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CHAPTER 6.3

Vascular Surgery

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[1] Endovascular stent-grafting

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Carotid Endarterectomy (Vascular)

Surgical Considerations

Description: Carotid endarterectomy (CEA) continues to be one of the commonly performed open vascular surgery procedures in the United States, even as carotid stenting is being more frequently employed as an alternative approach. Because of presumed microemboli from stenotic/ulcerated plaques at the carotid bifurcation, CEA has been championed as an effective procedure to reduce the risk of subsequent stroke. The NASCET Collaborators determined, in a prospective, randomized, blinded trial, that CEA is more effective than medical therapy for symptomatic patients with internal carotid artery narrowing between 60% and 90%. Symptoms are usually hemispheric (contralateral, upper or lower extremity paresis or numbness) or retinal (unilateral monocular blindness). Symptoms may be transient (TIA or reversible ischemic neurological deficit [RIND]) or permanent (CVA). The Asymptomatic Carotid Atherosclerosis Study (ACAS) has shown benefit from prophylactic CEA in asymptomatic patients with >60% stenosis of the internal carotid artery. Although some surgeons routinely prefer local anesthesia, most prefer GA with careful hemodynamic monitoring because of the frequent concomitant CAD.

The carotid artery is approached through an oblique neck incision along the anterior border of the sternocleidomastoid muscle. After division of the common facial vein, the carotid sheath is opened and the carotid artery is exposed, avoiding injury to the phrenic, vagus, ansa hypoglossi, and hypoglossal nerves (Fig. 6.3-1). After controlling the internal, external, and common carotid arteries, heparin is administered, and the internal, external, and common carotid arteries are clamped sequentially. To maintain carotid perfusion, an indwelling shunt may be utilized (Fig. 6.3-2 B), at the discretion of the surgeon. An endarterectomy plane is established proximally (Fig. 6.3-2 C), and developed distally into both the external and internal branches, with establishment of a fine tapered end point. After removal of all thrombus, loose smooth-muscle fibers and endothelium, the arteriotomy is closed, with or without a patch, the artery flushed, and flow restored. The incision is closed after meticulous hemostasis has been assured.

Usual preop diagnosis: Carotid artery disease

Summary of Procedures

Position	Supine with neck extended and turned away from the side of the lesion
Incision	Anterior to sternocleidomastoid from earlobe to base of neck or curvilinear in a skin crease over the carotid bifurcation
Special instrumentation	EEG monitor; ± shunt
Unique considerations	Capability to measure stump pressure may be needed. This can be accomplished by a high-pressure arterial line passed off the field to a pressure transducer. Avoid ↓ BP during carotid cross-clamping. An indwelling shunt may be utilized to restore carotid perfusion. Heparin 5,000–10,000

	U 5 min prior to cross-clamping, and protamine may be given after restoration of flow.
Antibiotics	Cefazolin 1 g iv at induction of anesthesia
Surgical time	Carotid cross-clamp: 30 min Total operating time: 90 min
Closing considerations	In order to assess the patient's neurologic status, it is best to be able to awaken and extubate the patient at the conclusion of the procedure. Avoidance of HTN is also critical during this period, because the endarterectomy tissues are thin and friable.
EBL	100–200 mL
Postop care	ICU × 12–24 h; BP control; cardiac monitoring
Mortality	1%
Morbidity	MI: Major cause of postop mortality Cranial nerve injury (recurrent and superior laryngeal nerves): 39% Restenosis Asymptomatic: 9–12% Symptomatic: < 3% Neurologic complications: < 2% Hemorrhage: 1% False aneurysm: < 0.5%
Pain score	3–5

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Patient Population Characteristics

Age range	55–80 yr
Male:Female	3:1
Incidence	Second most common vascular surgical procedure (after AAA repair)
Etiology	Arteriosclerosis; fibromuscular dysplasia
Associated conditions	Significant CAD coexists with carotid artery disease in at least 30% of patients, necessitating careful cardiac and hemodynamic monitoring.

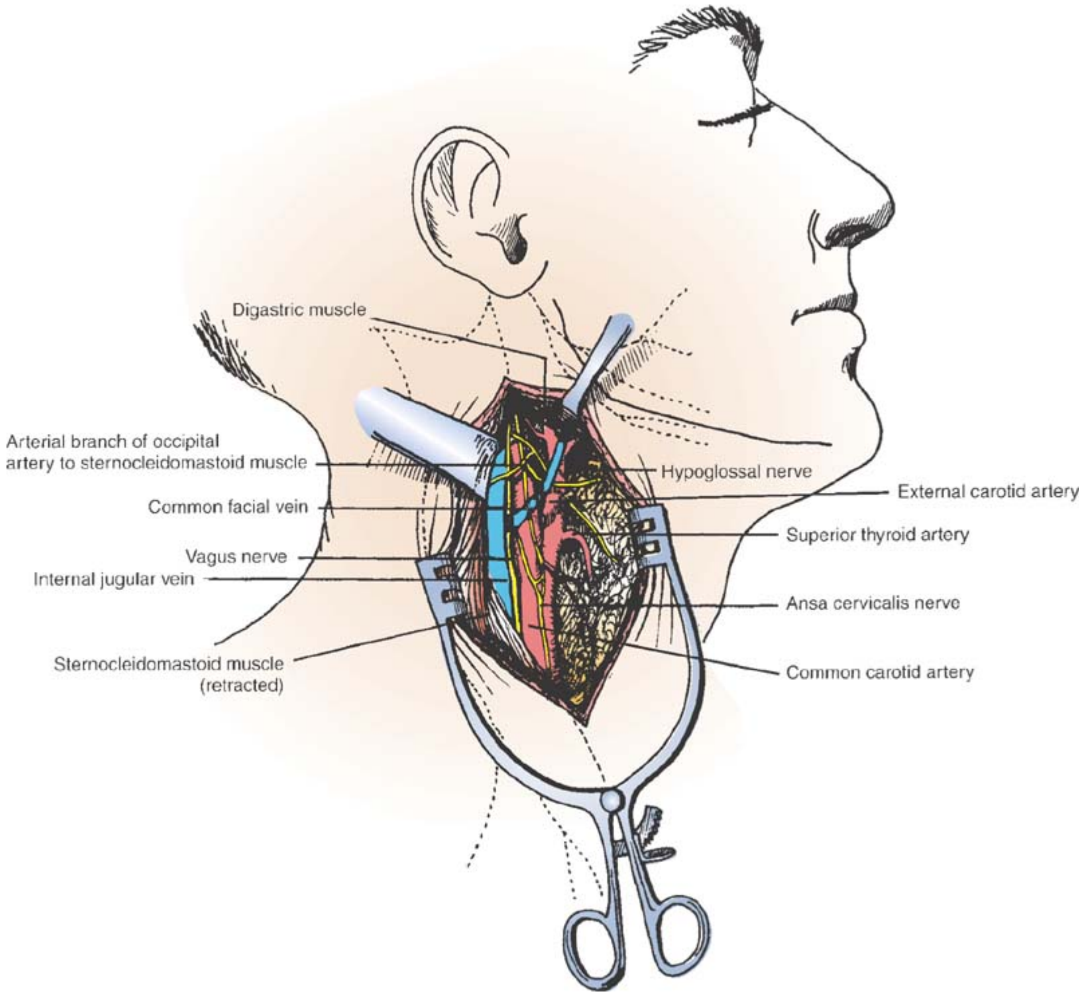

Figure 6.3-1. 1. Exposure of the carotid bifurcation. (Reproduced with permission from Scott-Conner CEH, Dawson DL: *Operative Anatomy*, 2nd edition. Lippincott Williams & Wilkins, Philadelphia, 2003.)

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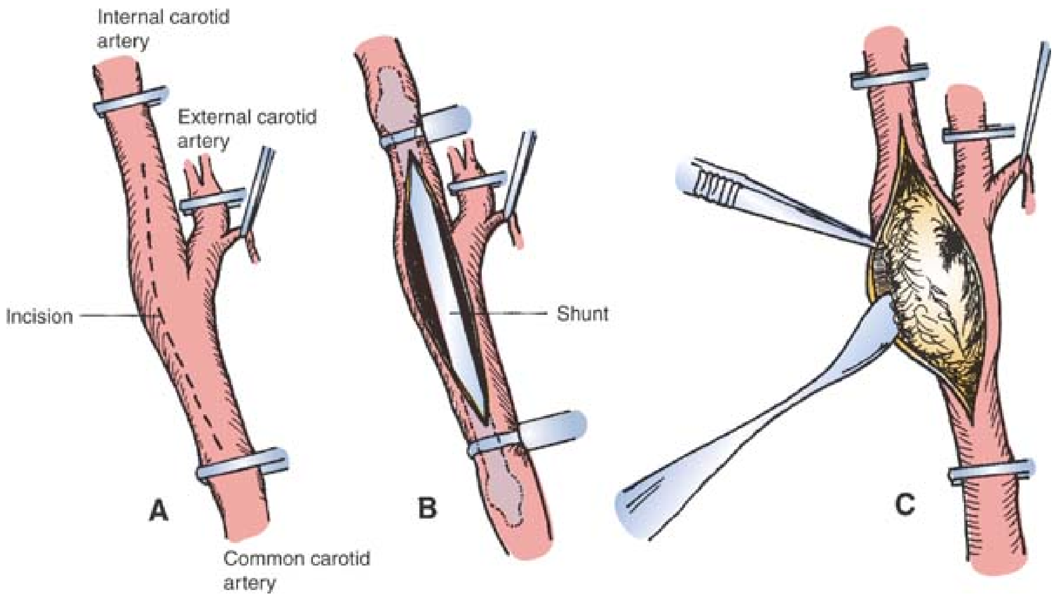

Figure 6.3-2. 2. Carotid endarterectomy: **A.** Following occlusion of the superior thyroid and internal, external, and common carotid arteries, an arteriotomy is performed opposite the external carotid take off. **B.** A shunt may be placed to restore internal carotid flow. **C.** Plaque is separated from the artery wall. (Reproduced with permission from Scott-Conner CEH, Dawson DL: Operative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia, 2003.)

Anesthetic Considerations

See Anesthetic Considerations for Carotid Endarterectomy (Neurosurgical) in Extracranial Procedures, p. 130.

Suggested Readings

1. Biggs KL, Moore WS: Current trends in managing carotid artery disease. *Surg Clin North Am* 2007; 87:995–1016.

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8. Pasternak JJ, Lanier WL: Neuroanesthesiology review–2006. *J Neurosurg Anesthesiol* 2007; 19:70–92.

9. Young B, Moore WS, Robertson JT, et al: An analysis of perioperative surgical mortality and morbidity in the Asymptomatic Carotid Atherosclerosis Study. ACAS Investigators. *Stroke* 1996; 27:2216–24.

Repair of Thoracic Aortic Aneurysms

Surgical Considerations

Description: Repairs of aneurysms of the ascending, transverse arch, and descending thoracic aorta are performed to repair expanding or leaking aneurysms, or prophylactically to prevent rupture. Patients with Sx of rapid expansion *(Print pagebreak 395)* or aneurysm leaking may require urgent repair. Each surgical type—ascending, arch, and descending—is considered separately, as follows. Aneurysms of the **ascending aorta** may arise 2° the degenerative changes of atherosclerosis (exacerbated by old age, HTN, tobacco use); from inborn errors of metabolism (Marfan syndrome); or from poststenotic dilatation and continued expansion of a chronic dissection. Diseases of the entire ascending aorta, including the sinuses of Valsalva, as in Marfan syndrome and annuloaortic ectasia, require replacement of the ascending aorta and aortic root with a composite valved conduit, while acquired diseases limited to the ascending aorta usually allow replacement of the aorta distal to the sinotubular ridge. Repair of the ascending aorta is usually accomplished on full CPB with an aortic cross-clamp placed just proximal to the innominate artery and arterial inflow through the femoral artery. The aneurysmal ascending aorta is replaced with a Dacron tube graft from the sinotubular ridge to the innominate artery. Dilatation of the sinuses of Valsalva mandates replacement with a composite valved conduit sewn proximally to the aortic annulus and distally to a normal caliber ascending aorta, with coronary ostia reimplanted in the side of the tube graft.

Aneurysms of the **aortic arch** are the least common of thoracic aortic aneurysms. Because of the need for concomitant replacement of the arch vessels, however, they are the most complex to repair. Total CPB is utilized, and cerebral protection is accomplished either by CPB perfusion of one or all cerebral vessels, or by profound hypothermic circulatory arrest at 15–18°C. Repair can originate from the aortic annulus and extend distally to the mid descending thoracic aorta at the level of the carina. Routine caval cannulation is accomplished via a median sternotomy, and arterial access is gained via the femoral artery or axillary artery. If circulatory arrest is to be used, the patient is cooled to 15–18°C, the heart is arrested and, with no distal cross-clamp, distal anastomosis is accomplished, followed by implantation of the cerebral vessels attached to an island of aorta. Perfusion is then reinstituted, the graft clamped proximal to the innominate artery, and the proximal anastomosis performed, while the patient is being rewarmed. Alternatively, if one elects to perfuse the cerebral vessels, the innominate and left carotid arteries can be individually cannulated and perfused via a "Y" connection from the femoral arterial perfusion line. If axillary cannulation is used, antegrade cerebral perfusion can be achieved by control of the proximal innominate artery. The necessity for profound hypothermic circulatory arrest is thus avoided. After completion of the distal aortic, arch vessel island and proximal aortic anastomoses, weaning from CPB and subsequent steps proceed in a routine fashion.

Repair of aneurysms of the **descending thoracic aorta** is usually performed for symptomatic and leaking aneurysms, enlarging aneurysms, and aneurysms of sufficient size to warrant prophylactic repair. **Aneurysm repair** is accomplished through a left posterolateral thoracotomy on partial CPB. After entry into the left thorax, venous drainage for CPB may be obtained from the left atrium or the femoral vein, and arterial return is via the femoral artery. If partial bypass without an oxygenator is elected, thus minimizing the amount of heparin necessary, venous access can be gained via the pulmonary veins or left atrium, and arterial return via the femoral artery or distal thoracic aorta. After institution of bypass, the aorta is cross-clamped above and below the aneurysm, the aorta is divided, a tube graft is interposed, and clamps are removed. The patient is weaned from bypass, and the operation is terminated in the routine fashion.

Usual preop diagnosis: Enlarging or symptomatic aortic aneurysm

Summary of Procedures

	Ascending Aorta	Transverse Arch	Descending Aorta
Position	Supine		Lateral decubitus with left side up
Incision	Median sternotomy		Left posterolateral thoracotomy with access to femoral artery and vein
Special instrumentation	CPB, if used.	Complete hemodynamic monitors; CPB	+ DLT; lower extremity BP monitor
Unique considerations	Routine CPB hemodynamic monitoring	If profound hypothermic arrest is utilized, neuroprotective adjuncts, including local hypothermia, barbiturates, and steroids, should be used.	OLV; partial CPB
Antibiotics	Cefazolin 1 g iv		
	Ascending Aorta	**Transverse Arch**	**Descending Aorta**
Surgical time	Aortic cross-clamp: 40–120 min	Aortic cross-clamp: 75–120 min	Aortic cross-clamp: 25–45 min
	CPB: 70–150 min	Circulatory arrest: 30–45 min	CPB: 30–60 min
	Total: 2.5–5 h	CPB: 3–4.5 h Total: 4–6 h	Total: 2.5–4.5 h
Closing considerations	Aggressive management of coagulopathy, if a long pump run is necessary.	Aggressive management of coagulopathy	Replacement of DLT with single-lumen tube
EBL	300–400 mL	400–700 mL	200–300 mL
Postop care	ICU, intubated 5–20 h, depending on preop condition	ICU, intubated 6–24 h	ICU, intubated 5–24 h
Mortality	5–10%	10–15%	
Morbidity	Renal failure: 5–10%	—	10–15%
	CVA: 4–6%	2–5%	2–4%
	Respiratory failure: 3–5%	10%	10–15%
	MI: 2–5%		2–4%
Pain score	7–10	7–10	9–10

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Patient Population Characteristics

Age range	23–80 yr (mean = 55 yr)	50–75 yr	34–79 yr (mean = 65 yr)
Male:Female	3:1	2:1	2.5:1
Incidence	10–30/yr at tertiary center	5–10/yr at tertiary center	10–30/yr at tertiary center
Etiology	Degenerative disease Atherosclerotic disease	Chronic dissections	
Associated conditions	CHF (50%); angina (30%); HTN (30%); COPD (15%)	Aortic valve disease (30%); COPD (20%); CAD (15%)	HTN (65%); CAD (50%); COPD (30%); CHF (10%)

Anesthetic Considerations

Preoperative

Typically, patients with thoracic aortic aneurysms have atherosclerosis and HTN. A subset of patients will have a connective tissue disorder (e.g., Marfan syndrome). In contrast with thoracic aortic dissections, thoracic aortic aneurysms may be of a more chronic and asymptomatic nature. A ruptured or leaking aneurysm, however, may have a more precipitous presentation.

Cardiovascular	**Arch and ascending aneurysms** (60–70% of aneurysms): commonly associated with HTN, cystic medial necrosis, connective tissue disorder (e.g., Marfan syndrome), atherosclerosis, or syphilis. CHF may occur 2° to dilation of the aortic annulus and aortic incompetence (AR). Aneurysmal compression or intrinsic disease of the coronary arteries may result in myocardial ischemia. **Descending (30%):** usually associated with HTN, cystic medial necrosis, Marfan syndrome, and atherosclerosis. **Tests:** ECG: for LVH, ischemia. ECHO: for valvular disease, size and extent of aneurysm, LV function. Angiography: exact extent of aneurysm (allows planning of procedure and sites for arterial monitoring), coronary artery anatomy, and degree of occlusion.
Respiratory	Recurrent laryngeal nerve palsy may → hoarseness (ascending/arch aneurysms). Tracheal deviation ± stridor or dyspnea may be present 2° tracheal or bronchial compression (CT scan). Hemoptysis or a hemorrhagic pleural effusion suggest an aneurysmal leakage or rupture. The implications include the possibility of compromised oxygenation, risk of massive hemorrhage on thoracotomy, increased intrathoracic pressure, and consequent decreased venous return (especially when IPPV is instituted). **Tests:** CXR: for widened mediastinum, distortion of trachea and left main bronchus (because it may affect the placement of DLT); MRI/CT with contrast: anatomic relation of aneurysm to surrounding structures (e.g., trachea/bronchi); others as indicated from H&P.
Neurologic	Any deficit should be well documented as neurologic sequelae (e.g., paraplegia/paraparesia) may occur after surgery.
Renal	Renal problems may occur 2° to AR (↓CO) and heart failure, HTN, or involvement of renal arteries in the aneurysm. **Tests:** BUN; Cr; consider Cr clearance; electrolytes

Gastrointestinal	Descending aneurysms that involve the celiac or superior mesenteric arteries may → bowel ischemia. **Tests:** Consider ABG: persistent metabolic acidosis (2% bowel ischemia). If indicated by H&P, consider abdominal CT/x-ray: ileus.
Hematological	If time permits, consider autologous blood donation; pre-existing coagulopathy increases risk of the procedure. **Tests:** PT; PTT; Hct/Hb
Musculoskeletal	Marfanoid appearance; others as indicated from H&P.
Laboratory	Others as indicated from H&P.
Premedication	Pain and anxiety may significantly contribute to HTN and should be treated (e.g., morphine 0.1 mg/kg iv ± midazolam 0.025–0.1 mg/kg iv); but avoid obtundation. Because many of these patients present emergently, consider full-stomach precautions—H_2 antagonists (e.g., ranitidine 5 0 mg iv), metoclopramide (10 mg iv), and antacids (e.g., Na citrate 0.3 M 30 mL po).

