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Intraoperative management of aortic aneurysm surgery

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Anesthesia for aortic aneurysm surgery

If the aorta dilates to greater than 3.0 cm, an aneurysm is formed. The risk of rupture increases exponentially when the aneurysm diameter is greater than 5.0 cm or if there are inflammatory lesions in the aortic wall. Ultrasonography is probably the most cost-effective diagnostic tool for making the diagnosis of an aortic aneurysm. However, angiography is the gold standard for establishing the diagnosis and is particularly helpful in patients with atherosclerotic and obliterative disease of the aorta and iliac arteries [1].

Management of aneurysms

Investigators in the United Kingdom studied over 1000 patients with aneurysms 4.0 to 5.5 cm in diameter and randomly assigned them to elective surgery groups or surveillance with ultrasonography. Surgery was offered to patients if the aneurysm grew greater than 5.5 cm or expanded more than 1.0 cm in diameter per year. In the observational group there was a 1.6% risk of rupture per year, with women having a fourfold greater risk of rupture than men. However, there was no difference in long-term outcome for either group [2,3].

In a large study (the aneurysm detection and management of the Veterans Affairs Cooperative Study) [4], 50- to 80-year-old patients with 4.5- to 5.5-cm aneurysms were assigned to one of two groups. Approximately half were assigned to undergo surgical repair of the aneurysm, and the other half was assigned to a surveillance group. Those in the surveillance group underwent ultrasonography or a computerized tomography (CT) scan every 6 months to monitor the size of the aneurysm. The surgical repair group had an operative

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mortality rate of 2.7%. The authors concluded that early surgical intervention for aneurysms less than 5.5 cm did not improve long-term survival [5].

Surgical management

Current practice is based on the results of studies such as these. Patients with aneurysms are observed and monitored if the aneurysm is less than 5.5 cm; if the aneurysm is greater than 5.5 cm, surgery is recommended [6]. Today, surgical management includes open repair or endovascular stenting, depending on the location and extent of the disease. Endovascular stents are placed if the aneurysm has a sufficient length of normal aorta, defined as a "neck" that allows placement of the stent without occluding adjacent blood vessels. Although the data do not justify open surgical repair of aneurysms less than 5.5 cm, the size at which placement of an endovascular stent should be considered has not been determined; presumably, an endovascular stent may be warranted in patients with smaller aneurysms. Aneurysms of the thoracic aorta are much more difficult to manage. If they are repaired using an open approach, the extent of the incision, the length of the aorta to be resected, and the multiple organs that are affected by the ischemic cross-clamp time, makes these aneurysms the most difficult to treat. A combined open and endovascular approach as a means to decrease morbidity has been advocated [7].

Assessment of anesthesia risk for aortic aneurysm surgery

Aortic aneurysm disease is associated with several comorbid conditions [8]. Smoking, which results in the development of vascular, pulmonary, and coronary artery disease (CAD), is very prevalent in this population. Hypertension is also quite prevalent. Diabetes is present in approximately 10% of patients. Goldman et al [9] and several others have published risk indexes to account for the multifactorial risks associated with aortic aneurism and chances of cardiac complications in a postoperative period. Goldman et al identified independent predictors such as age, previous myocardial infarction, S3 gallop, jugular–venous distention, aortic stenosis, cardiac dysrhythmias, the presence of other general medical problems such as electrolyte or blood gas disturbances, and whether the surgery was an emergency and the anatomic location of the surgery (either above or below the diaphragm). Goldman's risk index has proven to be a useful screening method for predicting patients who require further cardiac evaluation. However, newer strategies for screening patients continue to be developed (see articles elsewhere in this issue for further exploration of this topic). Patients who have cardiac conditions have been shown to have fewer cardiac complications in the perioperative period when they are given β-blockers or their β-blocker prescriptions are continued perioperatively [10–12]. Many β-blockers have been tested, and any β-blocker will reduce the incidence of cardiac morbidity and mortality in patients who have proven coronary disease and are undergoing vascular surgery [13–16]. β-blockade can be used to maintain as low a heart rate as possible in patients undergoing anesthesia and may be continued in the postoperative period to maintain a stable, low heart rate. Hypertensive patients should receive their antihypertensive medications throughout the perioperative period [17–19]; and β-blockers and clonidine should not be withdrawn from the patient because β-blockers have been shown to reduce the incidence of perioperative myocardial ischemia.

