Lesson 297-2: PreAnesthetic Assessment of the Patient Undergoing Thoracic Endovascular Aneurysm Repair: Part 2

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Read this article, reflect on the information presented, then go online and complete the lesson post-test and course evaluation before the termination date below. (CME credit is not valid past this date.) You must achieve a score of 80% or better to earn CME credit.

TIME TO COMPLETE ACTIVITY: 2 hours
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In Part 1 of this 2-part series, the causes of thoracic aneurysms and the noninvasive treatment by stent placement were described. In Part 2, the complications of this therapy and monitoring requirements will be outlined.

Professional Gaps

Thoracic endovascular aneurysm repair represents a technique with special considerations that may not be known by many practicing anesthesiologists. This lesson aims to explain these changes and developments.

Learning Objectives

At the end of this activity, the participant should be able to:

1. Outline the causes of aortic dissection and natural history of descending thoracic aneurysm.
2. Describe the criteria and technique used for performing thoracic endovascular aneurysm repair (TEVAR).
3. Prescribe the preanesthetic assessment of the patient undergoing TEVAR.
4. Evaluate the anesthetic implications for the patient undergoing endovascular graft deployment.
5. Tabulate the criteria for TEVAR.
7. Recognize the off-label status of endovascular stents when used in the treatment of aortic dissection.
8. List the indications for stent graft placement.
9. Identify perioperative goals.
10. Describe the intraoperative use of adenosine.
Case History

A 67-year-old woman presented to the emergency room with severe back pain and diaphoresis. She had a history of hypertension and coronary artery disease (CAD). Computed tomography (CT) angiogram revealed an aortic dissection involving the descending thoracic aorta distal to the left subclavian artery origin extending to the aortic bifurcation. There was a 6-cm dilatation of the proximal region of the descending thoracic aorta with evidence of extravasation. There was no disruption of blood flow to the celiac axis, superior mesenteric, and renal vessels on angiogram. Cardiac catheterization revealed nonobstructive CAD and an ejection fraction of 40%. Transthoracic echo revealed left ventricular hypertrophy with normal aortic root and ascending aorta.

On physical examination, the patient had no neurologic deficits; blood pressure (BP) was 170/110 mm Hg; heart rate was 110 beats per minute; and all peripheral pulses were palpable. She was scheduled to undergo thoracic endovascular stent placement to create a seal at the area of extravasation.

Preanesthetic Considerations for TEVAR

The goal of preoperative evaluation is to optimize the patient’s medical status and plan an anesthetic technique that minimizes complications. Aortic surgery and emergency operations are independent risk factors for major complications.

The anesthetic approach to the patient with a thoracic aortic aneurysm (TAA) is selected based on the urgency of repair. An unstable hemodynamic presentation suggests ongoing hemorrhage from a leaking aneurysm, cardiac tamponade, myocardial ischemia, or heart failure. Prior to surgery, it is important to discuss with the surgeon the operative procedure, cannulation strategy (if applicable), and whether evoked potential monitoring is planned. Symptomatic patients with leaking aneurysms require urgent intervention, and there generally is little time to perform more than the most basic preoperative assessment.

All antihypertensive and antianginal medications should be continued until the time of surgery. Systemic hypertension contributes to expansion and rupture of TAA. Strict control of hypertension is initially a top priority and is immediately implemented. The first-line management of hypertension includes a short-acting β-blocker such as esmolol. By lowering the heart rate and slowing the force of contraction, β-blockade reduces the shear force exerted on the dissection. The likelihood of propagation of the dissection is decreased. Second-line agents include vasodilators such as nitroprusside, which lower systolic blood pressure (BP), aortic wall stress, and the possibility of rupture.

Preoperative sedation should be based on the patient’s clinical condition and concurrent medical diseases.

Anxiolysis helps reduce hypertension and tachycardia, thus lowering the risk for myocardial ischemia and aneurysm rupture.