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Intraoperative

Anesthetic technique: The anesthetic management of patients with aortic dissections and aortic aneurysms are similar in many respects. For intraop and postop management of these conditions, see Anesthetic Considerations for Repair of Acute Aortic Dissections and Dissecting Aneurysms, p. 404.

Suggested Readings

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8. Kahn RA, Stone ME, Moskowitz DM: Anesthetic consideration for descending thoracic aortic aneurysm repair. *Semin Cardiothorac Vasc Anesth* 2007; 11:205–23.

9. Kazui T, Yamashita K, Washiyama N, et al: Aortic arch replacement using selective cerebral perfusion. *Ann Thorac Surg* 2007; 83:S796–8.

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11. Olsson C, Eriksson N, Stahle E, et al: Surgical and long-term mortality in 2634 consecutive patients operated on the proximal thoracic aorta. *Eur J Cardiothorac Surg* 2007; 31:963–9.

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Endovascular Stent-Grafting of Aortic Aneurysms

Surgical Considerations

Description: The standard treatment for descending **thoracic aortic aneurysm** is surgical resection of the aneurysm and replacement with a segment of prosthetic graft material. Although resection of aneurysms often can be performed without the need for extracorporeal circulation, the procedure has a reported mortality rate of up to 50% in emergency cases and 12–15% in elective cases. Transluminal endovascular stent-grafting offers an alternative treatment that is less invasive, less hazardous, and potentially less expensive than standard operative repair.

In the initial workup, all patients have contrast-enhanced spiral CT scans of the thorax, and thoracic aortography to assess the dimensions of the aneurysms. The most important features to consider in evaluating an aortic aneurysm for endovascular stent-graft treatment is the presence of an adequate proximal and distal neck. A minimum neck length of at least 1.5 cm is required to allow secure anchoring of most stent-grafts. The distance from the origins of the left subclavian artery and celiac axis to the aneurysm should be at least 1.5–3 cm to ensure that the stent-graft does not inadvertently block these arteries. In an effort to reduce the incidence of paraplegia, and to limit exclusion of intracostal arteries, the overall length of the stent-graft is kept to a minimum.

Another important anatomic consideration is the size of the proposed conduit vessel (e.g., iliac) to ensure that it is adequate for accommodation of the stent-introducer system, which usually requires at least an 8-mm-diameter vessel. Where the pelvic vessels are less than 8 mm, either a retroperitoneal iliac or retroperitoneal aortic approach is utilized. The stent is the metallic framework to which the graft material is applied. Various balloon-expandable or self-expanding stents are available. For application in the thoracic aorta, stents of 30–40 mm in diameter (mean 35 mm) are required.

Typically, thoracic aortic aneurysm stent-graft procedures are performed in the cath lab (although some may be performed in the OR, depending on equipment availability and local politics), with the patient intubated and under GA. The cath lab is prepared for aortic surgery, with the patient placed on the table in a shallow right decubitus position. The patient's thorax may be prepped and draped for a left thoracotomy. For an approach via the common femoral artery, the groin area is prepped for a femoral artery cutdown. When the iliac arteries are of insufficient size, the left lower abdomen is prepped for a retroperitoneal approach to either the aorta or the common iliac artery. High-quality fluoroscopic equipment is essential to assure accurate placement of the device, and a portable C-arm with digital subtraction capability is moved into position and centered over the thorax. When the iliac vessels are of sufficient size, a cutdown is performed on a femoral artery, the artery is punctured, and a guide wire is advanced into the thoracic aorta. A pigtail catheter is placed and an aortogram is performed. The patient is then anticoagulated with iv heparin (100 IU/kg). A long, stiff guide wire is placed, and the 24 Fr sheath and dilator assembly is advanced over the wire until the sheath tip is proximal to the proximal aneurysm neck. The dilator and guide wire are withdrawn, and the stent-graft is introduced into the sheath from its loading cartridge using the Teflon pusher. The device is pushed through the sheath until the stent-graft approaches the tip of the sheath.

In order to reduce the likelihood of inadvertent downstream deployment of the stent-graft caused by the force of blood flow during initial delivery, the arterial BP may be lowered to a mean of 50–60 mmHg using SNP. Holding the pusher firmly in position, the sheath is rapidly withdrawn, and the stent-graft expands into position. Rapid deployment helps to minimize distal migration of the stent-graft. Immediately following deployment, the SNP is discontinued, allowing the BP to normalize. Repeat aortogram is performed, and any early leakage of contrast into *(Print pagebreak 399)* the aneurysm is treated either with balloon angioplasty of the stent-graft or further stent-graft placement. Occasionally a faint, persistent leak of contrast is caused by leakage through the graft material. This typically ceases when the patient's coagulation status returns to normal. Following removal of the delivery sheath, heparin is reversed with protamine sulfate and the arteriotomy is repaired surgically. For stent placement through the retroperitoneal aorta, the procedure has a more extensive surgical component; however, the technique is similar.

The basic concept of **abdominal aortic aneurysm** (AAA) repair via an endovascular route is similar to the preceding section on thoracic aneurysm repair, with some notable exceptions. AAAs commonly arise inferior to the renal arteries, and 80–90% of cases involve either one or both iliac arteries. For this reason, stent-grafts that can accommodate this more complicated anatomy are required. The superior aneurysm neck needs to be of sufficient length (1.5–2 cm) inferior to the most inferior renal artery to provide for stable anchoring. Inferiorly the stent-graft must accommodate either or both iliac arteries. The procedure is performed in a two-stage fashion. Initially an aorta-to-single-iliac-artery device is placed from the infrarenal aortic neck into one of the iliac vessels. A contralateral femoral artery puncture is then performed, and a catheter and guide wire are used to access an open stump of the stent-graft from the contralateral limb. At this stage, a modular section of stent-graft is placed from the aortic component into the contralateral limb; in this way, an aorta-to-bi-iliac graft is placed.

Usual preop diagnosis: Aortic aneurysm

Summary of Procedures

	Thoracic Aortic Aneurysms	Abdominal Aortic Aneurysms
Position	Supine/slight right decubitus	Supine
Incision	Femoral artery cutdown	Bilateral femoral artery cutdowns
Special instrumentation	Catheters, guide wires, sheaths, dilators and stent-grafts	
Unique considerations	May require adjunctive procedure (e.g., brachial artery catheterization, balloon angioplasty, possible left subclavian-to-common carotid artery bypass procedure); iv heparin 100–300 IU/kg	
Antibiotics	Cefazolin 1 g iv	
Surgical time	1–3 h	
Closing considerations	None	
EBL	Usually minimal; however, can be up to 2–3 U	
Postop care	ICU × 1 d	
Mortality	3–5%	2–3%
Morbidity	Paraplegia: 2–3%	Acute rupture: < 1%
	Infection: 1%	
	Surgical conversion: < 1%	
Pain score	3–4	3–4

Patient Population Characteristics

Age range	30–90 yr	40–90 yr
Incidence	1/10,000 of the population in the United States.	1/1,000 of the population in the United States.
Etiology	Atherosclerosis; HTN; trauma; aortic dissection; infection	Atherosclerosis; infection
Associated conditions	CAD; aneurysmal disease elsewhere	

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Anesthetic Considerations

The anesthetic considerations for thoracic and abdominal stent-grafting are similar since the surgical techniques, complications, patient concurrent disease, and stent-graft deployment techniques are similar. Patients may be asymptomatic; most will have coexisting CAD, PVD, and/or cerebrovascular disease.

Suggested Readings

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Preoperative

Preop considerations for these patients are the same as for any patient undergoing repair of a descending thoracic aneurysm, abdominal aortic aneurysm, or aortobifemoral aneurysm. Many of these patients, however, are not suitable for conventional repair via a thoracotomy because of respiratory disease (e.g., FEV_1 < 1 L, severe COPD, $PaCO_2$ > 60 mmHg), CAD, renal failure, CHF, or a combination of these factors. As such, they generally are at very high risk for periop morbidity and mortality. Before surgery the anesthesiologist should consult with the surgical and radiological teams to decide what will be done should a complication such as penetration or rupture of the aneurysm occur during surgery (typically, an emergency thoracotomy or laparotomy performed in the cath lab).

Intraoperative

Anesthetic technique: Usually GETA (OLV may be required for emergency thoracotomy 2° ruptured thoracic aneurysm). Abdominal stent-grafts may be placed under epidural or spinal anesthesia. Rarely, stent-grafting may be carried out with local anesthesia or MAC in patients unable to tolerate GA or epidural. In that case, the patient will come to the OR for removal of the introducer system and repair of the femoral artery.

Induction	Since these patients are typically extubated, the dose of fentanyl (5–10 mcg/kg) is limited to that which will suppress the hypertensive response to intubation, while still allowing for early extubation. The same considerations apply to the use of muscle relaxants (e.g., vecuronium [0.1 mg/kg] or rocuronium [1–1.5 mg/kg]). A DLT or a Univent ETT should be used, unless the team decides that a thoracotomy will not be performed under any circumstance.
Maintenance	Usually a balanced anesthetic technique of O_2/air/isoflune or sevoflurane, supplemented with fentanyl (or remifentanil infusion) as needed. Hemodynamic control of BP (esmolol, SNP, NTG) and heart rate to avoid myocardial ischemia is important. **Anesthetic management during stent-graft deployment:** During stent-graft deployment, the aorta is momentarily occluded. Formerly, this resulted in a rapid ↑ BP → stent-graft being moved from its intended position. The newer generations of stent-grafts, using thermal or mechanical means for rapid deployment, cause minimal hemodynamic change, eliminating the need for aggressive BP control.
Emergence	Extubation is desirable, although hypothermia (<34° C) may prevent this. Otherwise, aim for early extubation in the ICU. DLT (if used) may be replaced with a standard ETT at end of procedure if the patient is not extubated in the cath lab. Recovery is usually in

	the ICU.	
Blood and fluid requirements	IV: 14–16 ga × 1 NS/LR @ 4–8 mL/kg/h PRBC available	Although usually minimal, blood loss can be considerable.
Monitoring	Standard monitors (p. B-1) Arterial line	Arterial line placement should be on the right as the radiologists may require access to the left brachial artery.
	CVP catheter Urinary catheter	CVP monitoring is usually sufficient. Central access for vasoactive drugs may be needed.
	TEE	TEE is used to aid in the identification of the thoracic aneurysm necks, to monitor deployment of the stent-graft and to identify any continued flow of blood into the aneurysmal sac after deployment (endoleak).
	CSF pressure/drainage	CSF drainage → ↓ CSF pressure may be necessary to minimize spinal cord ischemia (anterior spinal artery syndrome).
Positioning	and pad pressure points. eyes.	Supine ± slight right lateral decubitus
Complications	Hemorrhage	Hemorrhage at the groin site can be considerable and may be concealed.
	Vessel damage	Damage to the vessels (femoral, iliac, or abdominal aorta) during passage of the insertion system can occur with attendant massive hemorrhage.
	Rupture of aorta	Rupture or penetration of the thoracic aneurysm also can occur, necessitating rapid conversion to open thoracotomy.
	Deployment failure/incorrect position	The stent-graft may deploy in an incorrect position or fail to fully deploy. This may require positioning of further stent-grafts, balloon expansion of the stent-graft, or conversion to thoracotomy.
	Hypothermia	Hypothermia can be a problem as a circulating-water warming blanket cannot be used on the operating table (use of fluoroscopy). Much of the patient's body is exposed (upper-body Bair-Hugger usually ok) and a lower-body warming blanket cannot be used as the lower limbs may be ischemic during insertion of the stent-graft.

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Postoperative

Complications	Aortic perforation/rupture	Requires emergency surgery.
	Migration of grafts	→ loss of distal pulses, mesenteric ischemia, acute renal insufficiency.
	Femoral artery dehiscence	Requires prompt return to OR.
	Distal embolization	pulses; angiography/surgical intervention.
	Paraplegia	reflexes; prompt return to OR.
Pain management	Minimal analgesic requirements	If groin incision, local anesthetic infiltration may be used.

Tests	As indicated by patient condition.	CT scan, angiogram prior to discharge and at regular intervals following discharge.

Suggested Readings

1. Dake MD, Miller DC, Semba CP, et al: Transluminal placement of endovascular stent-grafts for the treatment of descending thoracic aortic aneurysms. *N Engl J Med* 1994: 331(26):1729–34.

2. Fleck T, Hutschala D, Weissl M, et al: Cerebrospinal fluid drainage as a useful treatment option to relieve paraplegia after stent-graft implantation for acute aortic dissection type B. *J Thorac Cardiovasc Surg* 2002; 123: 1003–5.

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3. Herold U, Piotrowski J, Baumgart D, et al: Endoluminal stent graft repair for acute and chronic type B aortic dissection and atherosclerotic aneurysm of the thoracic aorta: an interdisciplinary task. *Eur J Cardiothorac Surg* 2002; 22:891–7.

4. Mitchell RS, Dake MD, Semba CP, et al: Endovascular stent-graft repair of thoracic aortic aneurysms. *J Thorac Cardiovasc Surg* 1996; 111(5):1054–62.

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6. Schütz W, Gauss A, Meierhenrich R, et al: Transesophageal echocardiographic guidance of thoracic aortic stent-graft implantation. *J Endovasc Ther* 2002; 9:14–9.

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Repair of Acute Aortic Dissections and Dissecting Aneurysms

Surgical Considerations

Description: Repair of **acute aortic dissection** is performed to prevent life-threatening complications such as hemorrhage, tamponade, and heart failure 2° acute aortic valvular insufficiency and to redirect flow into the true lumen. Emergent repair of acute ascending dissections is generally accepted therapy to prevent rupture of the aortic root with exsanguination or pericardial tamponade. Mortality for acute ascending dissection is estimated at 1% per hour for the first 48 hours. The management of descending thoracic aortic dissections remains controversial, but surgical intervention probably should be recommended only for younger patients, patients with uncontrolled pain or evidence for continued expansion or extravasation, and those with branch-vessel compromise.

Ascending dissections typically produce sharp, tearing retrosternal pain that penetrates straight through to the subscapular area. The presentation, however, is so frequently variable that any patient in extremis, especially with migratory pain or vacillating findings, and even asymptomatic patients with valvular aortic regurgitation (AR), should be considered for the diagnosis. With a suggestive Hx, a new murmur, or a pulse deficit, an enlarged mediastinal shadow on chest radiography should prompt further diagnostic efforts. CT scanning, MRI, and aortography may all be diagnostic, but no diagnostic modality has 100% sensitivity. TEE appears to be highly sensitive in detecting a mobile intimal flap in the ascending or descending aorta. In addition, TEE can provide useful information regarding AR, periaortic hematoma and flow within a false channel. It is usually available at the bedside or in the emergency ward and does not subject the patient to a contrast load.

After the patients are diagnosed, they are transported immediately to the OR. Through a median sternotomy, venous access is gained via the right atrium, and arterial inflow is supplied through a femoral artery or axillary artery. CPB is established, the patient cooled to 18°C, and circulatory support discontinued although antegrade cerebral perfusion may be employed. During a period of circulatory arrest or antegrade cerebral perfusion, the ascending aorta is opened and the tear localized. The repair is carried distally into the arch, if the entire dissection can be resected, and the distal aortic layers are reapproximated with a Teflon felt strip supporting the medial and adventitial layers. The distal graft anastomosis is then completed, the graft clamped, the bypass pump restarted and systemic warming commenced. Proximally, the aortic root is reconstructed, again using Teflon felt to support the medial and adventitial layers and to resuspend the aortic valve, which can be salvaged in approximately 85% of cases. The heart is then cleared of air, and the cross-clamp removed to allow reperfusion of the coronary circulation. After a sufficient period of resuscitation, the patient is weaned from CPB. Aggressive management of an acquired coagulopathy is not unusual prior to chest closure.

Repair of **dissections** involving the **descending thoracic aorta** is accomplished through a left thoracotomy utilizing partial CPB. Venous drainage is usually via the femoral vein, although the pulmonary vein may be used. Arterial access is via the femoral artery. After institution of CPB, the dissected aorta above and below the most damaged area is cross-clamped and the aorta transected. After oversewing patent intercostal arteries, the medial and adventitial layers are buttressed with Teflon felt, and an interposition Dacron graft is sewn into place. After evacuation of air, clamps are removed, and the patient weaned from CPB. Heparin reversal, decannulation, and closure are accomplished in the usual manner.

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Usual preop diagnosis: Acute dissection of the aorta (See Fig. 6.3-3 for types of dissection.)

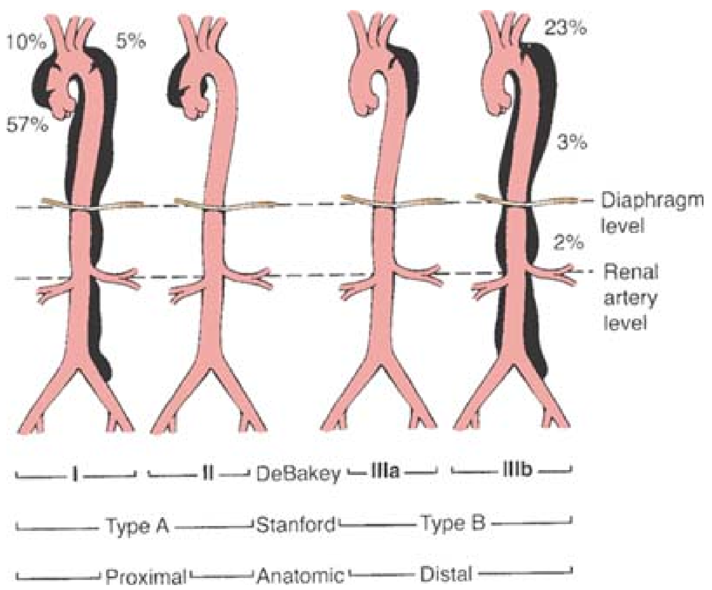

Figure 6.3-3. 3. The three classification systems of aortic dissection and the distribution of the intimal tear.

Summary of Procedures

	Ascending Aorta	Descending Aorta
Position	Supine	Lateral decubitus, left side up
Incision	Median sternotomy	Left lateral thoracotomy
Unique considerations	Full hemodynamic monitoring, with provisions for circulatory arrest, profound hypothermia, barbiturates and steroids; TEE	DLT; CPB; TEE; lumbar drain
Antibiotics	Cefazolin 1 g iv	
Surgical time	Cross-clamp: 30–50 min Circulatory arrest: 20–30 min CPB: 60–100 min Total: 3–5 h	30–60 min — 35–60 min
Closing considerations	Aggressively treat coagulopathy (frequently 2° ↓ Plt).	Replace DLT with single-lumen ETT.
EBL	400–800 mL	600–800 mL
Postop care	ICU: 1–2 d, intubated	
Mortality	10–25%	
Morbidity	Bleeding: 3–8% Respiratory insufficiency: 2–5%	Paraplegia: 5% CVA: 1–2%

	CVA: 2–4%	MI: 1–2%
Pain score	7–10	9–10

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Patient Population Characteristics

Age range	40–70 yr
Male:Female	3:2
Incidence	10/100,000
Etiology	Degenerative aortic disease
Associated conditions	HTN; secondary AR; bicuspid aortic valve; Marfan syndrome

Anesthetic Considerations

Preoperative

Sx are usually of sudden onset and depend on the site of dissection and specific organ involvement. Aortic dissections are divided into 2 types, depending on the site of intimal tear: **Type A**—ascending and aortic arch, and **Type B**— descending aorta (Fig 6.3-3). Initial treatment involves the use of antihypertensive medications (e.g., SNP) to control BP and β-blockers (e.g., esmolol) to ↓ contractility. Type A dissections usually require urgent surgery. Patients presenting electively for thoracotomy (descending aorta) may have a thoracic epidural catheter placed the night before surgery. These patients are only heparinized during the procedure.

