of left ventriculo(or ascending aorto)-descending aortic shunt, which later became to be known with his name, to prevent complications during thoracoabdominal aneurysm repairs(1).

Today preventive methods in thoracoabdominal aortic surgery draw much more interest of the researchers than the surgical

techniques alone. Among the large variety of techniques to prevent paraplegia and organ damage, three of them have found common acceptance. These are; active distal perfusion during aortic cross-clamping, hypothermia(31-33°C) and perioperative steroids. Nowadays, as extended procedures against thoracoabdominal aortic aneurysms have become to be performed much more in number, studies to improve these methods of organ protection have been increased.

PATHOPHYSIOLOGY

In thoracoabdominal aortic aneurysms, perioperative complications are seen in high numbers; especially paraplegia, renal failure, intestinal ischemia and hepatic failure(2-4). The common pathophysiologic mechanism resides in these complications is the end organ hypoperfusion (4). Although this may be caused by embolization of the debris in the aneurysmal sac or acute thrombosis, most common reason is the cross-clamping of the aorta.

Following cross-clamping of aorta, a decrease in pressure ensues with a drop in perfusion in the distal aortic segment. Hypoperfusion induces ischemia in organs (spinal cord, kidneys, liver, intestine). In addition to the ischemic injury, toxic mediators and cardiodepressant agents released in the ischemic period disturb the hemodynamic compensation and increase the severity of the ischemic state (5). Contrary to hypotension, there is hypertension proximally. This causes a rise in the intracranial and cerebrospinal fluid(CSF), and disrupts cerebral and medullary perfusion.

Katz and colleagues showed a direct and an important correlation between the duration of the aortic occlusion and neurologic deficits. The critical point of duration for aortic cross-

clamping is 25-30 minutes. Neurologic deficit risk in the lower extremity is increased in exceeding durations(6).

Spinal cord is perfused by 1 anterior spinal artery (ASA) and 2 posterolateral spinal arteries (PLSA) in the subarachnoidal space, both originating from vertebral artery (7). ASA supplies 75% of the spinal cord blood (7,8). 25-30 pairs of vessels originating from the aorta and its branches anastomose with ASA. 12 to 14 of these originate directly from the aorta, remaining originate from vertebral arteries, thyrocervical and costocervical trunks and iliac arteries. These vessels continue posteriorly and split into anterior and posterior branches. Anterior branches continue anteriorly as intercostal arteries while the posterior branches split more into anterior and posterior radicular arteries and reach spinal arteries. Anterior radicular artery anastomose with ASA. Among these anastomoses, 'Adamkiewicz' artery, originating mostly from the left T8-L3 segment, is significant (7). It has been shown that injury to this artery causes paraplegia in 70% of the cases (9). Blood flow in the spinal cord is 30-35 ml/100 g.tissue/min (8). Mean systemic arterial pressure of 50 to 135 mmHg can maintain this flow rate (10).

In normothermia, after a period of 3-4 minutes of ischemia, as substrate and oxygen necessary for oxidative phosphorylation can not be maintained, ATP reserves are depleted. Most critical point of irreversible damage is disturbance of calcium ion balance. During ischemia, in intracellular calcium activates release of cytoplasmic proteases and nucleases which results in catastrophic damage to structural proteins and DNA. Moreover, calcium activated phospholipase transforms membrane phospholipids into arachidonic acid and other vasoactive metabolites. Endothelial xanthine dehydrogenase

transforms into xanthine oxidase. Neurotoxic aspartate and glutamate levels are increased (11). After a period of ischemia, when the tissue is reperfused with oxygenated blood, various systemic or local injury may ensue related to changes during the ischemic period. Xanthine oxidase mediated formation of free oxygen radicals starts the sequence of lipid peroxidation while damaging structural components like DNA. As a result, there is an increase in vasoconstrictive prostaglandins like thromboxane A₂ causing microvascular vasospasm and thrombosis. As a result of reperfusion, local inflammatory response causes hyperemia and increased permeability leading ultimately to edema (11,12).

Under these circumstances, prevention of neurologic damage resides in maintaining perfusion pressure and using methods to increase durability against ischemia, thereby reducing reperfusion injury (13,14).

DISTAL PERFUSION

The basis of the idea of distal aortic perfusion (DAP) is to prevent spinal cord and other distal organs during cross clamping of the aorta by increasing distal aortic pressure and perfusion (15).

Various methods are used today to maintain distal aortic perfusion. Most commonly applied method is atrial-femoral by-pass procedure (5). Perfusion can be maintained directly between the left atrium or left upper or lower pulmonary veins and the femoral artery (15). Alternative methods are the left atrial-distal aortic by-pass (15), femoral artery-vein by-pass and axillo-femoral by-pass. Shunting the proximal aorta to the distal segment without using circulation assistance is applied by various clinics. Most famous example is the Gott shunt between the left ventricle and the distal aorta (1). An alter-

native method to achieve this goal is the side conduit use with an aorta-iliac graft (5).

Depending on the factors like the extent of the aneurysm, etiologic factors, indication of the operation, duration of the cross-clamping, neurologic complication rates differ between 0.5% to 38%(3,16).

CSF DRAINAGE

As the fall in the distal aortic and spinal arterial pressure can be corrected by distal aortic perfusion, the increase in cerebrospinal fluid (CSF) pressure can be corrected by the cerebrospinal fluid drainage (15,17,18,19). Blaisdell and Cooley are the first to show that the increase in CSF pressure causes ischemia in the spinal cord (20,21). Therefore, in addition to distal perfusion, cerebrospinal fluid drainage may be advantageous.