Patients undergoing an elective TEVAR need a detailed workup encompassing every organ system.
Cardiovascular System

Patients undergoing TEVAR are subjected to less hemodynamic stress, as the aorta is not cross-clamped and the anesthesiologist does not have to contend with major fluid shifts and blood loss. Clinicians should assess for the presence of comorbidities, such as coexisting hypertension, atherosclerotic disease, coronary artery disease, and congestive heart failure. The chart is reviewed for previous hospitalizations and procedures, including pacemakers, coronary artery bypass, and percutaneous stent placements.

Specific preoperative studies should include the following:

- Electrocardiography (ECG), which may reveal evidence of ischemia or prior myocardial infarction, left ventricular hypertrophy, and conduction blocks
- Echocardiography, which is used to determine the size, location, and extent of the aneurysm, assess the functional status of the valves, and evaluate biventricular function
- Computed tomography angiography or magnetic resonance angiogram (MRA), which determines the size, location, and extent of the aneurysm.

Pulmonary System

Preoperative pulmonary evaluation includes ascertaining the presence and severity of chronic obstructive pulmonary disease (COPD), smoking history, and functional status. There is less concern for respiratory failure in patients undergoing TEVAR than in those undergoing open descending thoracic aneurysm repairs, because there is less pulmonary insult from massive fluid shifts, transfusion of blood products, and one-lung ventilation. Respiratory failure is a likely sequela of TEVAR if the patient has baseline pulmonary insufficiency.

If feasible, active smokers should refrain from smoking for at least 4 weeks before surgery. Patients with poor diffusing capacity or severe COPD may require preoperative optimization, despite not being subjected to prolonged ventilation.

Dyspnea or stridor may be signs of tracheal or bronchial compression on physical examination. Hemoptysis may be a sign of aneurysmal leakage into the airway. Patients should be evaluated for a history of recurrent laryngeal nerve damage because there is potential for damage to the left recurrent laryngeal nerve if the procedure is converted to open repair.

Central Nervous System

Preexisting neurologic deficits in the central nervous system must be determined. A history of transient ischemic attacks, stroke, and seizures should be specifically sought preoperatively because of the potential for neurologic complications after surgery. Carotid angiography or duplex studies may be appropriate in selected patients with a history of stroke or severe atherosclerosis.

Renal System

Baseline renal insufficiency is related to hypertension, diabetes, and atherosclerotic disease and is an independent predictor of postoperative renal failure. The angiographic contrast dye used
preoperatively during CT imaging and during the intraoperative evaluation of the aneurysm often causes transient abnormalities of renal function. Elective repairs should be delayed until these values have normalized.

**Hematologic System**

Preoperatively, it is routine to discontinue antiplatelet medications and warfarin. Point-of-care testing is used to guide transfusion of blood products. Coagulopathy following TEVAR is uncommon but is likely to occur in the setting of hypothermia, and in the use of heparin.

**Gastrointestinal and Hepatic Systems**

Aneurysmal involvement of the celiac and mesenteric arteries can predispose to bowel ischemia. Abnormal liver function tests should be noted.

**Radiologic Evaluation**

The extent and location of the aneurysm is determined by reviewing the CT or MRA. It may be beneficial to locate the origin of the artery of Adamkiewicz (ARM) preoperatively by angiography if TEVAR is converted to open repair, as identification and reimplantation of ARM reduces the risk for paraplegia by 5%. However, the significance of identifying the origin of ARM for endovascular aneurysm repairs is not known.

**Anesthetic Considerations in Endovascular Graft Deployment**

Although endovascular repair is a less invasive procedure, patients should be anesthetized with the possibility that open surgical repair may be necessary. The risk has decreased with improvements in endovascular devices and with greater surgical experience.

Endovascular aortic repair should be classified, similar to aortic and peripheral vascular surgery, as a higher-risk procedure. Vascular patients are likely to have significant comorbid conditions such as hypertension, hyperlipidemia, stroke, ischemic heart disease, COPD, and diabetes. Preoperative assessment needs to address the typical issues associated with a general anesthetic in a vascular patient.