Respiratory	for recurrent laryngeal nerve palsy with chronic aneurysmal dilation. Tracheal and left main bronchus compression → difficult intubation, atelectasis; hemoptysis 2° rupture into lung; hemothorax → compromised oxygenation, ↑intrathoracic pressure → ↓ venous return, especially with IPPV. **Tests:** CXR: for widened mediastinum, tracheal or left main bronchus compression and distortion (affects DLT placement), atelectasis, pleural effusion (or hemothorax 2° rupture).
Cardiovascular	Aortic dissections may be associated with chronic HTN, cystic medial necrosis, or other connective tissue disorder (e.g., Marfan syndrome) and trauma. Dissection may result in cardiac tamponade, acute aortic valve incompetence, acute cardiac failure, angina, MI, or rupture of the aorta. Dissection of major arteries may result in ↓ or absent peripheral pulses, which may affect the placement sites for intraarterial monitoring and central venous access. Pain and anxiety may result in HTN, while rupture or leakage may result in ↓ BP and shock. **Tests:** ECG: for Sx of LVH, ischemia or infarction, low voltage (tamponade). ECHO: for site of dissection, valvular competence, LV function, pericardial effusion or tamponade. Angiography: for site of dissection (Type A or B), valvular function, involvement of coronary and other major arteries, sites of rupture, LV function. CT scan: site and extent of dissection.
Neurological	Deficits are not uncommon, especially with Type B dissections where the blood supply to the spinal cord may be jeopardized. Document preop exam carefully.
Renal	Renal failure 2° renal artery involvement in dissection, shock, or cardiac failure. UO should be monitored closely during initial medical therapy. **Tests:** UO; BUN; Cr; electrolytes
	Compromised blood supply to the bowel or liver may result in

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Gastrointestinal

ischemia → metabolic acidosis and ↓ liver function.
Tests: Consider ABG: persistent metabolic acidosis; LFTs, if indicated by H&P.

Hematologic

Coagulopathy may be present 2° massive hemorrhage or liver involvement, and can increase risk of the surgery.
Tests: PT; PTT; Hct/Hb

Laboratory

Other tests as indicated from H&P.

Premedication

Since many of these patients present emergently, consider full-stomach precautions: H_2antagonists (ranitidine 50 mg iv), metoclopramide (10–20 mg iv), antacids (Na citrate 0.3 M 30 mL po). Alleviate anxiety and pain (e.g., morphine 0.1 mg/kg im, ± midazolam 0.025–0.1 mg/kg iv or 0.05–0.2 mg/kg im), which may worsen HTN, but avoid obtundation.

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Intraoperative

Anesthetic technique: GETA ± thoracic epidural. Preinduction control of BP and contractility (NTG or SNP to SBP = 105–115 and esmolol to HR = 60–80) is important in preventing extension of the dissection or rupture of the aneurysm. Fluid resuscitation may be necessary prior to induction.

Induction

Control of hypertensive response to laryngoscopy and intubation is important and may be accomplished with moderate-dose narcotic (fentanyl 10–15 mcg/kg or sufentanil 1–2 mcg/kg) and etomidate (0.1–0.3 mg/kg), esmolol (5–10 mg iv bolus), or SNP (25–50 mcg bolus). Pretreatment with lidocaine (1.5 mg/kg) also may be required to further control the hypertensive response to laryngoscopy. Muscle relaxation may be obtained using vecuronium (0.1 mg/kg) or rocuronium (1–2 mg/kg). Remember the possibility of a full stomach in this patient population. Hence, a modified rapid-sequence induction (cricoid pressure with manual ventilation and NMR) may achieve the two goals of relatively rapid induction and intubation and tight control of BP. Usually a left DLT is used in patients with descending lesions to improve surgical access; however, it may be difficult to place due to aneurysmal compression of the trachea and left mainstem bronchus, and it is associated with a small risk of aneurysmal rupture. For these reasons, a right DLT may be preferred. FOB is mandatory to verify ET placement.

Maintenance

O_2/narcotic/benzodiazepine: low-dose volatile agent (isoflurane [0.3–0.5%] or sevoflurane [0.5–1%]) may be used to control BP (MAP = 60–80), although infusion of vasopressors, vasodilators, or inotropes may be necessary. Control HR (< 80; anesthesia, esmolol) and contractility (β-blockade or inotropes, depending on circumstances). Benzodiazepines may be used for amnesia (midazolam 100 mcg/kg). If thoracic epidural in place, fentanyl (20–30 mcg/kg) or sufentanil (4–6 mcg/kg) may be used. Most Type A aneurysms and ascending/arch aneurysms require hypothermic CPB (see Anesthetic Considerations for Cardiopulmonary Bypass, p. 338). Intraop anesthetic considerations are governed primarily by the site of the aortic pathology. These considerations are discussed below.

Emergence

Transported to ICU, sedated, intubated, and ventilated × 24–48 h. Following repairs of the descending aorta (thoracotomy incision), weaning from ventilator may be aided by epidural narcotics after documentation of normal spinal cord function and coagulation.

Blood and fluid requirements

Anticipate large blood loss. IV: 14 ga -7 Fr × 2 NS/LR @ 6–8 mL/kg/h Warm all fluids. Humidify gases. Cross-match 6–8 U of blood. UO 0.5–1 mL/kg/h	In Type A dissections and arch aneurysms, if possible, avoid iv placement in the left arm or left IJ/subclavian veins because of the possibility of innominate vein ligation. Mannitol (0.25–0.5 g/kg iv) should be given if renal perfusion is compromised by dissection or before cross-clamping. Consider normovolemic hemodilution if the patient is stable and the Hct > 35. After unclamping: furosemide (1 mg/kg), if

		hemodynamically stable.
Monitoring	Standard monitors (p. B-1). Arterial line CVP, PA catheter (optional) Urinary catheter	Arterial line site is dependent on type of surgery and location of the lesion. Because the right subclavian artery may be compromised in patients with ascending lesions, the left radial or femoral arteries may need to be used. Aortic arch lesions may involve the vascular supply to both upper extremities; hence, femoral artery catheterization may be necessary. In ascending lesions, two artery lines may be required—right radial (above clamp pressure) and left femoral (below clamp pressure). Consult with surgeon as to best site.
	TEE	TEE is useful to assess cardiac function, regional wall motion abnormalities, valvular pathology, aortic valvular repair (if required as part of a Type A repair). Probe passage may increase compression of the trachea, impeding ventilation. Caution should be used in the presence of aneurysmal compression of the esophagus.
	Temperature	Monitor both core (esophageal/bladder) and tympanic membrane T (as indicative of brain T)—important in deep hypothermic arrest.
	EEG/EP (arch/ascending lesions)	EEG/EP may help in assessing effectiveness of cerebral protection or adequacy of cerebral perfusion.
	SSEPs/MEPs (descending lesions)	SSEPs may detect posterior spinal perfusion problems, while MEPs may detect anterior cord dysfunction. Both EEG and EPs may require expert help to set up, monitor, and interpret.
	Cerebral oximetry	Cerebral oximetry may be helpful in detecting changes in cerebral blood flow after cannulation of the innominate artery.
Complications	Hemorrhage Coagulopathy	Both are common. Hemorrhage should be treated with crystalloid, colloid, or blood products, as indicated.
Ascending lesions	CPB AR Coronary arteries	Usual site of cannulation for CPB is the ascending artery or femoral artery. Aortic valve replacement may be necessary. Patients may have myocardial ischemia 2° coronary artery occlusion; may require CABG or reimplantation of vessels.
	Deep hypothermic arrest	Cerebral protective measures and selective perfusion of cerebral vessels may be required. (See below.)
Arch lesions	CPB Deep hypothermic arrest	Usual site of cannulation for CPB is femoral or axillary artery. Cerebral protection relies on hypothermia (15–18°C) and drugs (methylprednisolone [Solu-Medrol] 1 g, mannitol 0.5 g/kg, STP 15–30 mg/kg) to reduce $CMRO_2$ and neuronal injury. The head is surface cooled (protect eyes and ears from cold injury). EEG may

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		be monitored to ensure absence of brain electrical activity. Monitor tympanic membrane T as an indication of brain T. Avoid hyperglycemia and maintain normal pH and $PaCO_2$ when measured at 37°C (alpha stat). Maintain muscle relaxation.
	Precross-clamping	Mannitol (0.5 g/kg) should be given before clamp application to provide renal protection, even if a shunt is placed. Hypothermia (32–34°C) may protect spinal cord.
	Shunt	A heparin-bonded shunt may be used from the aortic arch to the femoral artery to provide distal perfusion.
	Partial bypass	Partial CPB may be used to provide distal perfusion. In this arrangement, the heart perfuses the head and upper extremities, while CPB is used to perfuse and oxygenate the lower body. Venous drainage is from the femoral vein, PA, or left atrium and returned via the femoral artery. Distal and proximal pressures are altered by controlling cardiac filling, pump flow, and vasodilators.
Descending lesions	Cross-clamping	Application of clamp may → acute HTN with ischemia and LV failure. This may be controlled by partial bypass, shunting or use of vasodilators (SNP 0.5–4 mcg/kg/min, NTG 0.5–4 mcg/kg/min). During cross-clamping, monitor UO and metabolic acidosis (renal or bowel ischemia) with serial ABGs. Cross- clamp time should be < 30 min to reduce incidence of paraplegia. The surgeons often request that a lumbar CSF drain be inserted to ↓ CSF pressure (to ≥ CVP) and, thus, improve spinal cord blood flow.
	Unclamping	Unclamping may result in severe ↓ BP and myocardial depression. Hypovolemia, acidosis, vasoactive factors, and reactive hyperemia have been implicated as the cause. Prior to unclamping, ensure adequate volume status (PCWP 2–5 mmHg above patient's normal); treat acidosis; have vasopressors available; and the clamp should be released slowly over 1–2 min. Use of partial bypass or a shunt to ensure distal perfusion will mitigate unclamping shock. When hemodynamically stable, give furosemide (1 mg/kg iv). Inotropes (dopamine) may be needed to support circulation.
	Positioning	eyes. and pad pressure points. Arch and ascending: supine, shoulder roll Descending: lateral decubitus, axillary roll, pillow between knees

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Postoperative

Complications	Myocardial ischemia, CHF Dysrhythmias Hemorrhage Coagulopathy Renal failure Bowel ischemia Respiratory failure	A DLT may be required in lesions of the descending aorta, if hemorrhage continues from left lung; otherwise, the tube may be replaced at the end of procedure by a single-lumen ETT. BP should be controlled to MAP 60–80 and HR < 100 to decrease the likelihood of repeat dissection, bleeding, or graft dehiscence.
	Paraplegia	Anterior spinal artery syndrome
Pain management	PCA (p. E-4) Epidural (p. E-6)	Thoracic epidural catheter may be used in patients following thoracotomy if coagulation status normal.
Tests	ECG: ischemia, infarction, dysrhythmias CXR: line and ETT placement; pulmonary contusion Coagulation profile Renal: BUN, Cr ABG: Respiratory, gut ischemia CT scan: CNS or spinal neurologic deficits Electrolytes	

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Suggested Readings

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thoracoabdominal aneurysm surgery for prevention of paraplegia. *Anesthesiology* 2000; 93:1115–22.

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Repair of Aneurysms of the Thoracoabdominal Aorta

Surgical Considerations

Description: Aneurysms of the thoracoabdominal aorta (TAAA) may occur because of degenerative aortic disease (atherosclerosis), as a consequence of hereditary disorders of metabolism (Marfan syndrome), or as a sequela of chronic aortic dissections. These aneurysms are classified into four types (Fig 6.3-4) that occur with equal frequency: Type I consists of aneurysms that involve most of the descending thoracic and upper abdominal aorta. Type II involves most of the descending thoracic aorta and most or all of the abdominal aorta. Type III involves the distal thoracic and varying segments of the abdominal aorta. Type IV involves most or all of the abdominal aorta, including the origins of the visceral vessels.

Repair of these aneurysms is an extensive, difficult, and demanding procedure, as blood flow to the entire body below the neck is interrupted, with resultant renal and visceral ischemia. Additionally, the blood supply to the spinal cord may arise from lumbar and/or intercostal vessels in the affected aortic segment, producing critical cord ischemia during cross-clamping and postop paraplegia.

Almost all thoracoabdominal aneurysm repairs are performed through a thoracoabdominal incision (Fig. 6.3-5) using the **inclusion technique** (Fig. 6.3-6) as advocated by **Crawford**, et al. After opening the chest, the incision is extended across the costal cartilage onto the abdomen. The diaphragm is radially incised to the aortic hiatus, and the retroperitoneal dissection plane established anterior to the psoas musculature. All intraabdominal contents, as well as the left kidney, are reflected anteriorly (Fig. 6.3-6). Only proximal aortic control is established. After minimal heparinization, OLV is established to allow collapse of the left lung, the proximal aorta at the aneurysm neck is cross-clamped, and the aneurysm is incised. Back-bleeding from patent intercostal, mesenteric, and renal vessels can be *(Print pagebreak 409)* controlled by balloon catheters; and aggressive blood salvage with autotransfusion devices is mandatory. The repair entails suturing a tube graft proximally to the divided aorta, and then sewing islands of aortic tissue containing intercostal visceral vessels onto appropriate sized holes in the side of the tube graft. This allows reperfusion of important intercostal, celiac axis, superior mesenteric, renal arteries and, finally, the distal aorta or iliac arteries. Because there is obligate visceral ischemia during the period of cross-clamping (which must be limited to < 60–75 min), the operation must proceed expeditiously.

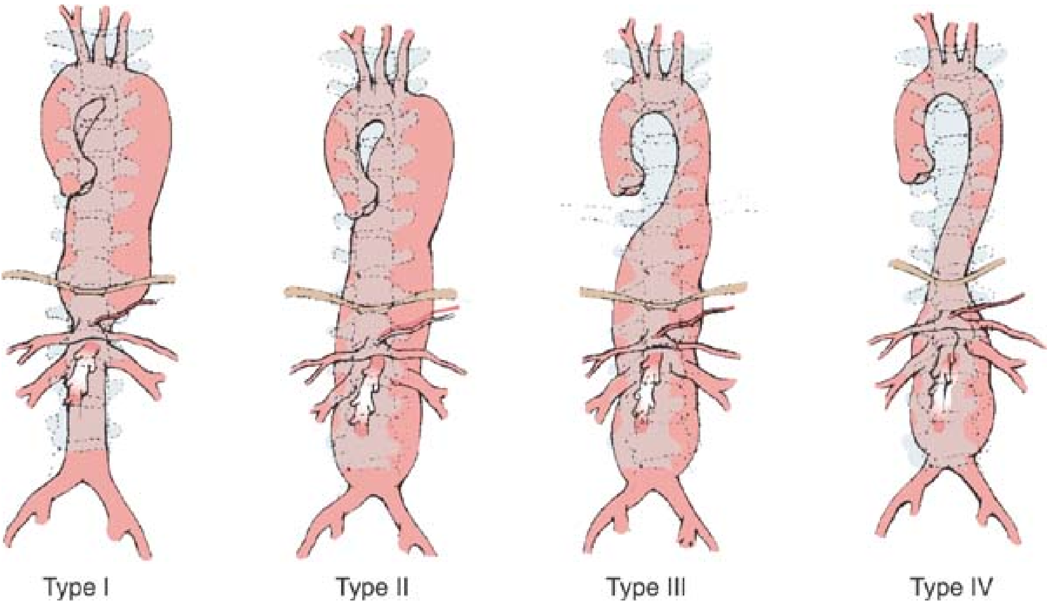

Figure 6.3-4. 4. Crawford's classification of thoracoabdominal aortic aneurysms (TAAA). (Reproduced with permission from Baker RJ, Fischer JE: *Mastery of Surgery*, Vol 2. Lippincott Williams & Wilkins, 2001.)

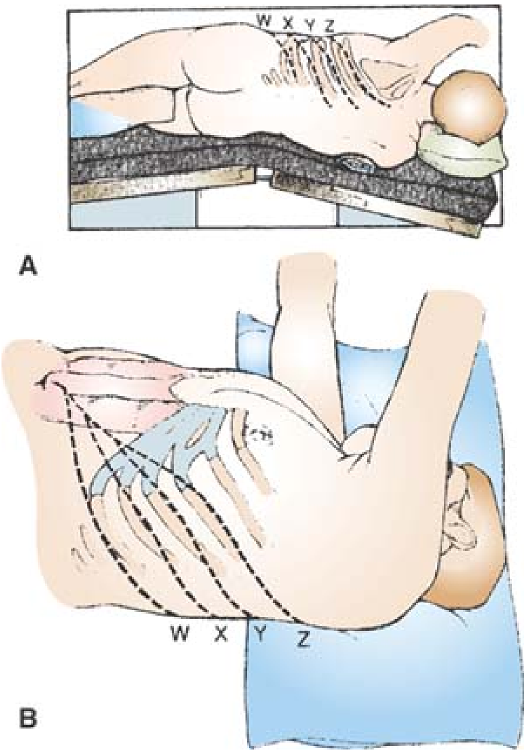

Figure 6.3-5. 5. Lateral (A) and frontal (B) views of the thoracoabdominal incisions used for repair of type IV (W,X), type III (Y,Z), and types I and II (Z) TAAAs. (Reproduced with permission from Baker RJ, Fischer JE: *Mastery of Surgery*, Vol 2. Lippincott Williams & Wilkins, 2001.)

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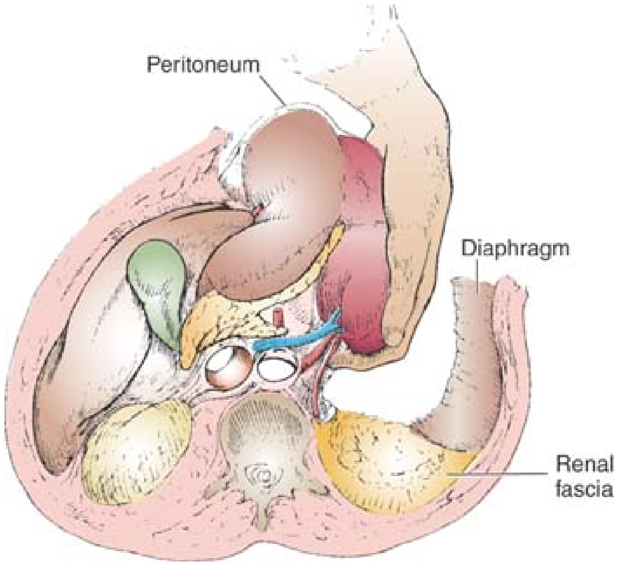

Figure 6.3-6. 6. During the inclusion technique, the anterior renal fascia is opened and the kidney is mobilized, along with the upper abdominal organs (on the left). (Reproduced with permission from Wind GG, Valentine RJ: *Anatomic Exposures in Vascular Surgery*. Williams & Wilkins, Baltimore, 1991.)

Alternatively, in an effort to afford both spinal cord and visceral protection through hypothermia, the operation may be performed on CPB during a period of profound hypothermic circulatory arrest, which may exacerbate hemorrhagic complications.

After aortic cross-clamping, the aneurysm is opened and the repair performed from within the aneurysm, sewing on-lay patches of the intercostal, mesenteric, and renal vessels to openings created in the tube graft. This no-clamp technique allows reasonable management of these very extensive aneurysms, but results in an obligatory and ongoing blood loss through back-bleeding of visceral vessels until the anastomoses are complete.