Although Goldman's risk index has proven to be a useful screening method for predicting patients who require further cardiac evaluation, the American Heart Association and the American College of Cardiologists have developed guidelines [20] for stratifying patient risk for cardiac morbidity (Fig. 1). This preoperative risk assessment technique is based on clinical predictors, the degree of risk associated with the particular surgery, and the patient's functional status. The major clinical predictors are unstable coronary syndrome, decompensated congestive heart failure, significant arrhythmias, and severe valvular disease. The intermediate predictors are mild angina, previous myocardial infarction (shown by history or electrocardiogram [ECG]), compensated or previous congestive heart failure, diabetes mellitus, and renal insufficiency. Aortic and major vascular surgeries are included in the high-risk surgery group. Functional capacity is measured with metabolic equivalence, which is the oxygen consumption of a 70-kg person in an arresting state. A functional status of excellent is the patient's capacity to perform exercises requiring greater than 7 metabolic equivalencies, such as jogging a 10-minute mile; a moderate status would be considered the ability to climb one flight of stairs, and poor would be a patient considered unable to perform simple tasks such as vacuuming. The indications, then, for further cardiac evaluation are the presence of a major clinical or intermediate clinical predictor with poor functional status, having high-risk or intermediate-risk surgery. In this situation, noninvasive testing is recommended and, if test results are positive, then to proceed to coronary angiography. Subsequent care is dictated by the results of the coronary angiogram [20,21].

Noninvasive testing is performed with exercise stress ECG. If the patients are able, they undergo exercise to obtain a maximal heart rate, and the ST segment is evaluated. In patients who cannot exercise, pharmacologic stress such as dobutamine administration is used to obtain a maximal heart rate. Eighty percent of maximal prediction, ST segment analysis, and segmental wall motion abnormalities using ECG are used to evaluate areas of inadequate coronary perfusion. Patients who are able to attain an 85% maximal heart rate during stress ECG without changes in the ST segment are at a lower risk for perioperative cardiac morbidity [22–24].

A standard echocardiographic examination measures left ventricular ejection fraction, regional wall motion, and valvular function. The left ventricular function, as measured by the ejection fraction, may not reflect the true left ventricular function because of loading conditions present at the time of measurement of the ejection fraction. In one study, dobutamine stress echocardiogram was found to