Perioperative goals during TEVAR are to provide hemodynamic stability while preserving cardiac, spinal, and splanchnic flow and maintaining intravascular volume, adequate oxygenation, and body temperature. Both general and regional techniques have been used successfully. However, with the increasing use of neurologic monitoring and transesophageal echocardiogram (TEE) during TEVAR, general anesthesia is an appropriate choice. Although epidural anesthesia can be used, it may be difficult to distinguish the effects of central neuroaxial blockade by local anesthetics from spinal cord ischemia (SCI). The use of epidural anesthesia is disadvantageous if lower extremity weakness ensues following operations involving the thoracic aorta. Neurologic examination is performed immediately upon emergence from general anesthesia. Any neurologic deficit detected should be considered to be SCI until ruled out.
In early cases of TEVAR, surgeons preferred a “still” field during stent graft deployment, accomplished by the use of adenosine to achieve transient bradycardia or ventricular asystole. With the availability of newer self-deploying stents, this technique is no longer necessary. Various imaging modalities such as angiography, fluoroscopy, and TEE may be used to confirm the position of the stent. The proximal and distal ends of the endograft are then sealed to the aortic wall by endoluminal balloon inflation. The transient balloon inflation may cause a short-lived hemodynamic change that usually will not require any intervention. However, even this ephemeral increase in afterload may be poorly tolerated in patients with severe ventricular dysfunction.

Blood loss may be difficult to quantify, as it often is lost around the sheaths and catheters and can be retroperitoneal in the case of injury to femoral or iliac vessels. A retroperitoneal approach is an alternative technique used in cases with failed femoral access. However, this approach results in higher chances of retroperitoneal bleeding and a longer procedure time. Large-bore IV access is useful in resuscitating unstable patients with rapid, ongoing blood loss. Because of the difficulty associated with accurate prediction of substantial blood loss and the possible need for allogeneic blood transfusion, it is appropriate to set up a cell salvage device in a backup mode. Intraoperative cell salvage and reinfusion can obviate allogeneic blood transfusion and its attendant risks. After graft deployment, vasopressors and inotropes are needed to manage hemodynamic emergencies and maintain higher mean arterial pressures (MAPs).9

**Spinal Cord Ischemia**

The risk for SCI is lower after TEVAR than after open procedures but the complication still occurs, with an incidence of approximately 4% to 7%.10 A Crawford type II thoracoabdominal aortic aneurysm involves most of the descending thoracic aorta and the entire abdominal aorta; this type of aneurysm has the highest incidence of neurologic complications following endovascular repair (19%). There are other risk factors for SCI related to patients’ underlying conditions and the nature of the surgery (Table 1).

The anatomic peculiarity of spinal blood supply explains the susceptibility of the spinal cord to ischemia. A single anterior spinal artery supplies the anterior two-thirds of the spinal cord, which represents the motor region. In the cervical region, the vertebral arteries mainly supply the anterior spinal artery. In general, very few radicular arteries bolster the anterior spinal blood flow. It is critical to maintain the patency of the largest supplier, known as the ARM, as major SCI is likely with its occlusion. Other noteworthy collaterals improving anterior spinal flow arise from intercostal and lumbar segmental arteries that are branches off the descending thoracic aorta. In severe atherosclerosis, in which these collaterals are occluded, the anterior spinal blood supply may be derived from lumbar and perivertebral vessels and the pelvic circulation. Thus, the collateral network is dynamic and can supply blood to the spinal cord from another source when one is reduced. The posterior third of the spinal cord is predominantly a sensory region supplied by 2 posterior spinal arteries.
Although the incidence of paraplegia is definitively lower with endovascular procedures, it remains one of the most dreaded complications. The cause differs from that encountered in open surgery, as no aortic cross-clamping is employed, and is most likely because of permanent coverage of important collateral arteries and intercostals supplying the spinal cord. With the recognition of this risk, cerebrospinal fluid (CSF) drainage during the perioperative period is an important consideration when extensive lengths of descending thoracic aorta are to be covered and in patients who had previous aortic repair.

**Monitoring Considerations in TEVAR**

In patients at high risk for SCI, additional intraoperative neurologic monitoring with transcranial motor evoked potentials (MEPs) and/or somatosensory evoked potentials (SSEP) is useful.