Usual preop diagnosis: Expanding, painful, or large thoracoabdominal aneurysm

Summary of Procedures

Position	Right lateral decubitus; hips rotated posteriorly to 45° and left arm draped forward over an airplane sling. Axillary roll placed. (See Fig. 6.3-5A.)
	Posterolateral thoracotomy incision, in appropriate interspace, extended across the costal

	margin to midline, then extended inferiorly as a midline abdominal incision (Fig. 6.3-5).
Incision	The incision is one of the largest incisions in surgery, necessitated by the absolute need for exposure in this difficult area, and is, unfortunately, associated with significant postop pain.
Special instrumentation	DLT; CPB; NG tube; Cell Saver; rapid-infusion device
Unique considerations	OLV with collapse of left lung necessary for most cases. Cold LR may be injected into renal or visceral arteries for organ preservation. Alternatively, operation can be performed under profound hypothermic circulatory arrest for spinal cord protection in patients with

	chronic dissections. Frequently, operation is performed with only proximal cross-clamping; so there may be an obligate ongoing blood loss.
Antibiotics	Cefazolin 1 g iv 6 h.
Surgical time	Proximal aortic cross-clamping until completion of visceral revascularization may extend to 60 min. Longer cross-clamp times may be anticipated in patients with aneurysmal dilation from chronic aortic dissection for which profound hypothermic circulatory arrest may be utilized.
Closing considerations	OR → ICU, intubated × 24–72 h. Ongoing back-bleeding from visceral and iliac vessels results in substantial volume loss during cross-

EBL	clamping. Most red-cell volume is salvaged via cardiotomy suckers and returned through cardiopulmonary bypass circuit or via a RBC salvage system (e.g. Cell Saver).
Postop care	ICU, intubated and ventilated × 24–72 h. Rewarming, hemodynamic monitoring and volume resuscitation are often required in ICU.
Mortality **Morbidity**	

Aneurysm Group:	**Type I**	**Type II**	**Type III**	**Type IV**
Overall: 9%	–	10–25%		**5%**
Paraplegia/spinal cord ischemia	6%	15%	3%	2%
Other neurological complications	6%	2%	2%	1%
Renal insufficiency	–	2–5%	–	–
Respiratory failure	–	10%	–	–
Hemorrhage	Common		6%	
Graft infection	–		–	
MI	Rare	Rare	–	–
Graft failure	–	2–10%	–	–
False aneurysm	Rare			
Embolization	Rare			
Bowel ischemia	–			
Impotence	Rare			
Ureteral injury	Rare			

Aneurysm Group:	**Type I**	**Type II**	**Type III**	**Type IV**
Overall: 9%	–	10–25%	–	5%
Paraplegia/spinal cord ischemia				
Other neurological complications		15%	3%	2%
	6%	12%	2%	1%
Renal insufficiency	6%	2–5%	–	–
	–	10%	–	–
Respiratory failure	–			
	Common			
Hemorrhage	–	1–6%	–	–
Graft infection	Rare	Rare	–	–
	–			
MI	Rare			
Graft failure	Rare			
	–			
False aneurysm	Rare	2–10%	–	–
	Rare			
Embolization				
Bowel ischemia				
Impotence				
Ureteral injury				
Pain score	6–10			

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Patient Population Characteristics

Age range	Non-Marfan: 55–75 yr; Marfan: 35–55 yr
Male:Female	3:1
Incidence	< 5 cases/yr in most hospitals, except major referral centers
Etiology	Predominantly atherosclerotic. Patients with Marfan syndrome may present with a progressive dilatation of a chronic dissection.
Associated conditions	HTN (75%); CAD (30%); COPD (30%); renal insufficiency (15%)

Anesthetic Considerations

Preoperative

Sx are usually of sudden onset and depend on the site of dissection and specific organ involvement. Initial treatment involves the use of antihypertensive medications (e.g., SNP) to control BP, and β-blockers (e.g., esmolol) to ↓ contractility. Patients presenting electively for thoracotomy (descending aorta) may have a thoracic epidural catheter placed the night before surgery. These patients are only heparinized during the procedure.

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Chronic pulmonary disease is associated with postop morbidity.

Respiratory	Preop preparation with bronchodilators, cessation of smoking, incentive spirometry, and chest physiotherapy may decrease the risk of postop problems. **Tests:** CXR: for distortion of the left mainstem bronchus, which may affect placement of the DLT. May need PFTs, ABG to determine severity of pulmonary disease.
Cardiovascular	CAD is the most frequent cause of periop and late death in elective thoracoabdominal aortic aneurysm repair. It is commonly associated with HTN. **Tests:** ECG: for LVH and ischemia.
Neurological	Increased risk of spinal cord ischemia with cross-clamping of the aorta; therefore, any preop neurologic deficits should be well documented. The use of CSF drainage and/or deep hypothermic circulatory arrest may be protective in patients with chronic aortic dissections.
Renal	Preop renal dysfunction increases the potential for postop renal problems. Aneurysmal involvement of the renal arteries also may occur. **Tests:** BUN; Cr. Consider creatinine clearance.
Gastrointestinal	Aneurysmal involvement of the inferior mesenteric and superior mesenteric arteries may cause visceral ischemia. **Tests:** Consider abdominal x-ray (ileus) and ABG (metabolic acidosis).
Hematologic	Pre-existing coagulopathy increases risk. Many patients have been on aspirin preop. Excessive alcohol use is associated with anemia, thrombocytopenia, and low production of vitamin K-dependent factors. Rarely, a DIC process may occur within the lumen of the aneurysm. **Tests:** PT; PTT; Plt count; Hct
Laboratory	Electrolytes; radiologic assessment of aneurysm (ultrasonography, CT, and arteriography)
Premedication	Anxiety and pain may contribute to HTN and risk of aneurysmal rupture. Rx: morphine 0.1 mg/kg iv and midazolam 1–5 mg iv. Full-stomach precautions for emergent procedures (e.g., metoclopramide 10 mg iv, ranitidine 50 mg iv, Na citrate 30 mL po).

Intraoperative

Anesthetic technique: GETA. The goals of anesthesia for this procedure are: (a) preserve myocardial, renal, pulmonary, CNS and visceral organ function; (b) maintain adequate intravascular volume so that CO is not impaired; (c) control BP so that the transmural pressure across the aneurysm does not increase, which would increase the risk of rupture; and (d) provide good perfusion of other organs. CPB is used to accomplish deep hypothermic circulatory arrest. The rationale for this use is controversial. Deep hypothermic cardiac arrest (DHCA) may confer spinal cord protection and is usually reserved for patients with chronic dissections. Removal of CSF has been proposed as another means of protecting the spinal cord against ischemic injury. CPB also may be used for distal perfusion of organs and afterload protection of the left ventricle. Partial CPB usually is reserved for suprarenal or supraceliac aneurysms to perfuse bowel and kidneys. (See Anesthetic Considerations for Cardiopulmonary Bypass, p. 338, and Repair of Acute Aortic Dissections, p. 404, for more discussion on CPB and DHCA.)

Induction	Prevent hypertensive response to laryngoscopy and intubation with moderate-dose narcotic technique (fentanyl 10–20 mcg/kg or sufentanil 1–2 mcg/kg) in combination with etomidate (0.2–0.3 mg/kg) or propofol (1–2 mg/kg). Esmolol 100–500 mcg/kg over 1 min, NTG 0.5–3 mcg/kg, or lidocaine administered either by topical spray or an iv dose of 1.5 mg/kg also will decrease the cardiovascular response to intubation. Muscle relaxation for intubation may be achieved with vecuronium (beware of ↓ HR) or rocuronium (1 mg/kg). A modified rapid-sequence induction may be necessary in emergent cases. A DLT is mandatory for this procedure; however it may be difficult to position due to distorted anatomy. FOB is mandatory to verify position of DLT.

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Maintenance	O_2/air/narcotic, ± low-dose volatile agent. Benzodiazepines may be used for amnesia (e.g., midazolam 100 mcg/kg). When epidural catheter in place, sufentanil (loading dose 25–50 mcg, followed by 4–6 mcg/h) may provide adequate additional analgesia. In hemodynamically unstable patients, scopolamine (400 mcg) provides amnesia. Maintain CO and control of BP at preop levels. These patients may have increased hemodynamic variability on cross-clamping aorta, 2° bleeding, and coexisting disease. Keeping the patient warm may be difficult due to large incision and visceral exposure.	
Emergence	Deferred to ICU. Postop ventilation 24–72 h. DLT may need to be maintained postop 2° to facial, oral, and airway edema.	
Blood and fluid requirements	Anticipate large blood loss. IV: 14 ga or 7 Fr × 2 Rapid infuser Cell Saver T&C 8–10 U PRBCs. Warm fluids and humidify gases. Maintain UO 0.5–1 mL/kg/h.	Large incision and visceral exposure requires administration of large volumes of fluid. Consider use of mannitol or furosemide if concerned about renal function and UO.
Monitoring	Standard monitors (p. B-1) CVP	
	± PA catheter ± ST segment analysis Arterial line UO	for ↑ PA pressures and PCWP, ↓ in CO, TEE wall motion abnormalities, and changes in SV. Consult with surgeon regarding placement of cross-clamp so arterial line will not be affected.
	TEE	TEE is a good monitor for ventricular filling and myocardial ischemia.
	Core temperature	Monitor core T (esophageal, bladder). Tympanic membrane T (indicative of brain T) is monitored for circulatory arrest cases.
	± EEG, SSEP, MEP	EEG and EPs may be useful in assessment of cerebral protection (SSEP) and spinal cord perfusion problems (MEP ± SSEP).
	± Cerebral oxymetry	In case of the need of DHCA, cerebral oxymetry may be helpful in monitoring cerebral blood flow.
Cross-clamping	Clamping	Application of cross-clamp at supraceliac level probably produces the greatest hemodynamic stress experienced by surgical patients. Application of the clamp may → HTN and ischemia. Preload, afterload, and HR can be controlled with SNP (0.25–5, mcg/kg/min) and esmolol (100–500 mcg/kg/min) infusions. Bolus dose NTG (100 mcg) may be useful to terminate an acute hypertensive episode.
	Unclamping	Ensure adequate volume; replace blood loss. Just before removal of the cross-clamp, filling volumes are allowed to rise gradually, avoiding the occurrence of myocardial ischemia. Dilators are D/C'd. ↓ BP may occur with removal of cross-clamp 2° hypovolemia, reactive hyperemia, acidosis, ↑ K^+, or myocardial dysfunction. BE > -5 should be corrected before unclamping. If necessary, surgeon can reclamp or occlude the aorta.
Positioning	Right axillary roll and pad pressure points. eyes.	Right lateral decubitus with hips rotated posteriorly. Left arm placed in airplane sling or supported by pillows.

Complications	Myocardial ischemia HTN Coagulopathy Hemorrhage Hemostasis Hypothermia Other organ ischemia	Coagulopathy due to dilutional and consumptive processes. Hypothermia may exacerbate coagulopathy, cause dysrhythmias, and depress cardiac contractility.

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Postoperative

Complications	Myocardial ischemia Neurologic deficits 2° cerebral or spinal cord ischemia Renal failure Respiratory failure	BP should be closely controlled postop to decrease bleeding from graft site and raw surfaces.
Pain management	Epidural narcotics (p. C-2)	In selected patients, a thoracic epidural catheter may be placed the night before surgery; otherwise, an epidural is placed only after normal neurologic and coagulation status is determined.
Tests	CXR: line and ETT placement Coagulation profile ABG analysis	

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Surgery of the Abdominal Aorta

Surgical Considerations

Description: Operations on the abdominal aorta are generally performed for aneurysmal or occlusive diseases. Although **aortic aneurysms** may involve the suprarenal aorta, the majority are infrarenal in origin and may extend into the iliac arteries (Fig. 6.3-7). Most (> 95%) are asymptomatic and are discovered incidentally during investigation *(Print pagebreak 415)* of another medical problem. Because of the associated increased risk for rupture as the aneurysm increases in size, most vascular surgeons recommend prophylactic repair for aneurysms > 5 cm in cross-section dimension. Repair also is indicated for painful aneurysms, those that have been associated with atheroembolism, and when there is documented recent increase in size or evidence of leak or rupture. CAD coexists in 30–40% of these patients and should be assessed preop.

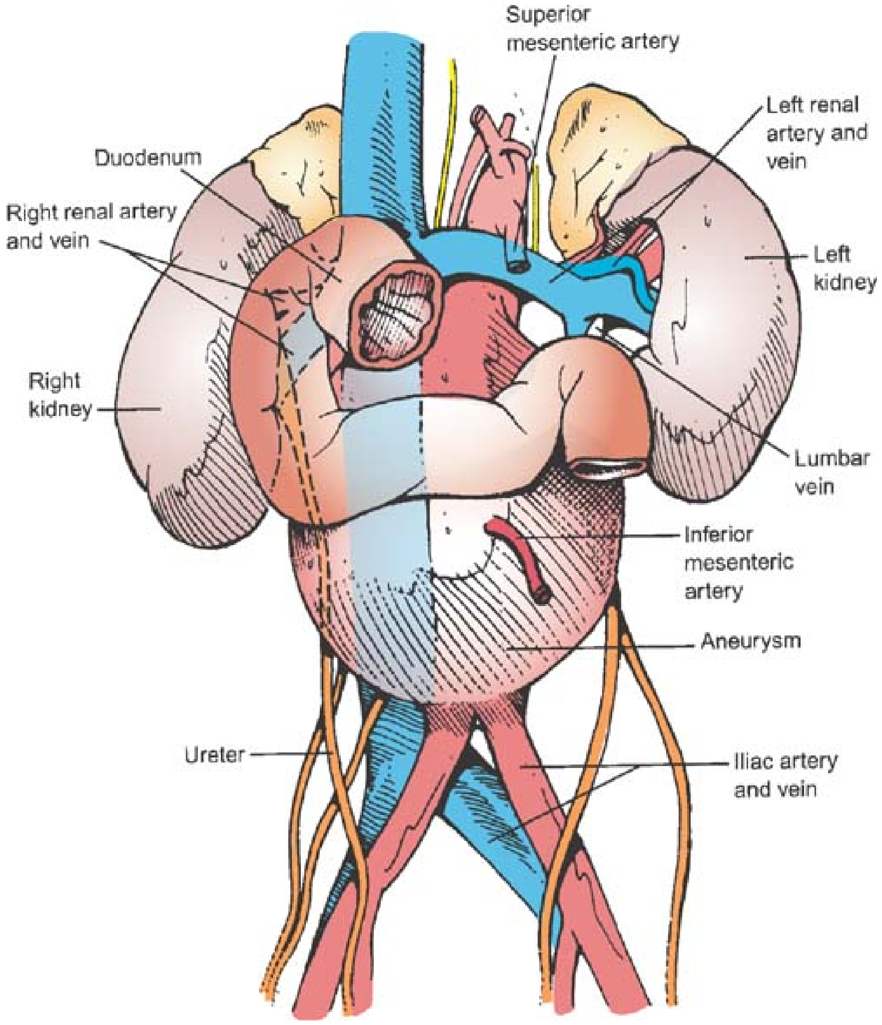

Figure 6.3-7. 7. Aneurysm of the abdominal aorta.

Endovascular stent-grafting of abdominal aortic aneurysm has emerged as an alternative therapeutic approach. The open surgical repair may be either **transperitoneal** or **retroperitoneal** (Fig. 6.3-8). After exposure of the abdominal aorta from the level of the renal vein distally to the iliac arteries, the aorta is cross-clamped, distally at first to prevent atheroembolism, and then proximally. Graft origin is usually from the infrarenal aorta, but may arise from the intramesenteric aorta or even the supraceliac aorta. Graft termination may be to the distal aorta above the bifurcation (tube graft), to the common or external iliac arteries (Y graft), or the femoral arteries. Immediately prior to cross-clamping, vasodilators are increased to reduce afterload, which is significantly increased with application of the aortic cross-clamp. The aorta is then incised, lumbar vessels oversewn, and the aorta transected to allow an interposition graft to be sewn into place. The retroperitoneal approach has many advocates, as it may require less volume intraop, may be associated with less temperature loss, and may result in a shorter period of postop adynamic ileus. In a randomized, prospective study, however, no significant differences could be detected between these two approaches for blood loss or postop recovery time.

Aortoiliac occlusive disease can be a significant cause of lower extremity arterial insufficiency. Although the operative approach may be similar to that for aneurysmal disease, there exists a significant intraop difference in that there are not such profound changes associated with aortic clamping, since there is already some element of increased afterload 2° the occlusive disease. Nevertheless, hemodynamic monitoring is mandatory to allow for rapid volume *(Print pagebreak 416)* shifts, and to assure adequate preload and sufficient afterload reduction, especially during the period of aortic cross-clamping.

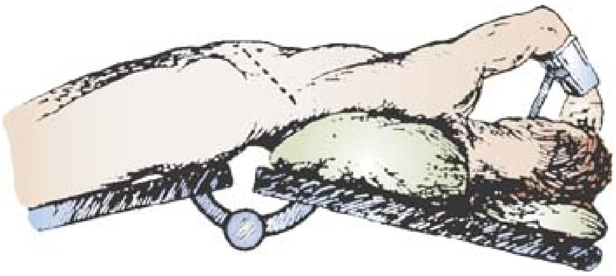

Figure 6.3-8. 8. Retroperitoneal approach to the aorta: the incision is extended from the tip of the 11th rib or 10th intercostal space laterally toward the midhypogastrium. (Reproduced with permission from Scott-Conner CEH, Dawson DL: *Operative Anatomy*, 2nd edition. Lippincott Williams & Wilkins, Philadelphia, 2003.)

Variant procedure or approaches: In the rare patient with COPD severe enough to preclude weaning from the ventilator postop, extraanatomic grafts (e.g., axillofemoral, iliofemoral, and fem-fem bypass) can be constructed under local anesthesia.

Usual preop diagnosis: Abdominal aortic aneurysm (AAA); severe aortoiliac stenosis sufficient to cause debilitating buttock, thigh, or calf claudication; isolated-inflow (aortoiliac) disease (rarely the sole cause for ischemic symptoms at rest or for tissue loss, except as a result of embolic complications)

Summary of Procedures

	Transperitoneal Approach	Retroperitoneal Approach
Position	Supine	Supine with mild elevation of left flank
Incision	Midline abdominal	Left subcostal, left oblique, along 10th rib toward umbilicus (See Fig. 6.3-8.)
Special instrumentation	Self-retaining retractor; TEE; If suprarenal change: SMA + renal artery perfusion catheters.	
Unique considerations	Will need pharmacologic manipulation to ↓ afterload or ↑ preload coincident with clamping or unclamping of aorta.	(The retroperitoneal approach is not used for emergency cases.)
Antibiotics	Cefazolin l g iv	
Surgical time	3–5 h	
EBL	500 mL	
Postop care	ICU 8–16 h, often extubated. Requires aggressive volume administration to allow for 3rd-space loss in 1st 12 h postop. Patient comfort and respiratory management markedly improved by epidural catheter for postop analgesia.	