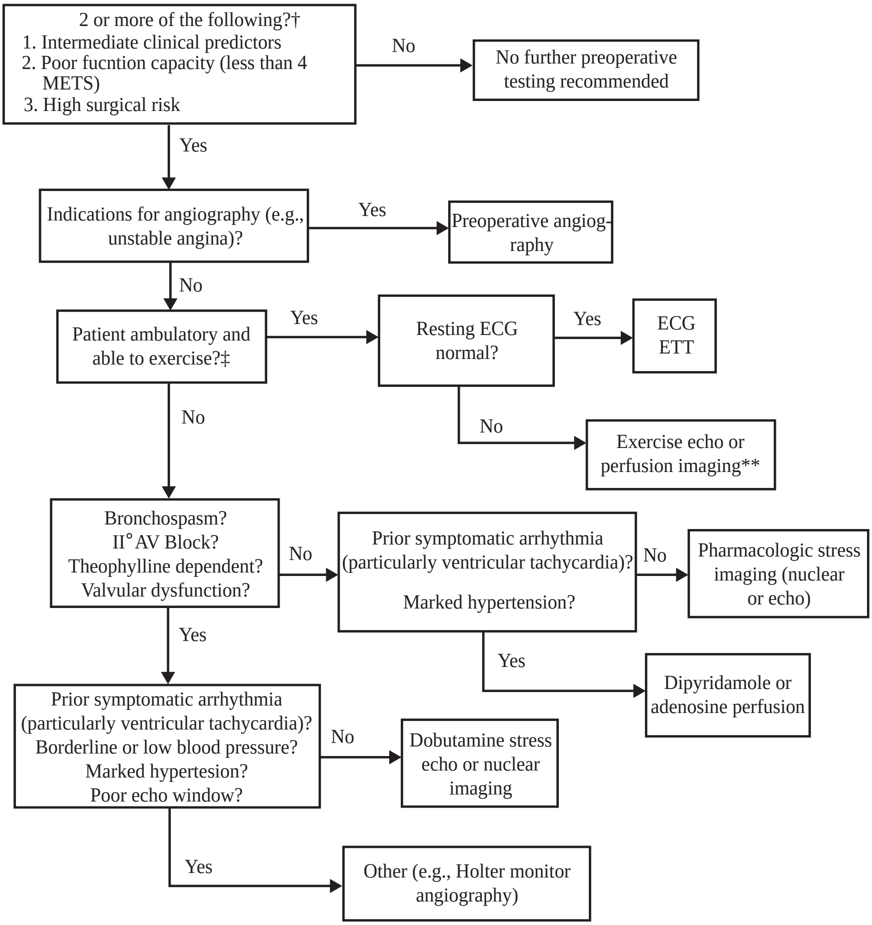

Fig. 1. Supplemental preoperative evaluation algorithm.*, Testing is only required if the results will impact care; †, see also published list of intermediate clinical predictors, metabolic (*MET*) equivalents, and definition of high-risk surgical procedures; ‡, able to achieve more than or equal to 85% maximum predicted heart rate (MPHR); **, in the presence of left bundle branch block (LBBB), vasodilator perfusion imaging is preferred. (*From* Eagle KA, Berger PB, Calkins H, Chaitman BR, Ewy GA, Fleischmann KE, et al. ACC/AHA Guideline update for perioperative cardiovascular evaluation for noncardiac surgery–executive summary: a report of the ACC/AHA task force on practice guidelines [Committee to Update the 1996 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery]. J Am Coll Cardiol 2002;39:542–53; with permission.)

be the best predictor of cardiac morbidity and risk of a cardiac event. Radionuclide ventriculography can also be used as an independent predictor of preoperative cardiac morbidity [25,26]. This test provides an accurate evaluation of left ventricular function, either with exercise or during rest. An ejection fraction less than 35% was associated with a 75% rate of perioperative myocardial infarctions, whereas an ejection fraction greater than 35% was associated with a

20% rate. Finally, Hertzer et al [27] examined patients who required vascular surgery and performed cardiac catheterization on 1000 of them to determine the incidence and severity of CAD. They found that only 8.5% of the patients had normal coronary arteries, and 60% had advanced coronary lesions with greater than 70% stenosis. Patients were offered coronary artery bypass grafting if they had severe CAD. Patients with mild to moderate CAD went on to have vascular surgery. Late mortality (greater than 5 years) was much higher in patients who did not undergo preoperative cardiac catheterization than those who did. It is important to recognize from Hertzer et al's study that the risk of concomitant CAD in patients with vascular atherosclerotic disease is high. Frequently, patients with vascular disease require urgent surgery, and an adequate cardiac workup cannot be completed. CAD should always be suspected in these patients.

Pulmonary insufficiency is another frequent comorbidity because of the high prevalence of cigarette smoking [28]. In patients with chronic obstructive pulmonary disease, a baseline preoperative measure of arterial blood gas on room air can be useful. A room air $PaCO_2$ level of greater than 45 mm Hg indicates a high risk for morbidity. The use of epidural anesthetics for postoperative analgesia has helped to decrease the incidence of postoperative respiratory complications. The risk of renal dysfunction in this population is high for a number of reasons. First, patients may be hypertensive or diabetic or may have some renal artery atherosclerosis. Second, the contrast material used for imaging is also nephrotoxic. Third, aortic cross clamping affects renal artery blood flow, either through direct interruption of flow or through thromboembolic events. Decreased intravascular volume and cardiac output also negatively affect renal function.

Monitoring

The ultimate goal of monitoring is to preserve the physiologic function of all organ systems while the aorta is being cross clamped, so patients should be monitored for myocardial ischemia, cardiac rate and rhythm, hemodynamics that include beat-to-beat blood pressure and intravascular filling pressure, and ventricular function. The ECG is the most common means for monitoring heart rate, rhythm, and myocardial ischemia. ECG leads 2 and 5 are commonly monitored because most ischemia occurs infralaterally. Pulmonary artery occlusion pressure (PAOP) has been used for monitoring myocardial ischemia, and an increase of 4.0 mm Hg or greater in PAOP has been associated with myocardial ischemia [29]. Subendocardial ischemia results in a depression of the ST segment in the ECG, and transmural ischemia results in ST segment elevation in the lead(s) facing the injury, with ST segment depression in other leads.