Patients are prepared for evoked potential monitoring with baseline measurements following induction of general anesthesia. Both inhalational and IV anesthetic agents have effects on neural synaptic and axonal functional activities. Intraoperative neurophysiologic monitoring can be challenging, because recording SSEP and MEP signals requires critical anesthetic choices and attention to temperature changes. The anesthetic effect on any given response depends on the pathway affected and the mechanism of action of the anesthetic agent. Inhaled anesthetics decrease the waveform amplitude and increase latency to a greater extent than IV anesthetics. Halogenated agents and nitrous oxide also depress MEP signals more than total IV anesthesia. An IV propofol–based anesthetic is preferred because it causes less suppression of cortical SSEPs with better preservation of SSEP amplitude at an equivalent depth of anesthesia compared with isoflurane. The management of pharmacologic neuromuscular blockade is crucial to myogenic MEP recording, as some blockade may be desirable for surgery, but excessive blockade may eliminate responses.

Monitoring helps in the early detection of SCI and permits intervention before ischemia evolves to infarction. Decreased SSEP and MEP amplitudes have been shown to correlate with SCI, but the sensitivity and specificity of these techniques remain to be determined.

Intraoperative loss of SSEP or MEP signals is not necessarily caused by SCI. SSEP latency is increased and the magnitude is reduced by benzodiazepines and normal clinical concentrations of volatile anesthetic agents. SSEP detects lateral and posterior column ischemia but is a poor monitor for anterior motor column. A potential limitation of SSEP monitoring is that SCI confined to the anterior spinal cord may cause a selective motor deficit with intact sensation.

Impaired peripheral nerve functioning from ischemia may affect the associated SSEPs or MEPs. Intraoperative strokes and lower limb ischemia from vascular insufficiency are known to cause loss of peripheral SSEPs or MEPs in the absence of SCI.

**Techniques To Improve Spinal Cord Perfusion**

Because spinal cord perfusion pressure (SCPP) is equal to the MAP minus the lumbar CSF pressure, close attention is given to CSF drainage if lumbar CSF pressure is increased. Spinal cord perfusion is improved by augmenting the arterial pressure alone or in combination with lumbar CSF drainage.
Vasopressor agents such as norepinephrine have been used to maintain a MAP of 80 mm Hg or greater to assure an SCPP of at least 70 mm Hg. Patients at risk for SCI may even need a higher MAP to improve SCPP. Attention needs to be given to optimizing oxygen delivery by improving cardiac output, correcting anemia, and maintaining a normal central venous pressure.

CSF is drained by the percutaneous insertion of a silastic catheter into the subarachnoid space. It is performed on an awake patient in the lumbar position. CSF is drained passively to reduce lumbar CSF pressure to approximately 10 to 12 mm Hg during the operation. The catheter is usually left in place for 48 to 72 hours postoperatively. Emergent CSF drainage has been performed postoperatively to reverse delayed-onset paraplegia in combination with augmentation of MAP up to 100 mm Hg.13

Hypotension should be assiduously avoided, as it worsens SCI. It results from bleeding, anesthetics, and an underlying cardiac condition. SCI, which may itself contribute to hypotension, is a neurogenic shock associated with autonomic dysfunction. Immediate treatment of hypotension is a priority, as prolonged ischemia may progress to spinal cord infarction.

The various options for spinal cord revascularization that exist in open repairs are not available in TEVAR. Here, the preservation of spinal artery blood flow by segmental vessels is not feasible if the aneurysm is excluded by the stent graft. In some situations, the left subclavian artery may need to be covered by the endovascular stent graft in order to exclude the aneurysm. Because subclavian arterial flow contributes substantially to anterior spinal artery supply, a prior transposition of the subclavian artery onto the left carotid artery is required. Another method used to preserve left subclavian artery flow in TEVAR is to perform a left carotid to subclavian bypass graft with subsequent coil embolization of the proximal left subclavian artery stump during TEVAR.14 Because coverage of the left subclavian artery without bypass has been independently associated with paraplegia, many centers now perform elective left subclavian revascularization before TEVAR if the preoperative plan involves coverage of this artery in order to obtain an adequate proximal seal zone.