Perfusion pressure of the spinal cord is the difference between spinal arterial pressure and the CSF pressure(23). Decrease in the distal aortic pressure causes a decrease in the spinal arterial pressure while CSF pressure increase due to the hypertension in the proximal aorta, both resulting disturbance in the spinal cord perfusion (15,22).The rise in the intracranial pressure due to the rise of blood pressure proximal to the cross clamp, causes an increase in CSF pressure which leads to compression in spinal vessels and neural tissue and decrease in spinal cord perfusion pressure thereby causing ischemia. Only one single factor is eliminated by distal perfusion which keeps distal aortic pressure above the minimum limit of 50 mmHg to maintain spinal cord perfusion. However at the mean time, uncontrolled CSF pressure brings the possibility of decrease in spinal perfusion pressure to dangerous levels. Therefore, keeping CSF pressure under control is necessary to prevent further injury and the possibility of ischemia in

the central nervous system and the spinal cord. Simply, inserting a CSF drainage catheter(14 Fr Touhy needle) helps to monitor the CSF pressure and perform drainage to keep it under 10 mmHg (8,17). CSF drainage is also useful to remove neurotoxic mediators that are secreted during cross-clamping (24).

HYPOTHERMIA

Following Bigelow's experiments in 1950 (25), hypothermia, in addition to the cardiopulmonary by-pass, has become one of the main methods of organ protection in cardiovascular surgery. Hypothermia is one of the most efficient methods for protection of nervous tissue (26). Several mechanisms play role to constitute this effect. Most evident one is the decrease in metabolism and oxygen consumption (27). Change in temperature affects the rate of biochemical and enzymatic reactions. In the nervous tissue each 10 degrees of drop in the temperature, slows metabolic rate 50 to 70% therefore preventing further damage to the tissue in prolonged periods of ischemia. Hypothermia preserves high energy phosphate reserves and decreases release of excitatory neurotransmitters (27,28). It is well-known that under ischemic conditions, release of neuroexcitatory amines especially glutamate increase dramatically in the neurons (29). Elevated levels of these excitatory and toxic amines open calcium channels and triggers a sequence of events that activate various enzymatic system, resulting tissue injury (27). It has also been suggested that, the events that start cellular injury during ischemia, also caused apoptosis and paraplegia in the late postoperative period (30). Hypothermia blocks calcium entry into the cell, and decrease cellular membrane permeability, thereby preventing these chain reactions (31).

Apart from systemic hypothermia, local hypothermia is also used for spinal cord protection. In patients who were applied cold isotonic saline infusion (4°C) via an epidural catheter at T10-T12 level to achieve local hypothermia, rate of lower extremity complications was reported to be 3.5% (32,33).

PHARMACOLOGIC AGENTS

In order to increase durability of nervous tissue to ischemia, several pharmacologic agents have been studied apart from other mechanical procedures like distal perfusion, CSF drainage. Papaverin, when applied intrathecally dilates spinal arteries especially anterior spinal artery which is useful in spinal cord protection(8). In addition to arterial dilatation, papaverin blocks calcium channels, inhibits electron transfer in oxidative phosphorylation, prevents aerobic oxidation of substrates in the Krebs cycle and superoxide formation(8,34).

In experiments performed on dogs, during periods of ischemia, a rise in β -endorphine levels was detected (35). So far, one of the opioid antagonists, naloxone was shown to decrease damages to nervous tissue formed during ischemia(36). In a study using CSF drainage and naloxone combination, protective effect from neurologic damage was found to be significant (37).

Several antioxidant agents like allopurinol, superoxide dismutase, which prevent formation of free oxygen radicals that play a basic role in ischemia and reperfusion injury, have been used in several trials, however, no significant effect was found (26).

During ischemia, increase in intracellular calcium results in irreversible cellular injury. In studies to prevent postoperative paraplegia, using calcium channel blocking agents in rab-

bits, did not show any beneficial effect (38).

Excitatory amine antagonists, to prevent aforementioned toxic effects of excitatory amine accumulation, were studied. Among these, anti-glutamate agent riluzole, has been shown to prevent neuronal necrosis and apoptosis related to spinal cord ischemia in rats (39).

Phenobarbital which decrease free fatty acid and arachidonic acid levels, has been shown to provide efficient protection to spinal cord during ischemia (38).

CONCLUSION

The support of distal aortic perfusion, CSF drainage, hypothermia and other protective procedures has increased the safe application period of the aortic cross clamp from the critical 45 minutes (22) to much longer durations (16). It has been shown experimentally that keeping the distal aortic pressure at levels of 60-70 mmHg, spinal cord is protected efficiently (40). In periods of single cross-clamping, rate of neurologic deficits was 16-31%. Today, using supportive procedures has decreased this high ratio to 2.4-6.6% (16,17). 14-42% mortality rate during single cross-clamping era, has changed in the last decade to 10-14% using these procedures (18,19).

Protective procedures like distal perfusion and CSF drainage are of importance in thoracoabdominal aortic surgery. These techniques provide enough time for the operation by prolonging safe applicable period of the aortic cross clamp, moreover decrease the fearsome complications of these operations by efficient visceral organ, spinal cord and cerebral protection. As our knowledge and experience on neural protection advances, operations will give more pleasing results each and every day.

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