Left ventricular dysfunction and left ventricular pressure elevation are other cardiac disorders that manifest themselves during aortic surgery. Transesophageal echocardiography (TEE) is thought to be the most sensitive means for monitoring cardiac function. Ischemia is characterized by decreased ventricular wall thickening during systole and segmental wall motion abnormalities. These changes are believed to occur earlier than the ECG changes. The pulmonary arterial changes associated with ischemia are believed to occur later than TEE changes, and they are either an increase in PAOP of 4 mm Hg or greater [30] or changes in the waveform of the pulmonary artery pressure tracing. Cross clamping of the aorta causes an increase in afterload on the left ventricle. In this case, either TEE or continuous cardiac output with pulmonary artery pressures are useful monitors; TEE is probably more useful but requires continual monitoring to detect regional wall motion abnormalities.

When the aorta is cross clamped, lower extremities should not be warmed because they have a higher metabolic rate than can be supported during aortic cross-clamping; therefore, an upper-body warming blanket should be placed (avoiding the surgical site), whereas lower-body warming devices should not be used until after the aortic cross clamp has been removed. Bladder and esophageal temperatures are good assessments of core temperatures; however, bladder temperatures are not accurate during cross clamping.

Temperature monitoring

Hyper- and hypothermia are associated with adverse physiologic effects [17,31]. Hyperthermia is associated with an increased metabolic rate and spinal cord ischemia, whereas hypothermia, which is associated with decreased metabolic rate, is protective of neural tissue but associated with coagulopathy and infectious complications. The goal is to maintain a core temperature in the range of 35° to 37°C, usually by using a forced-air warming blanket.

Hemodynamic monitoring is best achieved through the use of indwelling arterial lines. There are large amounts of blood lost and much third-spacing of fluid associated with aortic cross clamping. To monitor beat-to-beat blood pressure and to sample arterial blood gases, an indwelling arterial catheter should be placed. During thoracoabdominal aortic aneurysm (TAAA) surgery, a right radial arterial catheter frequently is placed because blood flow to the left subclavian can be altered by proximal aortic cross clamping, so measurements in a left-sided radial arterial line may be inaccurate. Frequently, a distal arterial catheter is placed during these operations, usually in the right dorsalis pedis artery. A central venous line provides both the means for crystalloid or colloid administration and for measuring intravascular pressures. Either central venous pressure (CVP) can be measured or a pulmonary artery catheter (PAC) can be placed, which enables monitoring of PAOP as an indicator of ventricular filling and intravascular volume. Continuous cardiac output can be measured with the PAC allowing hemodynamic trends to be monitored and analyzed.

Patients may require inotropic support, vasoconstrictors, or vasodilators. Information derived from a PAC, including mixed venous oxygen saturation, cardiac output, cardiac index, stroke volume, systemic vascular resistance, and pulmonary vascular assistance, is an important aid in guiding titration of this therapy. Frequently, the PAC is useful in the intensive care unit in guiding postoperative management [32]. We routinely use a PAC, frequently inserting an 8 F AVA large-volume infusion line through which the PAC is inserted.

Monitoring of evoked potentials

During TAAA surgery, the most dreaded complication is paraplegia secondary to inadequate perfusion, which results in a loss of motor neurons in the anterior portion of the spinal cord. There is no ideal monitor for spinal cord ischemia, although several institutions believe that monitoring evoked potentials may be of benefit [33]. Loss of motor-evoked potentials (MEPs) during aortic cross clamping is associated with paraplegia. If there is a change in latency or amplitude of the MEPs or somatosensory-evoked potentials (SSEPs) after the aorta is cross clamped, two strategies are suggested: move the aortic cross clamp to allow for greater perfusion of intercostal arteries and drain cerebrospinal fluid (CSF), which may improve spinal cord perfusion. To monitor MEPs, the dose of neuromuscular blocking agents must be limited to maintain compound motor action potential at approximately 10% of baseline. We have evaluated the use of MEPs and found a correlation with paraplegia if used within 10 minutes of cross clamping.

Anesthetic management of aortic aneurysms

Abdominal aortic aneurysms

Airway management of patients undergoing abdominal aortic aneurysm surgery may require the placement of a tracheal tube. In addition to routine monitors, a radial artery catheter and a central venous line, with or without a PAC, should be placed. Two large-bore peripheral intravenous lines are required for intravascular volume management.