Lumbar CSF drainage is performed in patients who will subsequently require anticoagulation with boluses of heparin for endovascular stent placement. It is generally deemed safe, although complications related to intraspinal or epidural hematoma may exist with a traumatic drain placement. Rapid drainage of CSF is another cause of serious complications such as subdural hematoma, intracranial hemorrhage, and remote cerebellar hemorrhage. Precautions such as continuous measurement of CSF pressure, controlled intermittent drainage of CSF, and assessment of coagulation function may decrease the risks associated with lumbar CSF drainage (Table 2).15
deployment of the graft and to ensure that the aneurysmal sac is completely excluded. Prevention is emphasized, as there is no specific treatment for contrast-induced acute renal failure (ARF). Preexisting renal failure and diabetes place patients at highest risk for contrast-induced ARF.

Measures include hydration with isotonic sodium bicarbonate along with the administration of the antioxidant acetylcysteine to reduce the risk for contrast-induced ARF. Diuretics and/or mannitol have no role in the prevention of contrast-induced ARF.

**Role of TEE in TEVAR**

The proximity of the esophagus to the aorta in the intrathoracic space makes TEE an appealing imaging modality for detection of aortic pathology. During TEVAR, intraoperative TEE provides valuable feedback regarding the extent and severity of the aortic pathology, guiding placement of the endograft, monitoring cardiac performance during and following aortic occlusion caused by transient balloon, and detecting endoleaks after endograft deployment. Cardiac performance may be monitored by TEE during the acute hemodynamic disturbances of stent deployment. Diastolic dysfunction is the end result of perioperative myocardial injury that remains undetected by any other monitoring modality (Table 3).16

<table>
<thead>
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<th>Table 3. Use of Intraoperative TEE for TEVAR Procedures</th>
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<td><strong>Confirming aortic pathology</strong></td>
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<td><strong>Detect the presence of widespread atherosclerotic plaques</strong></td>
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<td><strong>Endograft imaging</strong></td>
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<td><strong>Differentiate true from false lumen in dissections</strong></td>
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<td><strong>TEE probe used as a marker during fluoroscopy</strong></td>
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<td><strong>Monitoring cardiac performance</strong></td>
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<td><strong>Regional wall motion abnormality</strong></td>
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<td><strong>Check for endoleaks after graft deployment</strong></td>
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An endoleak is a unique complication of TEVAR and occurs when blood flows outside the lumen of the endograft but within an aneurysm sac. The causes of endoleak are described in Table 4. Endoleaks have been classified into types I to IV based on the underlying cause and anatomic site of origin. Accurate detection and classification are essential for proper management because the method of endoleak treatment is determined by its source.17
In general, high-pressure leaks (types I and III) require urgent management because of the relatively high short-term risk for sac rupture. Observational management of type II endoleaks may be associated with continued sac expansion, requiring close monitoring (Table 5).

Low-pressure lesions (type II) are considered less urgent but may require continued endovascular evaluation if there is impending growth of the aneurysm sac. Endoleaks requiring correction include all type I and III lesions as well as type II lesions associated with aneurysm enlargement. Techniques used incorporate extension endografts or cuff, balloon angioplasty, and bare stents. Type II endoleak continues to be the most common but also the most controversial in terms of evaluation, need for treatment, and methods of treatment. Postoperative lifelong follow-up with CT imaging is needed.\textsuperscript{18}
Management of the Case Presented

This patient has a type B aortic dissection complicated by periaortic leakage but with no evidence of organ malperfusion or limb ischemia. Surgical or endovascular repair was indicated for the periaortic leak with potential for aortic rupture. Maintaining BP control and hemodynamic stability is of critical importance, with the goal of keeping systolic BP below 120 mm Hg while maintaining sufficient organ perfusion to the brain, heart, and kidneys.

The patient was given esmolol and sodium nitroprusside infusions preoperatively for strict BP control and to minimize the shear forces on the aorta. She was not receiving anticoagulants or clopidogrel, so after discussion with the surgeon, a decision was made to place a lumbar drain, as the surgeon was planning to cover a large area of the thoracic aorta. The risk for SCI was anticipated for this procedure, and a plan was made to monitor her neurologic status intraoperatively using SSEPs and MEPs.