	Careful cardiac monitoring.	
Mortality	2–5% elective; 50% emergent	
Morbidity	MI: 10–15% (3% fatal) Respiratory insufficiency/pneumonia: 5–10% Lower extremity ischemia: 2–5% Renal insufficiency: 2–5% Bowel complications: 3–4% Hemorrhage: 2–4% CVA: < 1% Infection: < 1% Paraplegia: < 0.4%	
Pain score	8–10	7–10

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Patient Population Characteristics

Age range	55 yr +
Male:Female	4:1
Incidence	3% of males > 55 yr; > 5% of patients > 50 yr in a general cardiology clinic; 30–66/1000
Etiology	Atherosclerosis; Marfan syndrome; Ehlers-Danlos syndrome; dissection; infection, including syphilis
Associated conditions	HTN; CAD; COPD; cerebrovascular disease; renal insufficiency

Anesthetic Considerations

Preoperative

Patients presenting for AAA repair are typically older males with multiple coexisting diseases (e.g., CAD, HTN, PVD, COPD). Most commonly these patients are asymptomatic and the Dx is made as an incidental finding during routine exams or other medical procedures; however, some patients may present with severe ↓ BP following aneurysm rupture. These patients require prompt resuscitation (SBP goal: 90–100 mmHg) and emergent aortic cross-clamping. For anesthetic considerations, see Abdominal Trauma: Vascular Injuries (p. 737).

Respiratory	Many patients have COPD and a long Hx of smoking. Preop preparation—including bronchodilators, cessation of smoking, incentive spirometry, and chest physiotherapy—will ↓ risk of postop complications. **Tests:** CXR. May need PFTs and ABG to determine severity of pulmonary disease.
Cardiovascular	CAD is the most common cause of morbidity and mortality in this patient population. HTN increases risk of aneurysmal rupture; hence, preop control of BP is essential. BP in both arms to determine placement of arterial line intraop (arterial line should be placed in arm with higher BP). **Tests:** Radiologic assessment of aneurysm using ultrasonography, CT, arteriography, and MRI. ECG: for evidence of ischemia, infarction, and LVH. Stress testing, coronary angiography in case of suspicion of coronary disease.

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Renal	Chronic renal insufficiency occurs frequently in this patient population 2° HTN, diabetes mellitus (DM), and atherosclerotic renovascular disease. Hypovolemia 2° radiographic dye studies and bowel prep → renal failure. **Tests:** BUN, Cr; consider creatinine clearance; electrolytes
Hematologic	Preop coagulation disorders should be corrected. Many patients are on aspirin, which should be D/C'd 7 d preop. Alcohol abuse can be associated with anemia, thrombocytopenia, and ↓ vitamin K-dependent factors. **Tests:** PT; PTT; Hct; Plt
Laboratory	Other tests as indicated from H&P.
Premedication	Anxiety and pain may cause HTN and ↑ risk of aneurysmal rupture. Sedatives and analgesics should be used as indicated (p. B-1). Full-stomach precautions for emergent procedures (p. B-4).

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Intraoperative

Anesthetic technique: GETA or combination of epidural and GA. The goals of anesthesia are to: (a) preserve myocardial, renal, pulmonary, and CNS perfusion; (b) maintain adequate intravascular volume and CO; (c) anticipate the surgical maneuvers that will affect BP and blood volume; and (d) control BP to minimize risk of rupture, while ensuring perfusion of other organs.

Induction	If it is planned to extubate the patient postop, anesthesia should be induced using fentanyl (4–6 mcg/kg) in conjunction with propofol (2 mg/kg) or etomidate (0.2–0.4 mg/kg). If an epidural will be used for postop pain management, decrease intraop i.v. opioid dose. Patients with an epidural typically receive morphine (2–4 mg), hydromorphone (0.2–0.8 mg), fentanyl (150–200 mcg), or sufentanil (50 mcg) in 10 mL into the epidural catheter. Local anesthetics may cause hemodynamic instability after unclamping 2° sympathectomy. Muscle relaxants are chosen to minimize tachycardia or ↓ BP (e.g., vecuronium 0.1 mg/kg or rocuronium 1 mg/kg). Anesthesia is deepened before intubation by mask ventilation with 1% sevoflurane. If there is a hemodynamic response to oral airway insertion, tracheal lidocaine or further anesthetic is given before gentle laryngoscopy and intubation. Etomidate is useful for induction in hemodynamically unstable patients. Full-stomach precautions may be necessary.	
Maintenance	O_2/air/narcotic and volatile agent. N_2O can be used, but it may cause bowel distention. Combining epidural and GA offers good abdominal relaxation. Patients receiving epidural local anesthesia may require phenylephrine to treat ↓ BP 2° sympathetic blockade. Epidural catheter placement before systemic anticoagulation is a safe technique. Narcotic epidural analgesia should be given within 1 h of skin incision if morphine 3–8 mg is used. If hydromorphone (0.5–0.8 mg) is given epidurally, it is given within 1 h of abdominal closure. Patient may become hypothermic 2° large incision with visceral exposure and prolonged operation.	
Emergence	Normothermic (> 35.5°C) patients who have had uneventful surgery, especially utilizing a retroperitoneal approach, are frequently extubated in the OR, or shortly after arrival in the ICU. Patients with significant cardiac or pulmonary disease generally are left intubated, and weaned from the ventilator in the ICU. Prevention of HTN and tachycardia during emergence may require titration of β-adrenergic-blocking drugs (e.g., esmolol 50–300 mcg/kg/min) and/or vasodilators (e.g., SNP 0.25–2.0 mcg/kg/min) or NTG (0.25–2.0 mcg/kg/min). Epidural morphine (2–4 mg) or hydromorphone (0.5–0.8 mg) is given 60 min before the end of surgery. It is important to assure full reversal from neuromuscular blockade.	
Blood and fluid requirements	Major blood loss iv: 14 ga (or 7 Fr) × 2 4 U PRBC UO 0.5–1 mL/kg/h Warm all fluids. Humidify all gases.	Use of rapid infusion and blood-salvaging devices helpful. Consider acute normovolemic hemodilution. Hemorrhage should be treated with crystalloid, colloid, or blood products as appropriate. Upper-body Bair-Hugger or equivalent.

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Monitoring	Standard monitors (p. B-1)	Monitor for cardiac ischemia. Automated ST segment analysis is useful.
	CVP line	The measurement of CVP may be sufficient in patients with good ventricular function and exercise tolerance.
	PA catheter	In patients with recent MI, Hx of CHF, Hx of unstable angina, multisystem disease, or in those presenting emergently (without the benefit of a complete workup) a PA catheter is appropriate.
	TEE	TEE is invaluable for assessing cardiac changes 2° cross-clamping and unclamping the aorta.
	Arterial line Urinary catheter	The arterial line is generally placed in the radial artery of the arm having the higher BP (if difference exists).
Cross-clamping	↑↑ Afterload → HTN ↓ Preload ↑ Filling pressures ± ↓ Spinal cord perfusion ± ↓ Renal perfusion ↓ Perfusion to viscera below the clamp ABGs/electrolytes regularly	Application of aortic cross-clamp causes HTN proximal to the clamp. In a healthy heart, this is well tolerated, with minimal increase in filling pressure. In case of poor left ventricular function, filling pressures generally rise. Control of preload, afterload, and HR can be accomplished with vasodilators and β-blockers. Negative inotropic agents (e.g., β-blockers, inhalational anesthetics) are used cautiously. Occlusion of infrarenal aorta →↓ renal blood flow. Ensure adequate intravascular volume and CO. Administer mannitol (0.25–0.5 g/kg) before clamping to maintain UO.
Aortic unclamping	↓↓ Afterload Volume loading Lactate washout ± Phenylephrine	Immediately before unclamping, D/C dilators and negative inotropic agents. Gradually increase filling pressures (volume loading) to avoid myocardial ischemia. ↓↓ BP may occur with removal of cross-clamp 2° to hypovolemia, reperfusion, or myocardial dysfunction. Reperfusion of lower limbs and washout of lactate does not usually require use of HCO. Patients with an epidural sympathetic block often require phenylephrine support during unclamping. The surgeon can reclamp or occlude the aorta if ↓↓ BP persists. If hemodynamically stable with ↓ UO, consider furosemide 20–80 mg.
Positioning	and pad pressure points. eyes.	
Complications	Myocardial ischemia HTN Hemorrhage Coagulopathy	
	Hypothermia Organ ischemia	Hypothermia may cause dysrhythmias, depress contractility, and exacerbate coagulopathy.

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Postoperative

Complications	Myocardial ischemia Renal failure Respiratory failure	
Pain management	Epidural narcotics (p. C-1)	
Tests	CXR to line and ETT placement ABG Coagulation profile BUN; Cr	BP should be closely controlled postop to decrease bleeding from graft site and raw surfaces.

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Infrainguinal Arterial Bypass

Surgical Considerations

Description: Due to the limited durability of distal bypass procedures, surgical bypass to the infrainguinal arteries is indicated only for salvage of the severely ischemic lower extremity, as manifest by gangrene, ischemic ulceration, or ischemic rest pain. Less frequently, it is used to alleviate functional ischemia of claudication, or leg discomfort with exercise. Its use is predicated on the existence of adequate inflow to the level of the groin or femoral artery. Other necessary components include an adequate target vessel, preferably in continuity with runoff into the plantar arch of the foot, and an adequate conduit, preferably autologous saphenous vein. Long-term patency rates of nonautologous conduits to the below-knee arteries are distinctly inferior to that of saphenous vein and should be avoided whenever possible. This population, almost by definition, includes patients with diabetes mellitus (DM), CAD, and cerebrovascular disease, all of which must be assessed preop.

The operative repair usually involves incisions at the groin and distal bypass sites to expose the donor and recipient arteries and to harvest leg or arm venous conduit. The operative approaches are rather similar. An unobstructed inflow source—usually the common femoral, superficial femoral, or deep femoral artery—is exposed in the groin. The target distal artery, usually at the level of the knee or below, can be approached through a medial incision. More distally, the peroneal and anterior tibial arteries can be approached laterally at the midtibial level. At the level of the malleolus, both the dorsalis pedis and posterior tibial arteries can be revascularized. After control of donor and recipient vessels, an anatomic tunnel is created, and the bypass conduit (saphenous vein, prosthetic graft) is passed through its length. After administration of 10,000 U of heparin, the distal anastomosis is constructed first, followed by the proximal anastomosis. A completion arteriogram confirms unobstructed flow. Heparin is then partially reversed and meticulous hemostasis obtained, and the wounds are closed.

Although conventional wisdom has held that the anesthetic and operative risks for patients undergoing distal reconstructions are low, there may be little difference in postop morbidity and mortality when compared with patients undergoing a major inflow procedure within the abdomen.

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Usual preop diagnosis: Severe peripheral vascular disease (PVD); CAD; DM; HTN; obstructive PA disease. (These are almost ubiquitous comorbidities.)

Summary of Procedures

Position	Supine
Incision	Groin, medial knee, ± distal leg incisions; + incision to harvest venous conduit
Antibiotics	Cefazolin 1 g iv at induction of anesthesia
Surgical time	2–5 h
Closing considerations	Optimization of coagulation status
EBL	200–300 mL
Postop care	Possible ICU × 24 h; patients are at risk for myocardial ischemia.
Mortality	2–4%
	MI: 5–12%
	Respiratory insufficiency: 5%
Morbidity	Infection: 2–5%

	Amputation: 2–4% CVA: <1%
Pain score	4–6

Patient Population Characteristics

Age range	> 55 yr (mean age = > 70 yr)
Male:Female	4:1
Incidence	Claudication fairly common in elderly; however, 75% will remain untreated, but stable, over 2–5 yr, with < 5% requiring amputation.
Etiology	Arteriosclerosis (primarily); chronic embolic disease (rare); vasculitis; popliteal artery entrapment; cystic adventitial disease of popliteal artery
Associated conditions	CAD; cerebrovascular disease; DM; HTN; COPD

Anesthetic Considerations

(Procedures covered: infrainguinal arterial bypass; arterial embolectomy; lumbar sympathectomy; venous thrombectomy or vein excision)

Preoperative

Patients presenting for peripheral vascular surgery may suffer from major systemic diseases, including CAD, HTN, and DM. Three types of occlusive vascular disease have been described: Type 1—isolated to the aortic and iliac bifurcations; is not associated with CAD. Type 2—diffuse pattern involving coronary and cerebral circulations; associated with a higher incidence of DM and HTN. Type 3—involves small vessels, especially of the lower limbs; associated with higher postop morbidity and mortality.

Respiratory	Vascular patients frequently have Hx of smoking and COPD. Preop evaluation of pulmonary function helps to determine whether regional vs GA is appropriate, while providing baseline values for postop comparison. **Tests:** CXR; consider PFTs; ABG
Cardiovascular	Vascular surgery of the lower extremities is often associated with ↑ morbidity and mortality 2° ↑ incidence of CAD and HTN in this patient population. **Tests:** ECG: for LVH and ischemia; other tests as indicated from H&P.
Neurological	↑ incidence of cerebrovascular disease. Careful neurological assessment is necessary to document existing deficits.
Endocrine	↑ incidence of DM, which may be associated with peripheral and autonomic neuropathies (silent MI, labile BP) and delayed gastric emptying. Insulin requirements for most diabetic patients can be managed by administering one-half the usual a.m. dose of insulin, once a dextrose-containing iv (e.g., D5LR) has been established. Frequent blood glucose measurements should be made periop.
Renal	There is a higher incidence of renal artery disease and renal insufficiency in this patient population. **Tests:** BUN; Cr; consider creatinine clearance; electrolytes; UA
Hematologic	Many patients presenting for this surgery are taking anticoagulant/anti-Plt medications. Inquire as to bleeding or bruising tendency. **Tests:** Hct; Plt; consider PT, PTT.

Laboratory	As indicated from H&P.
Premedication	Continue usual medications up to time of surgery. Anxiety can contribute to HTN and tachycardia. Premedicate conservatively (midazolam 0.5–2 mg iv) for geriatric patients. If ischemic pain is present, a narcotic such as fentanyl (25–50 mcg iv) can be given. Avoid im administration in patients on anticoagulant therapy.

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Intraoperative

Anesthetic technique: Either regional anesthesia or GETA may be used. For **infrainguinal arterial bypass**, there is evidence that regional anesthesia is superior for promoting graft survival. To date, no study has shown a difference in patient mortality between these anesthetic techniques. **Lumbar sympathectomy** may be accomplished with regional or GA. For **thrombectomy**, GETA with IPPV may reduce the risk of pulmonary emboli.

General anesthesia:

Induction	Hemodynamic stability is important; therefore, a slow, gradual induction is carried out. Preoxygenation is followed by smooth iv induction, using small, incremental doses of fentanyl (1–3 mcg/kg); then STP or propofol is given in divided doses until the patient is asleep. Alternatively, if the LV function is poor, and the depressant effects of STP cannot be tolerated, etomidate (0.2 mg/kg iv) in combination with fentanyl (100–200 mcg) is appropriate. A full dose of muscle relaxant (vecuronium or rocuronium) is given and ventilation is controlled. Muscle relaxation is not necessary during the procedure, but muscle relaxant is given to facilitate intubation. The muscle relaxant is chosen to avoid undesirable effects on HR.
Maintenance	Standard maintenance (p. B-2) with fentanyl (1–2 mcg/kg/h). Continued muscle relaxation is usually unnecessary. These surgical procedures are associated with minimal hemodynamic instability.
Emergence	Tracheal extubation should be based on standard criteria, such as adequacy of ventilation, return of airway reflexes and reversal of muscle relaxation. Control of BP is accomplished with vasodilators (e.g., NTG 0.1–4.0 mcg/kg/min or SNP 0.25–5.0 mcg/kg/min). Esmolol can be given in incremental doses of 10 mg or by infusion (50–200 mcg/kg/min).

Regional anesthesia: Patients presenting for regional anesthesia must have a normal coagulation profile; also, they cannot be on heparin (including low molecular weight), urokinase, or streptokinase. The important goals in regional anesthesia are to achieve hemodynamic stability while establishing an adequate block. An epidural or spinal catheter (multiorifice) is frequently used to infuse local anesthetic for a gradual onset and to prevent an excessively high *(Print pagebreak 423)* block. Hemodynamic stability can be improved by infusing 500–1,000 mL of NS/LR before performing the block. The patient may be placed in the lateral decubitus position (with operative side down), which may provide a denser and more prolonged block on that side. Achieving a T8-T10 level is optimal. Overzealous hydration may → CHF in this patient population, when the vasodilation 2° regional sympathectomy dissipates. The use of regional anesthesia in patients who will receive intraop anticoagulation is controversial. We feel it is a relatively safe procedure and have not had a complication with this technique. If blood is aspirated after placement of an epidural, we remove the catheter and then replace it at a different interspace. Patients on minidose heparin should have a normal PTT before use of regional anesthesia.

Spinal	**One-shot spinal:** 1% hyperbaric tetracaine (6–10 mg) or 0.75% bupivacaine (10–15 mg). Add epinephrine 0.2 mg (generally increases duration of block about 50%) or phenylephrine 5 mg (generally increases duration of block about 100%). Do not add vasoconstrictor if patient is diabetic. Large doses of hyperbaric local anesthetic should be avoided as they may cause postop cauda equina syndrome.

	Continuous spinal: A 20-ga catheter is placed via an 18-ga Tuohy needle. 0.5% hyperbaric tetracaine or 0.75% bupivacaine is titrated to desired anesthetic level (T8-T10). Catheters should be redosed every 60–80 min or as soon as BP trends upward. The risk of spinal headache is very low with continuous spinals.	
Epidural	Lidocaine 2% with 1:200,000 epinephrine or 0.5% bupivacaine is used. Titrate to desired anesthetic level (T8-T10).	
Blood and fluid requirements	IV: 14 or 16 ga × 1 NS/LR @ 3–5 mL/kg/h Warm fluids. Humidify gases. Maintain UO 0.5–1 mL/kg/h.	Minimal-to-moderate blood loss. Use forced-air warmer (e.g., Bair-Hugger).
Monitoring	Standard monitors (p. B-1)	
	Arterial line ST-segment analysis	An arterial line is most often used in patients with severe cardiopulmonary disease or brittle diabetics. Blood sampling for ABGs, electrolytes, glucose, and Hct is facilitated by the use of an arterial line.
	± CVP/PA catheters	CVP and PA catheters are not used routinely because large changes in intravascular volumes are uncommon. Patients with poor LV function, recent MI, or severe valvular disease may need PA monitoring.
Positioning	and pad pressure points. eyes.	Diabetic patients may be at risk of skin ischemia due to poor positioning or inadequate padding of limbs, etc.
Complications	HTN Ischemic reperfusion syndrome (postembolectomy) Hypothermia Hemorrhage	Reperfusion of an ischemic limb → ↓ pH, ↑ K^+, and release of myoglobin from injured muscle → ATN.

(Print pagebreak 424)

Postoperative

Complications	CHF	Infrainguinal bypass: Avoid overhydration; when epidural sympathectomy fades, these patients are at increased risk for CHF. Maintain normovolemia so that peripheral vasoconstriction (which may limit outflow to the graft) does not occur.
	Hypothermia Graft occlusion	Hypothermia causes vasoconstriction and also may limit outflow to the graft.
Pain management	Epidural/spinal opiates (p. C-1) PCA	Epidural (or spinal) catheter may be used for postop analgesia (p. C-2).
Tests	CXR if central line placed Hct	

(Print pagebreak 425)

Suggested Readings

1. Brumberg RS, Back MR, Armstrong PA, et al: The relative importance of graft surveillance and warfarin therapy in infrainguinal prosthetic bypass failure. *J Vasc Surg* 2007; 46:1160–6.

2. Chung J, Bartelson BB, Hiatt WR, et al: Wound healing and functional outcomes after infrainguinal bypass with reversed saphenous vein for critical limb ischemia. *J Vasc Surg* 2006; 43:1183–90.

3. Damask MC, Weissman C, Barth A, et al: General vs epidural—which is the better anesthetic technique for femoral-popliteal bypass surgery? *Anesth Analg* 1986; 65:539.