The selection of anesthetic agents can be determined by the anesthesiologist, whose goal is to balance oxygen supply–demand ratio throughout the procedure. Thiopental, propofol, and etomidate have been used as induction agents; opioids such as fentanyl, morphine, and sufentanil have been administered for analgesia. Isoflurane is the preferred inhalation agent. Hepatic and renal functions influence the choice of neuromuscular blocking agent. Neuromuscular blocking agents that are not eliminated through the kidneys should be used in patients with renal dysfunction, for example atracurium or cisatracurium. If pancuronium is to be used, its vagolytic properties should be blunted with prior administration of fentanyl. Agents available for blunting hemodynamic response, such as esmolol, sodium nitroprusside, nitroglycerin, phenylephrine, and short-acting β-blockers such as esmolol, should be available for bolus and continuous infusion administration, as needed.

Using a combination of general and epidural anesthesia remains controversial [34–37]. Epidurals have been found to produce more severe hypotension at the time of cross clamping, with a requirement for more fluid and vasopressors in patients whose epidural anesthesia is running during the cross-clamp time. Some clinicians have avoided using epidural local anesthetics until after the cross clamp is removed, injecting only opioids before declamping. Yeager et al [38] compared the outcomes in patients who had general anesthesia and found that those who had epidural anesthesia in the postoperative period experienced fewer cardiovascular and infectious disease complications and lower medical care costs than those who received only general anesthesia without postoperative epidural. However, it appears that earlier extubation can be achieved in patients who have an epidural for analgesia. Attenuation of the adrenergic response with a lower incidence of hypertension in the postoperative period has also been found by Breslow [39] in patients who have an epidural.

Effects of aortic cross clamping

When the aorta is cross clamped, the degree of cardiovascular and systemic effects depends on the level at which the cross clamp is applied. Mean arterial pressure above the clamp increases up to 40% of baseline. This occurs at the same time that cardiac output and global ventricular function deteriorate. CVP, mean pulmonary artery pressure, and PAOP all increase between 30% and 50% over baseline [40]. Heart rate and ventricular stroke volume are unchanged. Ejection fraction decreases by 38% during cross clamping [40]. There is also an increase in left ventricular systolic and end diastolic pressures and an increase in wall motion abnormalities [41]. The increases in filling pressures, PAOP, and CVP are the result of blood volume redistribution during cross clamping. There is also an increase in intracranial pressure because of proximal hypertension. Blood pressure below the clamp decreases by up to 80%, and hepatic and renal blood flows and urine output are severely reduced with a resultant increase in serum lactate production and development of metabolic acidosis. Low-dose dopamine and the use of fenoldopam, a dopamine-1 agonist, have been used to try to improve renal blood flow. Fenoldopam has been found to lower blood pressure and maintain renal blood flow and urine output and to decrease the instance of renal failure in patients undergoing aortic surgery [42,43]. Mannitol and furosemide have also been administered to stimulate urine output.

Before aortic declamping, the patient should be prepared for the side effects of reperfusion. Blood and fluid loss should be replaced, with the “goal” of normalizing preload levels before declamping. As the lower extremities are reperfused, the washout of vasoactive and negative inotropic mediators from ischemic tissue will increase lactic acid load and oxygen-free radicals, with release of cytokines and myocardial depressant factors [5]. The patient’s volume status should be optimized with blood, albumin, or crystalloid, based on interpretation of the CVP, PAOP, blood pressure, and clinical judgment. The FIO_2 should be increased to 100% if the patient is not already receiving 100% oxygen. The concentration of inhalation anesthetic agent should be reduced because it has a potential cardiac depressant effect. Epinephrine, phenylephrine, sodium bicarbonate, and calcium chloride should be available just before the release of the cross clamp, as well as 500 mg of calcium chloride, with enough volume loading to maintain an adequate CVP or PAOP. The aortic cross clamp can be gradually released and reapplied or the aorta compressed manually by the surgeon if significant hypotension occurs. Sodium bicarbonate can be given to counteract the effect of the lactic acid load from the lower extremities based on arterial blood gas drawn before declamping. Blood pressure can be supported with 50- to 100-μg boluses of neosynephrine, or epinephrine can counteract vasodilatory effects of cytokines and myocardial depressant factors. Attention should be given to coagulation abnormalities in the post–cross-clamp period. At this time, the use of TEE to evaluate segmental wall motion abnormalities can be useful and help the anesthesiologist to evaluate and maintain the patient's cardiac function.