Prior to the patient’s arrival in the operating room, a right radial arterial cannula was placed for close BP monitoring and frequent blood gas sampling, along with a large-bore peripheral IV. The right radial artery was chosen for arterial line placement due to the possibility of the proximal landing zone covering the left subclavian artery, thereby inhibiting flow to the left radial artery.

The patient received premedication with IV midazolam and was brought to the operating room, where standard monitors were placed. A lumbar drain was placed atraumatically in sitting position. Opening CSF pressures were normal. CSF pressures were transduced and fluid intermittently drained if CSF pressure exceeded 10 mm Hg.

Anesthesia was induced with sufentanil, propofol, and succinylcholine, and she was maintained with propofol and sufentanil infusions along with 0.5% inspired isoflurane. After induction, central venous access was obtained by a right internal jugular vein 9 Fr introducer for potential central venous pressure monitoring and for rapid infusion. A central line is recommended for rapid fluid administration from acute blood loss secondary to procedure-related complications or aortic pathology. It provides portals for pharmacologic therapy with pressors or inotropes, and for insertion of invasive monitors, such as a pulmonary artery catheter if necessary, to optimize hemodynamic status in hypotensive states. Although there are concerns about central line–related complications leading to pneumothorax, hematoma, infection, and thrombosis, we routinely place a central line for this procedure using ultrasound guidance and remove the catheter early if it is not required. Pulse pressure variations are dynamic preload indicators and also can be used to assess volume responsiveness in ventilated patients.

TEE probe was placed atraumatically to provide rapid real-time assessment of cardiac structures, with a view to assessing functional status and treating hemodynamic instability. Pericardial effusion and aortic valve abnormalities were excluded, and aortic pathology comprising aneurysm and intimal flap in descending thoracic aorta was identified. True and false lumens were confirmed, and the location of guide wire in the true lumen was checked. The aortogram demonstrated a descending thoracic aortic aneurysm with a portion of the posterior aorta showing extravasation. Both proximal and distal landing zones were observed, and it was determined that the left subclavian artery would not be covered by the endograft. A 34 mm ×10 cm TAG device was chosen based on the aortogram, and was advanced over the guide wire and brought into position and deployed. This was followed by ballooning of the proximal and distal portions of the graft. A proximal type I endoleak was noted distally by TEE, so the
balloon was reinserted and inflated along the length of the graft. The balloon inflation resolved the endoleak on TEE. A final aortogram revealed adequate seal of the proximal and distal landing zones.

TEE helped to guide administration of fluids and pressors. Patient had decreased end-diastolic volume on transgastric short axis view, with increased contractility and no regional wall motion abnormality. Fluid boluses and norepinephrine infusion helped achieve a MAP between 80 and 90 mm Hg for adequate spinal cord perfusion after the stent deployment.

The patient was successfully extubated in the operating room, and her neurologic exam was normal. She was monitored in the intensive care unit, and MAPs were maintained between 80 and 90 mm Hg. The spinal drain was removed after 48 hours. A follow-up CT angiogram was performed and confirmed adequate placement of the endograft with no evidence of extravasation or displacement. She was transferred to floor, in stable condition.

**Conclusions**

TEVAR is emerging as the treatment of choice for acute surgical emergencies involving the descending thoracic aorta. The data support the safety and efficacy of TEVAR for aortic pathologies with a low mortality rate. We described a case of successful anesthetic management of a patient who presented with acute aortic dissection Stanford type B associated with periaortic hematoma and aortic dilatation necessitating surgical intervention. Her BP was initially controlled while further workup and imaging studies were performed.

The patient met the surgical criteria for endovascular stent placement and had no complications related to organ malperfusion. She was considered at high risk for SCI, and a lumbar drain with CSF pressure and intraoperative neurologic monitoring were done. Invasive hemodynamic monitoring and TEE were additionally employed. We conclude that perioperative workup and anesthetic technique need to be tailored to the patient’s underlying comorbidities and aortic pathology. Current endograft technology has evolved sufficiently to allow for successful treatment for emergent conditions involving the descending thoracic aorta.