4. Darling RC, Reddy BP, Chang BB, et al: Long-term results of revised infrainguinal arterial reconstructions. *J Vasc Surg* 2002; 35:773–8.

5. Denny N, Masters R, Pearson D, et al: Postdural puncture headache after continuous spinal anesthesia. *Anesth Analg* 1987; 66 (8):791–4.

6. Rosenfeld BA, Beattie C, Christopherson R, et al: Perioperative Ischemia Randomized Anesthesia Trial Study Group: The effects of different anesthetic regimens on fibrinolysis and the development of postoperative arterial thrombosis. *Anesthesiology* 1993; 79:435–43.

7. Singh N, Sidawy AN, Dezee K, et al: The effects of the type of anesthesia in outcomes of lower extremity infrainguinal bypass. *J Vasc Surg* 2006; 44:964–8.

8. Taylor SM, Cull DL, Kalbaugh CA, et al: Critical analysis of clinical success after surgical bypass for lower-extremity ischemic tissue loss using a standardized definition combining multiple parameters: a new paradigm of outcomes assessment. *J Am Coll Surg* 2007; 204:831–8.

Arterial Embolectomy

Surgical Considerations

Description: The etiology of acute arterial insufficiency is often the result of thromboembolism, which is usually of cardiac origin. Patients at high risk for embolization are those with MI, mitral stenosis, or atrial fibrillation (AF), all of which increase the risk of intracardiac thrombus formation. Noncardiac causes include thoracic and abdominal aortic pathology, such as aneurysms, severe atherosclerotic disease, and paradoxical embolus via a patent foramen ovale (PFO). The emboli usually become lodged at tapering regions and branch sites and most commonly involve the extremities; the cerebrovascular and mesenteric vasculature also may be involved. In the lower extremities, emboli frequently lodge at the iliac, femoral, or popliteal arteries; the common femoral artery is involved in up to 50% of all embolic events. Emboli to the upper extremities typically affect the brachial artery. Because the collateral circulation may not be well developed in patients without underlying peripheral vascular disease, muscle necrosis can appear within 4–6 h after onset, although this time frame is highly variable. Patients are heparinized at time of diagnosis. Therapy directed at the specific etiology is critical to achieve a successful outcome. Revascularization after 8–12 h of ischemia usually is less effective. If the underlying source of the emboli is not adequately treated, recurrence is likely and is associated with poor prognosis. The surgical approach to femoral embolectomy is a groin incision and isolation of the common, superficial, and deep femoral arteries. Both the superficial and deep femoral systems are explored, and small embolectomy catheters are passed into the distal lower extremity. In addition to passage of embolectomy catheters, angioscopy may be helpful. Residual thrombus on intraop arteriogram requires distal surgical exposure and exploration.

Usual preop diagnosis: Peripheral artery embolism

Summary of Procedures

Position	Supine
Incision	Limited groin, medial knee, possible distal leg incisions
Antibiotics	Cefazolin 1 g iv
Surgical time	Variable, 1–4 h

Closing considerations	Ischemia-reperfusion syndrome with acidosis and hyperkalemia, renal tubular necrosis from myoglobinuria
EBL	100–300 mL
Postop care	May need ICU for cardiac monitoring; monitor metabolic disturbances, neurovascular status, and for compartment syndrome
Mortality	10–40% (80% cardiac); older age; acute onset →→ risk.
Morbidity	Arterial reocclusion or thrombosis: 20% Wound hematoma: 10–20% Recurrent emboli: 6–45% (less with anticoagulation) Amputation: 5–10% Metabolic complications: Frequent Compartment syndrome: Occasional
Pain score	4–6

(Print pagebreak 426)

Patient Population Characteristics

Age range	30–90 yr
Male:Female	3:2
Incidence	50/100,000 admissions
Etiology	Cardiac origin (AF accounts for 50–75% of patients; less frequent, LV thrombus from MI) or noncardiac origin (mural thrombus from thoracic or abdominal aortic pathology)
Associated conditions	Rheumatic heart disease and mitral stenosis, mitral or aortic valve prosthesis, CAD and MI, CHF, endocarditis, peripheral vascular and cerebrovascular disease.

Anesthetic Considerations

See Anesthetic Considerations following Infrainguinal Arterial Bypass, p. 421.

Suggested Readings

1. Brewster DC: Acute peripheral arterial occlusion. *Cardiol Clin* 1991; 9:497–513.

2. Dregelid EB, Stangeland LB, Eide GE, et al: Patient survival and limb prognosis after arterial embolectomy. *Eur J Vasc Surg* 1987; 1:263–71.

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5. Panetta T, Thompson JE, Talkington CM, et al: Arterial embolectomy: a 34-year experience with 400 cases. *Surg Clin North Am* 1986; 66:339–53.

6. Varty K, Johnston JA, Beets G, et al: Arterial embolectomy. A long-term perspective. *J Cardiovasc Surg* 1992; 33: 79–84.

Lumbar Sympathectomy

Surgical Considerations

Description: The role of open surgical or endoscopic **lumbar sympathectomy** is not well defined. The procedure is used selectively in patients with causalgia, inoperable lower limb ischemia with rest pain or toe gangrene, symptomatic vasospastic disorders (e.g., Raynaud's phenomenon, frostbite), and sometimes as an adjunct to distal *(Print pagebreak 427)* revascularization procedures. Causalgia responds well to lumbar sympathectomy, especially if performed early in the clinical course. There may be some benefit of the procedure in 50–60% of patients with rest pain or ischemic ulceration. Sympathectomy may increase collateral blood flow and local skin blood flow. Scleroderma with impending 'minor' amputation may benefit from sympathectomy with improved wound healing. Sympathetic denervation involves the division of preganglionic fibers along their segmental origins and resection of corresponding relay ganglia. For most clinical indications, L2 and L3 **ganglionectomy** sufficiently sympathectomizes the lower extremity (Fig. 6.3-9).

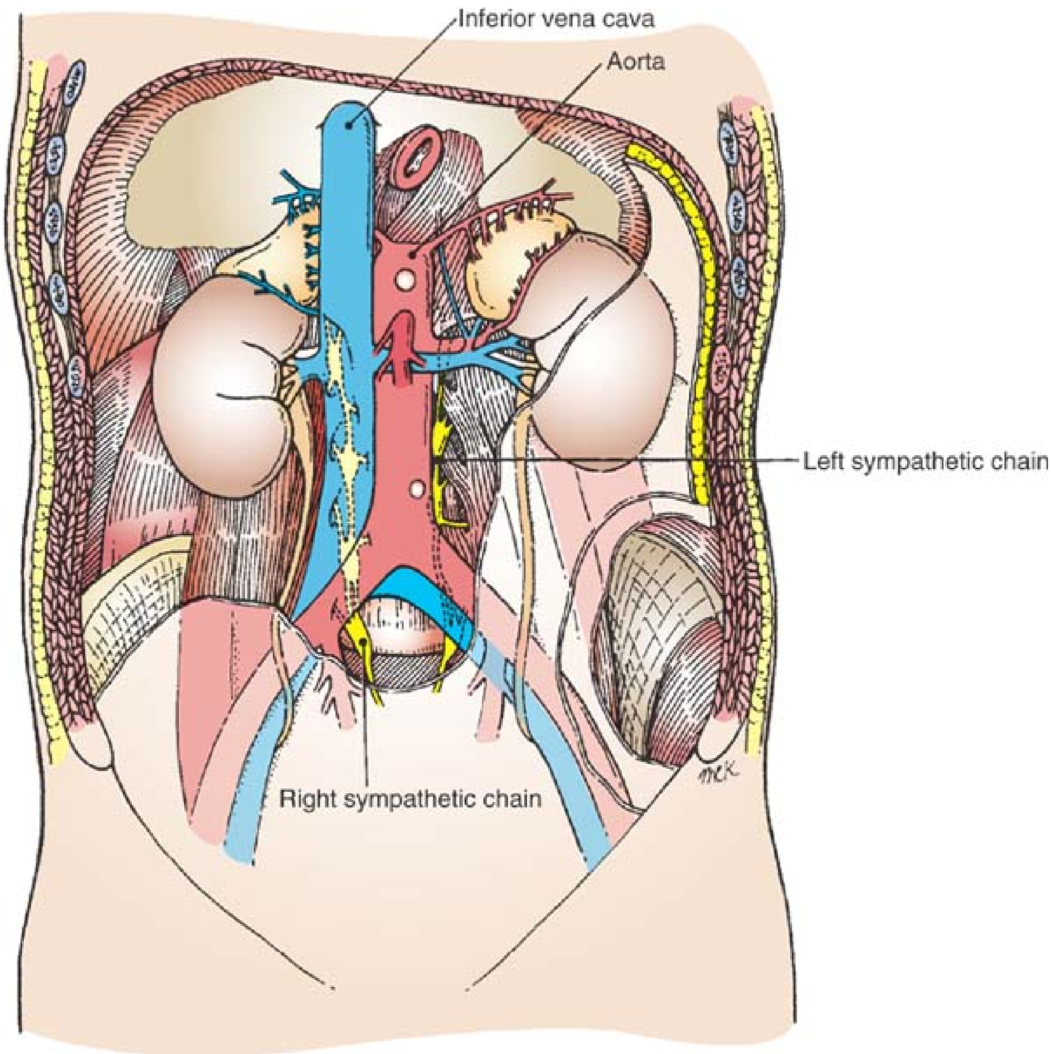

Figure 6.3-9. 9. Surgical anatomy for lumbar sympathectomy. (Reproduced with permission from Scott-Conner CEH, Dawson DL: *Operative Anatomy*, 2nd edition. Lippincott Williams & Wilkins, 2003.)

The **anterolateral retroperitoneal approach** is the most commonly performed open surgical technique because of the adequate exposure and a relatively well tolerated incision. For this approach, an oblique incision is made through the abdominal musculature, extending from the lateral border of the rectus abdominus to the anterior axillary line. Cephalad and caudad blunt dissection is performed between the transversalis fascia and peritoneum. The dissection is continued in a retroperitoneal fashion. The psoas muscle is identified, with care being taken to leave the ureter and gonadal vessels attached to overlying peritoneum. The sympathetic *(Print pagebreak 428)* chain is identified between the psoas muscle and the vertebra (medial to psoas and overlying the transverse process of lumbar vertebra). On the left side, the sympathetic chain is lateral to the abdominal aorta; on the right, the sympathetic chain is beneath the IVC. The sympathetic chain is dissected free from surrounding tissue, clipped proximally and distally, and

ISBN: 0-7817-6670-2 | 4th_Edition
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resected. Hemostasis is achieved and the abdominal wall is closed in layers.

A **posterior approach** is used less often because of significant postop paraspinous muscle spasms. In this approach, a transverse lumbar incision is made, and the paraspinous muscles are partially divided and retracted to expose the vertebra. The sympathetic chain is identified and resected as described. The **anterior/transperitoneal approach** is performed in conjunction with an abdominal aortic or intraperitoneal procedure. Dissection is carried to the psoas muscle; the retroperitoneum is entered and the sympathetic chain is isolated in the groove between the psoas and the vertebra. The sympathetic chain is clipped proximally and distally and resected.

Usual preop diagnosis: Causalgia; inoperable arterial occlusive disease with limb-threatening ischemia causing rest pain, ulceration, or superficial digital gangrene; symptomatic vasospastic disorders (e.g., Raynaud's phenomenon or frostbite)

Summary of Procedures

	Anterolateral (Flowthow)	Posterior (Royle)	Anterior (Adson)
Position	Supine (flank slightly raised); widen distance between costal margin and iliac crest.	Prone	Supine
Incision	Oblique (lateral edge of rectus to ribs at anterior axillary line)	Posterior transverse over mid-lumbar region	Transverse or midline abdominal
Special instrumentation	Self-retaining retractor		
Unique considerations	May use frozen section to confirm specimen.		
Antibiotics	Cefazolin 1g iv		
Surgical time	2–3 h	3 h	4 h
Closing considerations	Flex table to facilitate abdominal wall closure; occasionally drain is placed.		
EBL	50–100 mL (unless complicated)	50–100 mL	
Postop care	PACU → ward. (May require cardiac and hemodynamic monitoring in high-risk patients, or if combined with distal revascularization.)		
Mortality	Minimal		
Morbidity	Postsympathectomy neuralgia: 50% Sexual derangement—retrograde ejaculation (usually bilateral L1 sympathectomy): 25–50% Wound hematoma: 10% Wound infection: 1–3%	50% 25–50% 10% 1–3% Paraspinous muscle spasms	
Pain score	5	5	5 (related to primary procedure)

Patient Population Characteristics

Age range	38–91 yr; younger patients with vasospastic disease; older patients with PVD
Male:Female	2:1

Incidence	Unknown. Approximately 30 cases/yr at Stanford University Medical Center, mainly for inoperable lower extremity ischemia or as an adjunct to revascularization procedures.
Etiology	PVD (rest pain and tissue loss);vasospastic disorders; causalgia
Associated conditions	PVD (rare); vasospastic disorders (rare)

Anesthetic Considerations

See Anesthetic Considerations following Infrainguinal Arterial Bypass, p. 421.

Suggested Readings

1. Abu Rahma AF, Robinson PA: Clinical parameters for predicting response to lumbar sympathectomy in patients with severe lower limb ischemia. *J Cardiovasc Surg* 1990; 31(1):101–6.

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4. Claeys LG: The use of lumbar sympathectomy for peripheral vascular disease. *World J Surg* 1999; 23:981–3.

5. Repelaer van Driel OJ, van Bockel JH, van Schilfgaarde R: Lumbar sympathectomy for severe lower limb ischaemia: results and analysis of factors influencing the outcome. *J Cardiovasc Surg* 1988; 29(3):310–14.

6. Sanni A, Hamid A, Dunning J: Is sympathectomy of benefit in critical left ischaemia not amenable to revascularization? *Interact Cardiovasc Thorac Surg* 2005; 4:478–83.

7. Watarida S, Shiraishi S, Fujimura M, et al: Laparoscopic lumbar sympathectomy for lower-limb disease. *Surg Endosc* 2002; 16:500–3.

Venous Surgery—Thrombectomy or Vein Excision

Surgical Considerations

Description: Standard therapy for acute DVT consists of anticoagulation, bed rest, and elevation of the extremity. Endovascular or catheter-directed thrombolysis and thrombectomy systems have been shown to extract large venous thrombus burden. Open surgical thrombectomy for acute iliofemoral DVT remains controversial. **Venous thrombectomy** is recommended for patients with threatened limb loss or venous gangrene caused by massive DVT associated with high compartment pressures and arterial insufficiency (phlegmasia cerulea dolens). Surgical venous thrombectomy requires exposure of the femoral vein via a groin cut-down. The common femoral vein is isolated (located medial or posteromedial to the femoral artery) and controlled proximally and distally. The patient is given iv heparin at this stage, if not already heparinized. A transverse venotomy is followed by extraction of the thrombus, using forceps and Fogarty embolectomy catheters (Fig. 6.3-10). Distal thrombi are expressed through the same incision with the aid of an Esmarch bandage placed on the extremity. After complete removal of the thrombus, the venotomy is closed with nonabsorbable sutures, and flow through the femoral vein is re-established. The femoral incision is closed in layers. A plastic/Silastic drain may or may not be used. The best results of thrombectomy are obtained in young patients with the first episode of proximal (iliofemoral) thrombosis.

Nonsuppurative thrombophlebitis of the superficial veins may develop due to local trauma, prolonged inactivity, fungal infection, or the use of oral contraceptives. Suppurative thrombophlebitis may occur as a complication of iv line placement or iv drug abuse.

Underlying varicose veins may predispose to thrombophlebitis. Migratory superficial thrombophlebitis may be associated with chronic ischemia of the extremities in Buerger's disease, or it may develop in patients with a malignancy. Conservative management with hot compresses, nonsteroidal anti-inflammatory medications, and elevation of the extremity is effective in most cases. Rarely, **excision** of the acutely thrombosed greater saphenous vein is indicated to prevent progression of thrombosis to the saphenofemoral junction and into the deep venous system. Vein excision is simply approached by a longitudinal incision directly over the affected vein. *(Print pagebreak 429)* The phlebitic vein is dissected from the surrounding tissue, ligated proximally and distally, and removed. The surrounding fibrotic tissue is débrided gently. The wound is irrigated and packed open with moist gauze. Suppurative phlebitis is treated with iv antibiotics and complete excision of the involved vein segment through multiple small incisions.

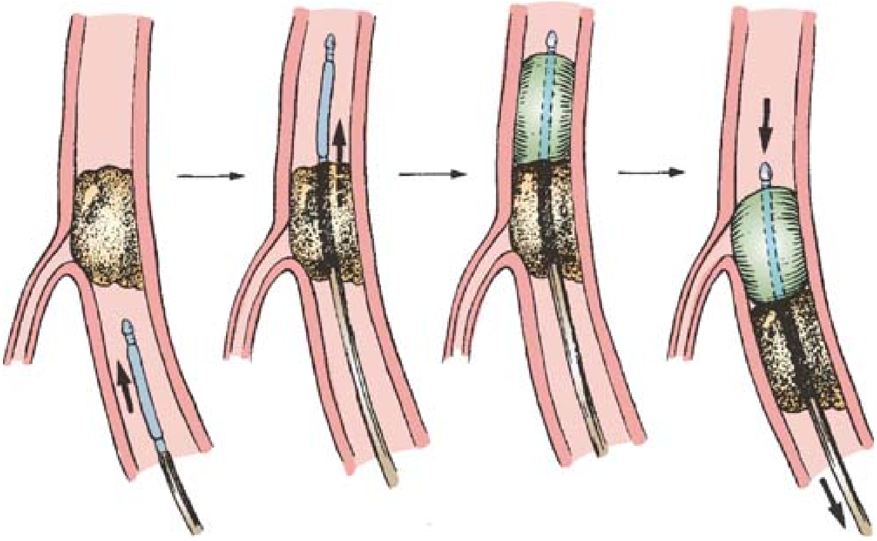

Figure 6.3-10. 10. Fogarty catheter embolectomy with catheter insertion in the distal vessel. (Reproduced with permission from Baker RJ, Fischer JE: *Mastery of Surgery*, Vol 2. Lippincott Williams & Wilkins, 2001.)

Usual preop diagnosis: Lower-limb venous thrombosis threatening viability; femoral thrombosis < 10 d; iliac thrombosis < 3 wk; floating thrombi at hip level; acute deep or superficial venous thrombosis; suppurative thrombophlebitis.

Summary of Procedures

	Thrombectomy	Vein Excision
Position	Supine	
Incision	Ipsilateral longitudinal or oblique groin incision	Multiple small incisions along the course of vein to be excised
Special instrumentation	Fogarty embolectomy catheters; RBC salvage System	None
Unique considerations	IPPV during thrombectomy may decrease chance of PE 2° ↓ venous return → more complete extraction of the thrombus.	None
Antibiotics	Cefazolin 1 g iv. If the patient has septic thrombus, antibiotic is dependent on blood culture.	Dependent on culture of aspirate. Usually a septic patient is on broad-spectrum antibiotics (guided by culture).
Surgical time	2–3 h	1–3 h
Closing considerations	None	Wound packed open for drainage
EBL	50–250 mL	
Postop care	PACU → ward; ICU in high-risk patients; heparin administered before and after procedure, followed by Coumadin for 1–6 mo.	PACU → ward; support stockings
Mortality	Minimal (depending on underlying illness)	Minimal

Morbidity	Postthrombotic syndrome: < 10–44% Venous stasis Nonpitting edema Brawny induration Aching pain	Minimal
Pain score	3	2

(Print pagebreak 430)

Patient Population Characteristics

Age range	Young adult—elderly
Male:Female	1:2
Incidence	6–7 million in the United States have adverse effects from chronic venous stasis; 500,000 have complications of leg ulceration.
Etiology	Chronic primary varicose veins; defective venous valves; impaired pumping action of muscles in leg; previous iliofemoral thrombophlebitis; obstruction of venous return
Associated conditions	Multifactorial: varicose veins; underlying malignancy; altered coagulation status (hypercoagulability, acquired or congenital); Hx of DVT/thrombophlebitis

Anesthetic Considerations

See Anesthetic Considerations following Infrainguinal Arterial Bypass, p. 421.