Anesthetic management for thoracoabdominal aneurysms

Cause and classification of thoracic aneurysms

A thoracoabdominal "aneurysm" may be a true aneurysm or a false aneurysm. A false aneurysm has a normal internal diameter with a dissected channel that causes a dilated aorta, and a true aneurysm is dilation from one endothelial wall to the other. Crawford and DeNatale [44] classified TAAAs based on the anatomic location (Fig. 2). Type I involves the descending thoracic aorta below the subclavian vessels and the upper abdominal aorta. Type II involves most of the descending aorta and most of the abdominal aorta below the diaphragm. Type III involves the lower portion of the thoracic aorta. Type IV aneurysms begin at the

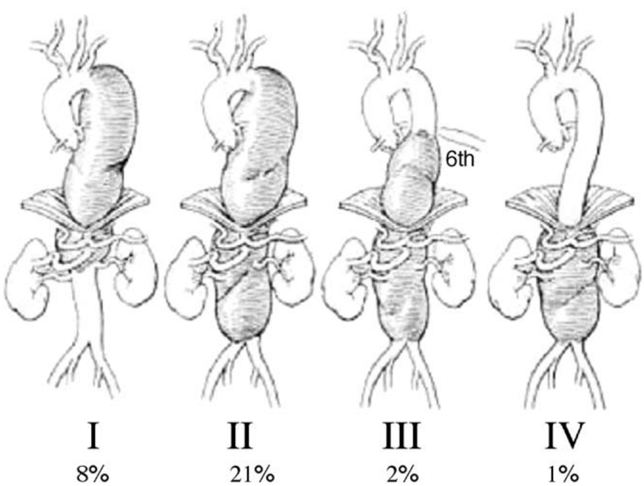

Fig. 2. Crawford's classification of thoracoabdominal aortic aneurysms and incidence of paraplegia.

diaphragm and extend caudally. Type II and III TAAAs are the most difficult to repair. Type II aneurysms have the highest risk for spinal cord injury and renal failure.

Paraplegia is the most devastating complication of surgical repair of the TAAA. The incidence varies from 5% to 40%. The incidence of paraplegia varies with the Crawford classification: 8% in Crawford Type I, 21% in Crawford Type II, 2% in Crawford Type III, and 1% in Crawford Type IV [44]. Postoperatively, approximately 6% of patients have some degree of renal failure and require dialysis [45]. The anesthetic strategies for repair of TAAAs that have been advocated include (1) the use of extracorporeal circulatory support, (2) spinal cord monitoring, (3) spinal cord protection, and (4) hemodynamic monitoring and airway and ventilator support, both intraoperatively and postoperatively.

Coordination with the blood bank is important to assure availability of adequate supplies of packed red blood cells and blood component factors, such as fresh frozen plasma and platelets. Laboratory services also should be available for immediate testing of blood for electrolytes, hemoglobin, coagulation function, and arterial blood gases. After induction of general anesthesia, a double-lumen endotracheal tube is often placed to facilitate exposure with collapse of the left lung and one-lung ventilation. A left-sided double-lumen endotracheal tube is most commonly used. Using a right-sided tube adds a risk of occlusion of the right upper lobe bronchus. However, a right-sided tube may be placed if the aneurysm is large enough to compress the left mainstem bronchus. An alternative method to collapse the left lung includes the use of a single-lumen tracheal tube incorporating an endobronchial blocker. The choice of lung isolation method will usually be determined by the skill of the operator. The double-lumen tube will have to be exchanged for a single-lumen tracheal tube at some point in the postoperative period. This is a high-risk procedure depending on the degree of facial swelling. The use of endobronchial blockers provides an advantage in that they can be withdrawn, leaving a single-lumen tube in place for postoperative ventilation.

The spinal cord can be monitored with MEPs and SSEPs. Patients are at high risk of spinal cord injury if latency is increased or if amplitude is decreased or lost after 10 minutes of cross clamping. If possible, the surgeon may want to move or readjust the cross clamp, or the proximal blood pressure can be increased to provide increased perfusion of the cord through collateral arteries. SSEPs monitor only posterior column function and are, therefore, not as good for detecting anterior column ischemia. Anesthetics can interfere with MEP monitoring. There are different surgical techniques for repairing TAAAs. Some surgeons use a “clamp-and-sew” technique with rapid surgical repair to limit the amount of ischemic time, whereas others use extracorporeal support. As the duration of the cross-clamp time is the most important determinant of spinal cord injury, it is vitally important to restore distal aortic flow within 30 minutes. Such a short cross-clamp time is associated with very little spinal cord injury [46,47], and as the cross-clamp time increases to greater than 30 minutes, the incidence of paraplegia increases [48,49]. The most commonly used bypass procedure is a partial bypass in which oxygenated blood from the left atrium is passed to the left iliac artery. Frequently, oxygenators are not used in this type of bypass because only the left heart is bypassed. During this left-heart bypass, monitoring blood pressure above and below the aortic cross clamp is necessary. Intravascular volume and pump flow are regulated to achieve adequate flow proximal and distal to the cross clamp (Figs. 3 and 4).