Dr. Elizabeth A.M. Frost, who is the editor of this continuing medical education series, is clinical professor of anesthesiology at The Mount Sinai School of Medicine in New York City. She is the author of Clinical Anesthesia in Neurosurgery (Butterworth-Heinemann, Boston) and numerous articles. Dr. Frost is past president of the Anesthesia History Association and former editor of the journal of the New York State Society of Anesthesiologists, Sphere. She is also editor of the book series based on this CME program, Preanesthetic Assessment, Volumes 1 through 3 (Birkhäuser, Boston) and 4 through 6 (McMahon Publishing, New York City).
REFERENCES


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### Post-test

1. **The indications for surgical intervention in Stanford type B aortic dissection include _____**
   
   a. extravasation of blood from the aorta  
   b. rapidly expanding false aneurysm  
   c. hypertension  
   d. obstruction of renal vessels

2. **Using the technique of thoracic endovascular aneurysm repair (TEVAR) to manage descending thoracic aneurysm entails the following anesthetic plan:**
   
   a. Use of one-lung ventilation to visualize the descending aorta.  
   b. Radial line can be placed in either upper extremity.  
   c. Mean arterial pressures (MAPs) need to be maintained higher than 80 mm Hg before stent graft is deployed.  
   d. Monitoring blood loss, as significant loss can occur from groin and retroperitoneal hematomas.

3. **The surgical considerations for endovascular repair of thoracic aortic aneurysm include all of the following EXCEPT:**
   
   a. adequate proximal and distal landing zones  
   b. access to femoral or iliac vessels  
   c. endograft coverage may span coverage between left common carotid artery and celiac axis  
   d. the celiac axis must never be covered to achieve an adequate distal landing zone

4. **Anesthetic considerations for endovascular graft deployment include all of the following EXCEPT:**
   
   a. consideration should always be given to the idea of an open procedure being needed.  
   b. the procedure is performed on vascular patients with significant comorbidities.  
   c. regional techniques are preferred, as they facilitate neurologic examination.  
   d. vasopressors and inotropes should be immediately available for management of hemodynamic emergencies.
5. **A lumbar drain**
   a. should be routinely used in all patients undergoing TEVAR.
   b. may be placed postoperatively if there is delayed-onset paraparesis.
   c. should not be used if heparin is given intraoperatively during TEVAR.
   d. should be continuously drained to prevent spinal cord ischemia.

6. **Cerebrospinal fluid (CSF) pressures during TEVAR should be maintained at _____**
   a. <12 mm Hg
   b. 12-15 mm Hg
   c. 15-17 mm Hg
   d. 17-20 mm Hg

7. **Each of the following is a method of treatment or prevention of spinal cord ischemia during TEVAR EXCEPT:**
   a. early detection of ischemia by intraoperative monitoring with somatosensory evoked potential and motor evoked potential (MEP).
   b. augmentation of spinal cord perfusion by elevated blood pressure and CSF drainage.
   c. performing an elective subclavian revascularization if the subclavian artery needs to be covered by endovascular stent graft.
   d. MAP may be kept lower and lumbar drain is not needed in treating type II Crawford thoracoabdominal aortic aneurysm.

8. _____ can be used to maintain adequate MEP signals intraoperatively.
   a. Nondepolarizing muscle relaxants
   b. High-dose volatile anesthetics
   c. Propofol infusion
   d. Succinylcholine

9. **All of the following are true regarding aortic aneurysms EXCEPT:**
   a. they are classified according to location, morphology, and etiology.
   b. location is NOT used to determine surgical approach.
   c. aortic dissection may be associated with an aneurysm.
   d. true aneurysms involve all layers of the aortic wall.

10. **Which of the statements regarding endoleaks is true?**
   a. A type I endoleak is a diagnosis of exclusion, and a contrast angiography is not needed for its diagnosis.
   b. Most type II leaks should only be observed if they are associated with continued sac expansion.
   c. A type I leak occurs due to reactions of the endograft within the aneurysmal sac environment.
   d. Transesophageal echocardiography is not helpful in the detection of type I endoleaks.