Suggested Readings

1. Bluckians A, Meier GH 3rd: Treatment of symptomatic lower extremity acute deep venous thrombosis: role of mechanical thrombectomy. *Vascular* 2007; 15:297–303.

2. Gloviczki P, Merrell SW: Surgical treatment of venous disease. *Cardiovasc Glin* 1992; 22(3):81–100.

3. Kim HS, Patra A, Paxton BE, et al: Catheter-directed thrombolysis with percutaneous rheolytic thrombectomy versus thrombolysis along in upper and lower extremity deep vein thrombosis. *Cardiovasc Intervent Radiol* 2006; 29:1003–7.

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Surgery for Portal Hypertension

Surgical Considerations

Description: Alcoholic liver disease is the major cause of portal HTN; and end-stage liver disease (ESLD) with cirrhosis is the 10th leading cause of death in the United States (exceeding 23,000/yr). Of patients with portal HTN, 15–20% have variceal hemorrhage during the first yr of diagnosis (additional 5–10 % incidence of bleeding per yr); and the initial episode of variceal hemorrhage is associated with 50% mortality. Portal HTN (>15 mmHg) develops *(Print pagebreak 431)* when splanchnic venous flow to the right heart becomes impeded. Medical and surgical therapeutic interventions are directed not at portal HTN per se, but at its complications—notably bleeding esophageal varices. Intractable ascites and hypersplenism are less common indications for operative therapy. Presinusoidal portal HTN, unlike sinusoidal or postsinusoidal obstruction, is not associated with severe hepatocellular disease; thus, the prognosis for patients with presinusoidal block is better than for those with sinusoidal or postsinusoidal disease. Surgical approaches can be divided into shunt and nonshunt procedures. **Shunt procedures** can be classified as either **total** (decompression of the portal venous system) or **selective** (decompression of only the varix-bearing area). It should be noted, however, that surgery for portal HTN has been replaced largely by the TIPS procedure (see p. 1462).

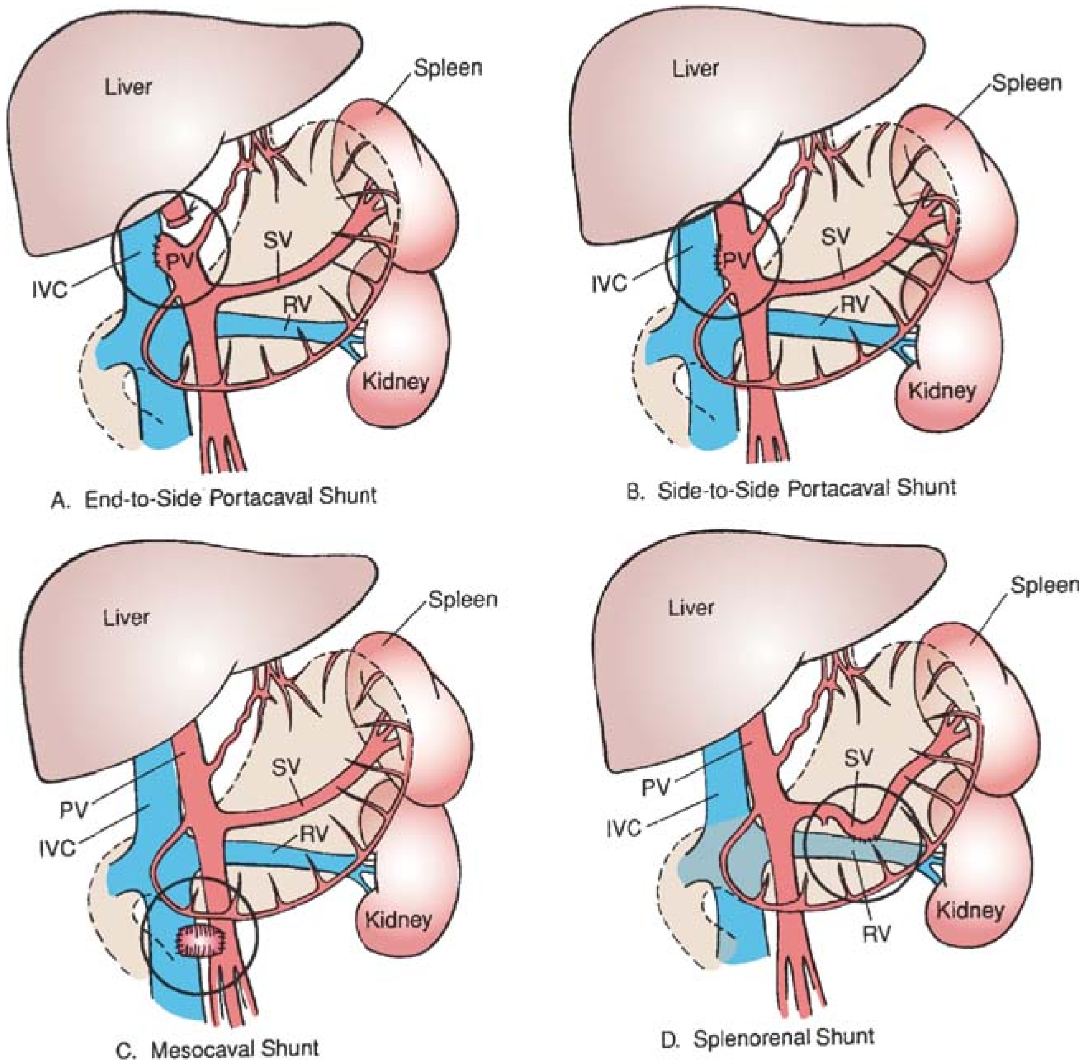

Figure 6.3-11. 11. Types of shunts: **A.** End-to-side portacaval; **B.** side-to-side portacaval; **C**. mesocaval shunt; **D.** distal splenorenal. (Reproduced with permission from Hardy JD: *Hardy's Textbook of Surgery*, 2nd edition. JB Lippincott, 1988.)

Shunt Procedures

There are two general types of total shunt (**portosystemic shunt**) procedures. The **end-to-side portacaval shunt** (Fig. 6.3-11A) is technically simpler and may be more appropriate in emergency situations. It is associated with immediate control of hemorrhage in the majority of cases. The portacaval shunt, however, does eliminate portal perfusion of the liver and does not decompress the hepatic sinusoids. Alternatively, the **functional side-to-side shunt** *(Print pagebreak 432)* (Fig. 6.3-11B) allows decompression of hepatic sinusoids and may preserve some degree of portal perfusion of the liver. Also, it is more effective in controlling ascites. Variations of the side-to-side shunt include: **portacaval, splenorenal, mesocaval** (**Clatworthy**), and **portarenal** (rarely used).

For the **end-to-side** and **side-to-side portacaval shunts**, the approach is via an extended right subcostal incision. **Cholecystectomy** usually is not performed because of the likelihood of profuse bleeding from the liver bed. The hepatoduodenal ligament is identified, and the portal vein is exposed from the hilum of the liver to the pancreas. The gastroduodenal and right gastric branches may be divided to provide additional exposure of the portal vein. The IVC is exposed by incising the peritoneum just beneath the hepatic triad. Proximal and distal control of the portal vein is achieved; and a side-biting clamp is placed on the IVC. In order to perform an end-to-side portacaval shunt, the portal vein is divided and oversewn proximally; the end-to-side anastomosis is performed from the portal vein to the IVC. The alternative is to perform a side-to-side anastomosis of the portal vein to the IVC without division of the portal vein.

The **proximal splenorenal shunt** is approached through a left thoracoabdominal or transabdominal incision. The spleen is isolated and removed, and the distal splenic vein is mobilized from the distal pancreatic bed. The left renal vein is exposed and controlled. The distal splenic vein is then anastomosed in an end-to-side fashion to the mid renal vein. The **mesocaval shunt** (Fig. 6.3-11C) is indicated in cases of ascites, periportal fibrosis, portal vein thrombosis, and Budd-Chiari syndrome. The mesocaval shunt is approached through a vertical midline incision. The colon is retracted cephalad and the superior mesenteric vein (SMV) is identified at the root of the mesentery. A length of the SMV is isolated and encircled. A **Kocher maneuver** (mobilization of the duodenum) is performed and the IVC is exposed anteriorly and laterally. A side-biting clamp partially occludes the IVC and a 14–20 mm dacron graft is anastomosed in an end-to-side fashion to the IVC. The graft is clamped and the side-biting clamp removed from the IVC, thereby restoring flow via the IVC. The SMV is clamped and an end-to-side anastomosis is created from the graft to the SMV. Flow is, thus, re-established from the SMV through the graft to the IVC.

Selective shunts are designed to decompress esophageal varices, while some portal perfusion of the liver is maintained. The hallmark example of this approach is the **distal splenorenal shunt** (**Warren**) (Fig. 6.3-11D), which is seldom used in emergency situations. The principal feature of this shunt is disconnection of the splenic and superior mesenteric venous drainage systems. The distal splenorenal shunt is approached through a left chevron or extended left subcostal incision. The lesser sac is entered after division of the gastroepiploic vessels and mobilization of the splenic flexure of the colon. The stomach is retracted cephalad and the peritoneum overlying the inferior aspect of the pancreas is incised. The splenic vein is identified and controlled proximally and distally. The inferior mesenteric vein is divided. The splenic vein is divided proximally and the proximal stump is oversewn. Then the splenic vein is mobilized from the pancreatic bed. The left renal vein is identified and 5–7 cm of the vein is isolated. The splenic vein is anastomosed in an end-to-side fashion to the renal vein. The coronary vein is ligated close to its origin. The distal splenorenal shunt decompresses the stomach, distal esophagus, and spleen and controls variceal hemorrhage in 85% of patients.

Variant procedure or approaches: Total shunt (e.g., portacaval, proximal splenorenal, mesocaval); **selective shunt** (e.g., **Warren**); **non-shunt procedures** (e.g., **Sugiura, Hassab**, and **esophageal transection with stapling**)

Usual preop diagnosis: Bleeding esophageal varices (as a result of portal HTN); ascites; hypersplenism

Summary of Procedures (Total and Selective Shunts)

	Portacaval	Proximal Splenorenal	Mesocaval (Clatworthy)	Distal Splenorenal (Warren)
Position	Supine	Supine ± left flank elevated	Supine	Supine, left side elevated slightly
Incision	Extended right sub-costal—may be lengthened or converted to left thoracoabdominal.	Left thoracoabdomi- nal or left subcostal, or vertical midline	Vertical midline ab-dominal	Left chevron or left subcostal with midline extension
Special instrumentation	Self-retaining retractor			
Unique considerations	May need FFP; consider Cell Saver.			
Antibiotics	Cefazolin 1 g iv			
Surgical time	4–6 h			
Closing considerations	None			
EBL	1,000–2,000 mL			
Postop care	Patient → ICU; careful fluid management; consider Na+ restriction; may require PA catheter.			

Mortality	Emergency: 38% Elective: 3% Child's A: 0–15%* Child's B: 1–43%* Child's C: 6–58%*	5–10%		1–16%
Morbidity	Late liver failure: 50%	50%		–
	Encephalopathy: 32%	32%		5–47% (overall)
	Child's A: 8%*			5% at 2 yr
	Child's B: 20%*			12% at 3–6 yr
	Child's C: 30%*			27% at 10 yr
	Early rebleeding:	0–19%		–
	0–19%	20%	9–30%	–
	Shunt thrombosis:	1–10%	Duodenal obstruction Erosion through bowel wall	Loss of selectivity: 60% (@ 2 yr) Recurrent varicealhem-orrhage (shunt occlusion): 3–19% Portal vein thrombosis: 4–10%
Pain score	6	6	6	6

Note: In addition to the shunt procedure itself, other factors that determine postop morbidity and mortality include: severity of hepatocellular disease, degree of hepatic reserve, and urgency of the procedure. Although the specific numbers may vary, several comparative series have shown no difference in operative mortality rate or long-term survival rate among the various open shunt procedures.

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Nonshunt Procedures

Nonshunt procedures are designed to devascularize the esophagogastric region, thus eliminating acute variceal hemorrhage. Procedures of this type include: **portazygous disconnection; splenectomy; coronary vein ligation;** and **transesophageal** or **transgastric varix ligation**.

The **Sugiura operation**, approached via abdominal and thoracic incisions, includes esophageal transection and devascularization, splenectomy, and pyloromyotomy. This procedure is usually performed in two operative stages, sometimes with a delayed second stage. The **Hassab procedure** involves devascularization of the upper half of the stomach and splenectomy, thus effectively disconnecting the esophageal varices. (This operation has been reserved in some centers for the failures of sclerotherapy.) Finally, **esophageal transection**, using a stapling device, disconnects the varices in the lower esophagus. This is accomplished by placing a row of staples at the esophagus just above the esophagogastric junction. Because portal perfusion of the liver is maintained after the nonshunt procedures, hepatic function is preserved.

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Summary of Nonshunt Procedures

	Sugiura (Two Stages)	Hassab	Esophageal Transection
Position	Supine, left side elevated	Supine	
Incision	Abdominal stage: midline; thoracic stage: left thoracotomy	Vertical midline	
Special instrumentation	Self-retaining retractor		
Antibiotics	Cefazolin 1 g iv		

Surgical time	4–6 h for both stages	4 h	
EBL	1,000–2,000 mL		
Postop care	ICU; careful hemodynamic monitoring; PA catheterization		
Mortality	Overall: 5–14% Emergent: 14% (≥ 60%) Elective: 3%	12–38% 10%	10–83%
Morbidity	Recurrent hemorrhage: 2–50% Esophagopleural leak: 6% Encephalopathy: 3% Ascites: 2% Wound infection: 2%	7% – 1–25% 4% –	0–50% 3% 33% 11% 11%
Pain score	6	5	5

Patient Population Characteristics for Shunt and Nonshunt Procedures

Age range	11–72 yr (mean age = 48 yr); depending on etiology: pediatric (e.g., congenital hepatic fibrosis) to adult (e.g., alcoholic liver disease)
Male:Female	2–8:1
Incidence	Rare
Etiology	Alcoholic liver disease (alcoholic hepatitis, chronic alcoholism, cirrhosis); postnecrotic cirrhosis; portal vein thrombosis; splenic vein occlusion; hematologic diseases; hepatic vein occlusion; schistosomiasis; congenital hepatic fibrosis; sarcoidosis; sinusoidal occlusion (vitamin A toxicity, Gaucher's disease); venoocclusive disease
Associated conditions	Alcohol dependency; cirrhosis/liver failure; poor nutritional status; coagulopathy; encephalopathy

Anesthetic Considerations

(Procedures covered: shunt and nonshunt procedures for portal HTN surgery)

Preoperative

Respiratory	Hypoxemia may be present 2° ascites, V/Q mismatch, ↑ R→L pulmonary shunting, atelectasis, pulmonary infections and ↓ pulmonary diffusing capacity. **Tests:** Consider ABG; PFTs, as indicated; CXR
Cardiovascular	Patients presenting with portal HTN often have a hyperdynamic circulatory state with ↑ plasma volume, ↑ CO, and ↓ SVR, with a decreased ability to ↑ SVR or ↑ HR in response to stimuli. Ventricular performance may be abnormal (CHF), especially in patients with alcoholic liver disease. Ascites →↑ intrathoracic pressure, ↓ FRC, ↓ venous return, and ↓ CO. Older patients in this population usually have CAD. **Tests:** ECG. If LV function in question, ECHO or angiography.
Hepatic	The physical manifestations of hepatic disease include palmar erythema, caput medusae, spider angiomas, and gynecomastia. Albumin and other products of liver synthesis (e.g., coagulation factors) may be decreased. Encephalopathy may be present 2° impaired ammonia metabolism.

	Tests: Bilirubin; albumin; PT; SGOT; SGPT; ammonia; alkaline phosphatase
Gastrointestinal	Portal HTN eventually → esophageal and gastric varices. Patients may present emergently with profuse GI bleeding. Ascites occurs in 80% of patients with portal HTN and splenomegaly is invariably present. As a result of elevated intraabdominal pressure from ascites, and slow gastric emptying, a rapid-sequence induction with full-stomach precautions will be necessary (see p. B-4).
Renal	Portal HTN →↓ GFR and ↓ renal blood flow → renal failure. **Tests:** Consider UA; creatinine clearance as indicated from H&P
Hematologic	These patients are often anemic as a result of poor nutrition, malabsorption, and intestinal tract blood loss. Hypersplenism may be present (Plt count < 50,000 and WBC < 2,000). Synthesis of all coagulation factors is decreased except factor VIII and fibrinogen. A low-grade DIC may be present. T&C for 8–10 U PRBC. **Tests:** CBC; Plt count; PT; PTT; consider DIC screen.
Pharmacologic	The liver is the major site of drug biotransformation; however, the effects of hepatic dysfunction on drug elimination and disposition are inconsistent.
Laboratory	These patients may have significant electrolyte disturbances (e.g., ↓↓ Na^+; ↓ K^+). **Tests:** Electrolytes and others as indicated from H&P.
Premedication	If premedication is appropriate, small doses of anxiolytic, such as midazolam (0.5–1 mg iv), are preferable. Avoid im medications in patients with possible coagulopathy. Full-stomach precautions are necessary. Metoclopramide (10 mg iv) and ranitidine (50 mg iv) may be given 60 min before surgery.

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Intraoperative

Anesthetic technique: GETA. Preservation of intravascular volume and myocardial stability can be a challenge in these patients.

Induction	Instable patients rapid-sequence induction with propofol (1–2 mg/kg) and succinylcholine (1–2 mg/kg) should be used. Replace blood loss and ensure normovolemia before induction (if possible). Etomidate (0.2 mg/kg) or ketamine (1 mg/kg) may be preferable for induction in hemodynamically unstable patients.	
Maintenance	High-dose narcotic technique with fentanyl (50–100 mcg/kg) or sufentanil (10–15 mcg/kg) and low-dose isoflurane. Midazolam (0.1–0.2 mg/kg) often is given in conjunction with the narcotic to ensure amnesia during times of hemodynamic instability when isoflurane cannot be tolerated. N_2O is avoided to prevent bowel distention. Muscle relaxation is needed (e.g., vecuronium 0.1 mg/kg or less, titrated using a nerve stimulator). ***NB:** After drainage of ascitic fluid, there may be a precipitous drop in BP requiring rapid volume replacement ± vasopressor.	
Emergence	Generally deferred to ICU due to large fluid shifts and transfusion requirements. Patients who have undergone uneventful and nonemergent surgery may be candidates for extubation.	
Blood and fluid requirements	Anticipate large blood loss. IV: 14 ga × 2 or 7 Fr × 2 Rapid infuser RBC salvage device 8–10 U PRBC Warm all fluids. Humidify all gases.	FFP, Plt, and cryoprecipitate should be available to treat coagulopathy.