The anesthesiologist and the perfusionist must work cooperatively to maintain adequate filling pressure of the heart while providing blood flow to the lower aorta. When the aneurysm involves the aortic arch, deep hypothermic circulatory arrest is used. In that case, the femoral artery is cannulated, and deep hypothermic circulatory arrest is used, with the patient cooled to 18°C. Sometimes antegrade selective cerebral perfusion with cold oxygenated blood is added, extending the safe ischemic time of the brain. Deep hypothermic circulatory arrest allows for a surgical field that is bloodless for the proximal aortic anastomosis and, after this anastomosis is finished, full cardiopulmonary bypass can be reinstituted to complete the other anastomosis. Surface cooling of the patient's head with ice packs and before deep hypothermic circulatory arrest is sometimes used. Pentothal and steroids are given to provide some measure of cerebral protection.

The anesthesiologist should choose monitoring techniques and anesthetic agents with which he or she is most familiar. Controlled intravenous induction

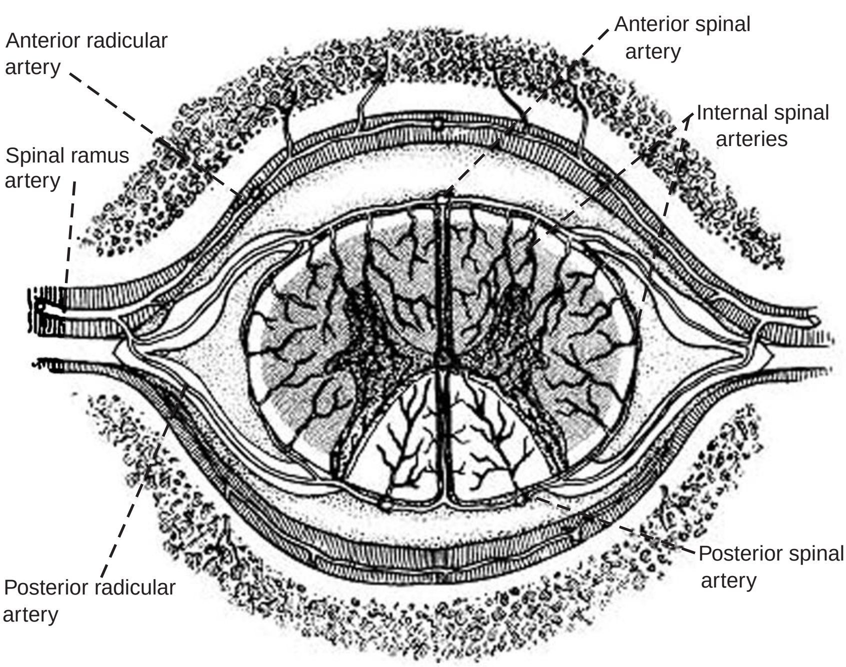

Fig. 3. Cross section of the distal thoracic cord with blood supply. (Reproduced with permission from the Mayo Foundation.)

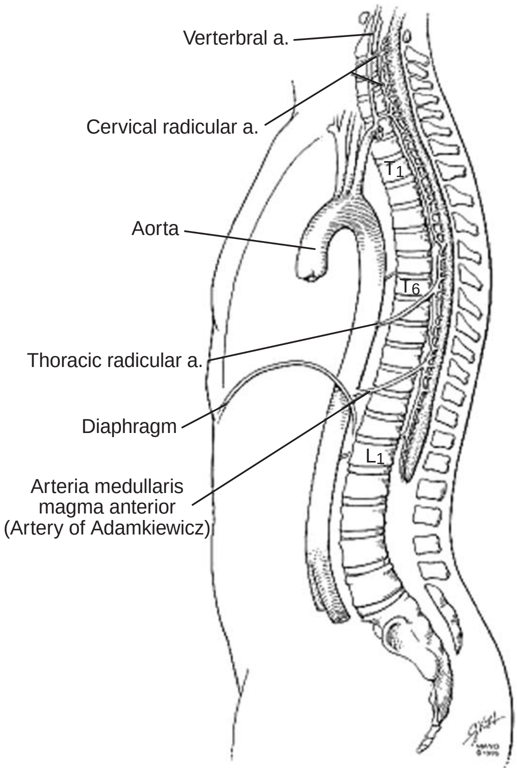

Fig. 4. Cross section of a human torso showing the origin of the anterior spinal artery from cervical radicular arteries. The anterior spinal artery, through its course to the conus, receives additional blood from medullary arteries that derive from intercostals off the aorta. The majority of these arteries arise from the thoracic aorta. Any time the thoracic aorta is cross clamped, the spinal cord is at risk of ischemia leading to the development of paraplegia postoperatively (Reproduced with permission from The Mayo Foundation.)

with hemodynamic stability to avoid stress on the aneurysm wall is preferred. CSF drainage can be used to improve spinal cord perfusion during thoracic aneurysm repair. Spinal cord perfusion pressure is defined as distal mean aortic pressure minus cerebral spinal pressure or CVP, whichever is greater. Drainage of CSF is believed to help by keeping the increase in CSF pressure as low as possible. When the aortic cross clamp is applied, CSF pressure can increase by 10 to 15 mm Hg. Spinal cord drainage can ameliorate this increase and thus help maintain spinal cord blood flow.

Hypothermia has also been advocated as a means of neural protection. Nugent et al [50] and Vacanti and Ames [51] recommend passive hypothermia, which allows the temperature to drop 32° to 35°C. For every degree centigrade decrease in temperature, oxygen requirement is reduced by approximately 5% to 7% with prolongation of the safe ischemic time [52]. Unfortunately, this degree of passive hypothermia is associated with a high incidence of coagulopathy [53]. Cambria et al [54] used regional lumbar epidural cooling with good results. Localized cooling through the artery of Adamkiewicz has also been tried [54,55]. Rewarming the patient in this situation can be accomplished with the forced-air warmers with an upper-body blanket. The lower body should not be rewarmed until perfusion of the legs has been completely restored.

At our institution, we have tried regional lumbar epidural cooling in approximately 150 patients with no improvement in the incidence of paraplegia [53]. Pharmacologic measures to protect the spinal cord include the uses of barbiturates, corticosteroids, calcium channel blockers, and methyl-D aspartame receptor antagonists. Magnesium, naloxone, and papaverine have shown some promise in animal studies and in some preclinical work [56–62].

Anesthetic management of thoracoabdominal aortic aneurysm

After induction of general endotracheal anesthesia, a double-lumen endotracheal tube is usually placed in the left side. If there is a large aneurysm obstructing the left bronchus, then a right-sided double-lumen tube is placed. Position of the tube is usually confirmed with bronchoscopy. Bronchial blockers are used as alternative methods of lung isolation. Before induction, a radial arterial line usually is placed and then two large bore peripheral intravenous lines and a central 7.5-F, large-bore cordis sheath are placed, through which an oxymetric Swan-Ganz catheter is placed, allowing continuous monitoring of cardiac output, mixed venous oxygenation, pulmonary capillary pressures, and left and right ventricular filling pressures. A TEE probe is placed in the esophagus. The patient is turned on their side, and CSF drainage is placed in the lumbar region. If epidural cooling is to be performed at T10 and L3–4, lumbar epidural catheters are placed. The patient is then placed in the lateral position, left side up, or in a modified lateral position, depending on the surgeon’s preference.

Anesthetic induction can be accomplished with any of the induction agents; however, care must be taken not to increase the pressure to avoid rupture of the aneurysm and also to maintain myocardial oxygen supply–demand ratio in an adequate range. The level of anesthesia can be maintained according to the anesthesiologist’s preference for different techniques, either inhalation or a narcotic, or a combination of both. If spinal cord monitoring is used, care is to be taken with the level of inhalation anesthesia and muscle relaxants to avoid loss of the MEP or SSEP response.

Summary

Managing the anesthesia of patients undergoing open aortic surgical repair is a great challenge. The anesthesiologist’s role in myocardial, renal, and neurologic protection is crucial to the patient's overall outcome. Each case presents different challenges, and there is no one right way to manage the patient intraoperatively.

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