	Warming blanket	e. g. Bair-Hugger warmer
Monitoring	Standard monitors (p. B-1) Arterial line CVP or PA catheter	Arterial and central pressure monitoring are essential. A PA catheter is useful in this setting because most patients are cirrhotic and may have excessive blood loss and large fluid shifts.
	UO	UO is measured and is helpful as a monitor of renal perfusion. Mannitol (0.25–1 g/kg iv) may be needed to maintain UO.
	Temperature	In these procedures, prevention of hypothermia is important. In patients with large varices, avoid esophageal placement of T probes or stethoscopes.
	ABGs	Serial ABGs to determine adequacy of ventilation and normal acid base status should be done.
	Hct, coags, Ca^{++}	Hct, coagulation, and Ca++ should be measured following replacement of large blood volumes.
	Electrolytes Blood glucose	Electrolytes and glucose also should be monitored. Glucose metabolism in liver disease may be impaired →↓ glucose.
Positioning	and pad pressure points. eyes.	
Complications	Coagulopathy Hemorrhage Hypothermia	

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Postoperative

Complications	Coagulopathy Hypothermia Encephalopathy Renal failure	
Pain management	PCA (p. C-3) Parenteral opiates	
Tests	CXR: line placement Hct Electrolytes Glucose	DIC screen, if continued bleeding.

Suggested Readings

1. Gusberg RJ: Selective shunts in selected older cirrhotic patients with variceal hemorrhage. *Am J Surg* 1993; 166(3):274–8.

2. Haberer JP, Schoeffler P, Couderc E, et al: Fentanyl pharmacokinetics in anesthetized patients with cirrhosis. *Br J Anaesth* 1982; 54:1267.

3. Hassab MA: Nonshunt operations in portal hypertension without cirrhosis. *Surg Gynecol Obstet* 1970; 131(4):648–54.

4. Henderson JM: The distal splenoral shunt. *Surg Clin North Am* 1990; 70(2):405–23.

(Print pagebreak 437)

5. Jenkins RL, Gedaly R, Pomposelli JJ, et al: Distal splenorenal shunt: role, indications, and utility in the era of liver transplantation. *Arch Surg* 1999; 134:416–20.

6. Langer B, Taylor BR, Greig PD: Selective or total shunts for variceal bleeding. *Am J Surg* 1990; 160(1):75–9.

7. Orozco H, Mercado MA, Takahashi T, et al: Elective treatment of bleeding varices with the Sugiura operation over 10 years. *Am J Surg* 1992; 163(6):585–9.

Arteriovenous Access for Hemodialysis

Surgical Considerations

Description: Peripheral subcutaneous arteriovenous (AV) fistula, or **prosthetic graft**, is the current procedure of choice for patients requiring permanent hemodialysis access. The blood flow in the autogenous AV fistula increases with time, and the resulting vein wall thickening prevents venous tears and infiltration during dialysis.

The standard AV fistula is usually constructed by anastomosing the cephalic vein to the radial artery at the wrist level (**Brescia-Cimino fistula**) (Fig. 6.3-12). Other locations include the 'snuff box,' or antebrachium. Vascular access using vascular substitutes or prosthetic grafts is performed when there is a lack of suitable veins in patients who have had failed-access procedures, peripheral vein sclerosis, or severe arterial disease involving the upper extremity. Forearm grafts are constructed as a direct communication between the radial or ulnar artery and the antecubital or *(Print pagebreak 438)* brachial vein, or as a 'loop' between the brachial artery and these veins (Fig. 6.3-13). Similarly, an access can be constructed in the upper arm as a communication between the brachial artery above the elbow and the basilic or axillary vein in a straight fashion. The polytetrafluoroethylene (Teflon) graft has become the mainstay for hemodialysis access in patients who are not candidates for Brescia-Cimino fistula placement. These grafts are associated with a primary patency rate of 50–60% at 2–3 yr.

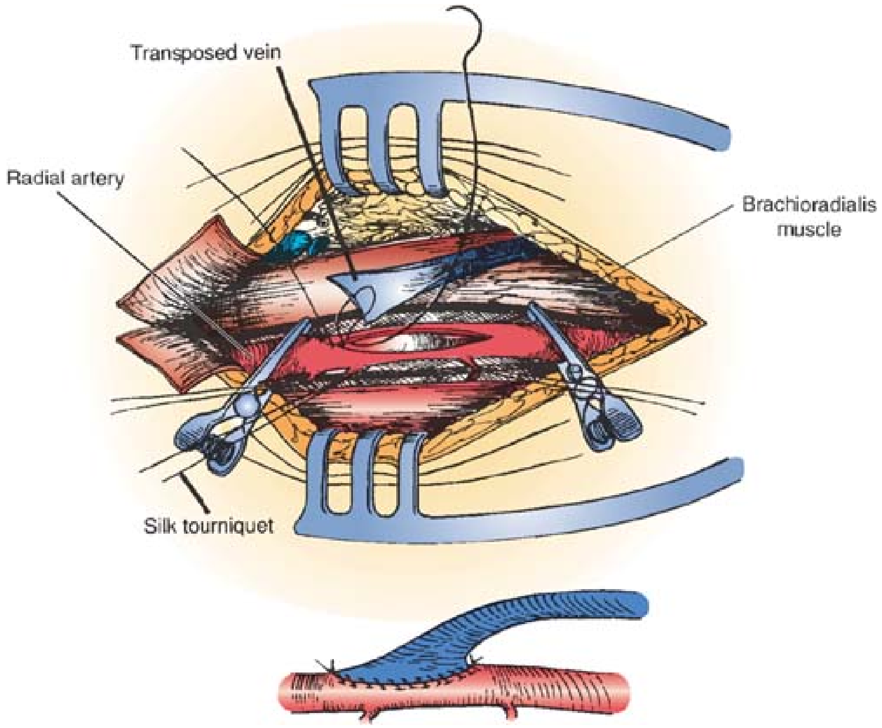

Figure 6.3-12. 12. Brescia-Cimino fistula (side-to-end anastomosis). (Reproduced with permission from Scott-Conner CEH, Dawson DL: *Operative Anatomy*, 2nd edition. Lippincott Williams & Wilkins, Philadelphia, 2003.)

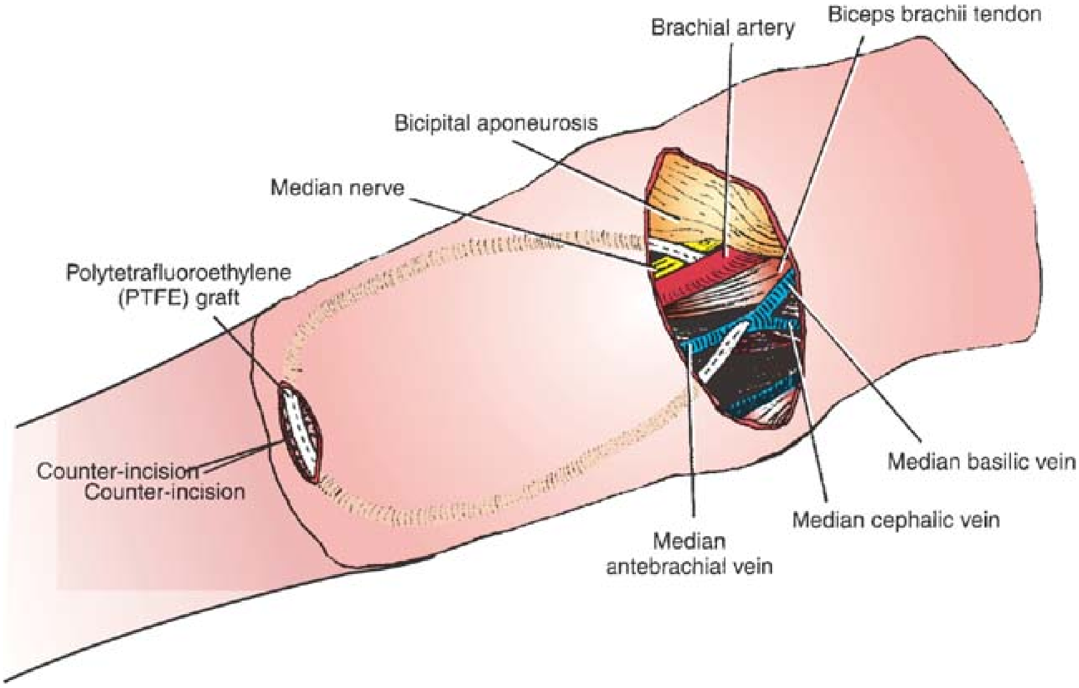

Figure 6.3-13. 13. In arteriovenous hemodialysis access with prosthetic graft, the brachial artery and the median antebrachial, median basilic, and median cephalic veins are exposed via a horizontal incision below the antecubital joint crease. (Reproduced with permission from Scott-Conner CEH, Dawson DL: *Operative Anatomy*, 2nd edition. Lippincott Williams & Wilkins, Philadelphia, 2003.)

Variant procedure or approaches: Loop or straight graft, using vascular substitute in forearm; **upper-arm straight graft**

Usual preop diagnosis: End-stage renal failure requiring graft hemodialysis

Summary of Procedures

	Forearm AV Fistula	Forearm Loop or Straight Graft	Upper-Arm Straight Graft
Position	Supine, arm abducted		
Incision	Longitudinal or transverse at wrist, or “snuff box”	Transverse at antecubital fossa and/or at wrist; counterincision in forearm	Transverse or longitudinal in upper arm
Special instrumentation	Arm/hand table (for arm abduction); Doppler flow probe may be used.		
Unique considerations	Local anesthesia; consider brachial plexus block (increased incidence of hematoma); heparinization		
Antibiotics	None	Vancomycin 1 g iv	
Surgical time	1–2 h		
Closing considerations	Use of Doppler to 3 shunt patency		
EBL	25–50 mL	25–100 mL	
Postop care	Hemodynamic monitoring for poor-risk patients; can be done as outpatient.		
Mortality	Minimal, depending on associated risk factors		
	Thrombosis: 20%	8–32%	8–32%

Morbidity	Technical failure: 10–15% Arterial steal: Rare Cardiac failure: Rare Infection: Rare No venous outflow: Rare Seroma: Rare Venous aneurysm: Rare Venous HTN: Rare	 10% 6%	 6%
Pain score	1	2	2

(Print pagebreak 439)

Patient Population Characteristics

Age range	Pediatric and adult population
Male:Female	1:1
Incidence	Hemodialysis access is one of the most commonly performed procedures by vascular surgeons.
Etiology	Glomerulonephritis; diabetes; HTN; pyelonephritis
Associated conditions	Diabetes mellitus; PVD/CAD

Anesthetic Considerations

See Anesthetic Considerations following Permanent Vascular Access, p. 441.

Suggested Readings

1. Allon M, Robbin ML: Increasing arteriovenous fistulas in hemodialysis patients: problems and solutions. *Kidney Int* 2002; 62:1109–24.

2. Khosla N, Ahya SN: Improving dialysis access management. *Semin Nephrol* 2002; 22:507–14.

3. Spergel LM, Ravani P Asif A, et al: Autogenous arteriovenous fistula options. *J Nephrol* 2007; 20(3):288–98.

Permanent Vascular Access

Surgical Considerations

Description: Silastic or plastic catheters are placed in patients who require venous access for chronic antibiotic therapy, TPN, chemotherapy, or hemodialysis. **Hickman, Broviac**, and **Groshong catheters** are made of silicone rubber or plastic with a cuff near the skin exit site, which (in theory) serves as a barrier to infection. Access is generally *(Print pagebreak 440)* achieved via subclavian, IJ, or femoral vein puncture. These catheters are available in various sizes and in single- or double-lumen configurations. Larger diameter (13 Fr) Hickman or **Permacath DL** catheters have been introduced for hemodialysis. **Mediport** and **Portacath devices** have a metallic or plastic reservoir connected to the catheters and are intended for complete subcutaneous implantation. These catheters are used in chronically ill patients, particularly those requiring chemotherapy. The implantable access ports have been associated with improved patient comfort and reduced infection rates. Long-term catheter survival is limited by infection. Removal and replacement of the catheter is the only way to eradicate the infection.

Variant procedure or approaches: Two major distinctions: Hickman/Broviac catheters (no reservoir) vs Mediport/Portacath catheters (subcutaneous with reservoir). Subclavian, IJ, or femoral vein puncture is selected, depending on vein status, previous operations, and patient comfort.

ISBN: 0-7817-6670-2 | 4th_Edition
Golianu, Brenda | Schmiesing, Clifford | Samuels, Stanley | Jaffe, Richard

Usual preop diagnosis: Chronic antibiotic therapy; TPN; chemotherapy; end-stage renal failure

Summary of Procedures

	Hickman/Broviac/Groshong	Mediport/Portacath
Position	Supine, slight Trendelenburg	
Incision	Puncture site (subclavian, IJ, or femoral vein); subcutaneous tunnel for passage of catheter. Alternative: cephalic or IJ vein cut-down to achieve access.	Puncture site (subclavian, IJ, or femoral vein); subcutaneous pocket for port. Alternative: cephalic or IJ vein cut-down to achieve access.
Special instrumentation	I.I. or fluoroscope	
Unique considerations	Local anesthesia; may need iv sedation; monitor for ectopy during placement.	
Antibiotics	Cefazolin 1 g iv	
Surgical time	30–90 min	45–90 min
EBL	10–25 mL	25–50 mL
Postop care	CXR in recovery room; may be outpatient.	
Mortality	Minimal	
Morbidity	Catheter thrombosis: 25% Skin exit site infection: 13% Poor flow: 10–13% Catheter sepsis: 5–8% Arterial puncture: 6% Local bleeding: 5% SVC thrombosis: 5% Catheter displacement: 3% Subclavian thrombosis: 2% Pneumothorax 1–2% Failed attempt: 1% Infection: 3–5/1,000 cath days	4% – 10–13% 2% 6% – 5% 3% 2% 1–2% 1% – Pocket hematoma: 2% Pocket infection: 3% Catheter leakage: 1%
Pain score	1	2

Patient Population Characteristics

Age range	Pediatrics and adults, 8–80 yr
Male:Female	1:1
Incidence	Depending on underlying disease
Etiology	Access for chemotherapy; infections; hemodialysis; chronic TPN
Associated conditions	Malignancy; chronic illness/infection; renal failure

(Print pagebreak 441)

Anesthetic Considerations for Vascular Access

(Procedures covered: arteriovenous access for hemodialysis; permanent vascular access)

Preoperative

The patient populations presenting for vascular access surgery are extremely diverse. Patients requiring vascular access for chemotherapy, TPN, and chronic antibiotic therapy frequently can be done with MAC (p. B-3). Also presenting for these procedures are end-stage renal failure patients who need arteriovenous access for hemodialysis (generally involving the upper extremity). These patients return to the OR frequently for revising or replacing of fistulas. They are often ASA III & IV patients who may require GA or an upper extremity block. Anesthetic considerations for the **chronic renal failure patient** are discussed below.

Respiratory	Pulmonary edema may be present from fluid overload. CHF and uremic pleuritis can occur. Pneumonia occurs more frequently in these patients due to depressed immune systems. Hemodialysis contributes to hypoxemia due to V/Q mismatch and hypoventilation. **Tests:** CXR; consider ABG.
Cardiovascular	Often have HTN related to hypervolemia and a disorder of the renin-antiogensin system. May have LVH 2° to HTN. Cardiomyopathy, pericarditis, and pericardial effusion occur with uremia. Hypervolemia and hypoalbuminemia can contribute to CHF. Uremic patients often have defective aortic and carotid body reflex arcs. Ejection murmurs are common. **Tests:** ECG; others as indicated from H&P.
Renal	A comprehensive preop evaluation should include an assessment of renal function and adequacy of recent dialysis therapy. Ascertaining the patient's usual and recent weights is useful. Dialysis is usually advisable shortly before anesthesia and surgery. The symptoms of uremia (Plt dysfunction, electrolyte/fluid abnormalities, CNS, and GI disturbances) improve with dialysis. If a transfusion is needed, it is best done during dialysis so intravascular volume can be controlled. **Tests:** Serum BUN; Cr. If patient produces urine, consider creatinine clearance, UA.
Hematologic	Chronic anemia with Hct ranging from 15–21 g/dL. Normochromic, normocytic anemia present 2° bone marrow depression, lack of erythropoietin, nutritional deficiency, and diminished red-cell survival time. Patients adjust to chronic anemia through ↑CO and ↑2,3-DPG levels. Accumulation of waste products inhibits Plt function. Defects do occur in the coagulation cascade, but PT and PTT are usually normal. **Tests:** CBC; Plt; PT; PTT
Gastrointestinal	Uremic patients commonly have hiccups, anorexia, N/V, and diarrhea. They are very prone to developing GI bleeds. Renal failure causes ↓ gastric emptying. Premedication with metoclopramide (10 mg po) and ranitidine (150 mg po) will ↓ gastric volume and pH.
Nervous system	CNS Sx of uremia range from malaise to Sz to coma. Fatigue and intellectual impairment commonly occur. Peripheral and autonomic neuropathies exist. Peripheral neuropathy presents as itching and paresthesia of the lower extremities. Autonomic dysfunction can cause postural ↓ BP. Document deficits carefully.
Endocrine	Diabetes frequently may be the cause of renal failure, with its attendant problems. **Tests:** Glucose
Immune system	Often impaired. Patients prone to sepsis. Hepatitis and HIV infections from blood products may exist.

Metabolic and biochemical	Accumulation of K^+ urea, parathyroid hormone (hypercalcemia), Mg, aluminum (neurotoxicity), acid metabolites, and phosphate occurs. Knowing hyperkalemia exists is of importance because of the potential for fatal cardiac dysrhythmias. Shift of the oxyhemoglobin curve to the right occurs due to the metabolic acidosis and ↑ 2,3-DPG (improves tissue oxygenation). Hyponatremia is a common electrolyte disturbance in chronic renal failure.
Premedication	If warranted, it is best to use light premedication with sedatives or opioids due to the possibility of exaggerated effects (p. B-1).

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Intraoperative

Anesthetic technique: GA, upper extremity block, or MAC.

Regional anesthesia: May be advantageous due to decreased number of drug effects. See section on upper extremity blocks (Anesthetic Considerations for Wrist Procedures, p. 914). If the patient was very recently dialyzed, there may be a residual heparin effect. Regional anesthesia is contraindicated if coagulopathy is present.

General anesthesia: The duration of action and elimination of many anesthetic drugs is altered in the patient with renal failure.

Induction	If general anesthesia is indicated, preferably LMA is used. Induction with propofol and low-dose fentanyl (25–50 mcg) is usually well-tolerated. In case of the need for intubation, succinylcholine is indicated if $K^+ < 5.5$ mEq/L. If succinylcholine is contraindicated, cisatracurium (0.1–0.2 mg/kg) is the alternative muscle relaxant of choice, since its elimination is not affected by renal failure. Etomidate (0.2–0.3 mg/kg) is preferred in case of preop hemodynamic instability.	
Maintenance	Inhalation anesthetics (isoflurane, sevoflurane) offer the advantage of not requiring renal elimination. Biotransformation may produce some inorganic fluoride (nephrotoxin); however, this is not an issue in dialysis patients. Opioids can produce an increased magnitude and duration of effect. Increased accumulation of morphine glucuronides → prolonged respiratory depression. Fentanyl and remifentanil are good choices, 2° rapid tissue redistribution (fentanyl) or rapid metabolism (remifentanil). Benzodiazepine dosage should be adjusted, since protein binding in renal insufficiency/failure is reduced.	
Emergence	Prolonged effect of anticholinesterases (e.g., neostigmine and edrophonium) effectively offsets prolongation of blockade. Other factors affecting reversal of nondepolarizers should be taken into account. These include acid-base status, depth of blockade, temperature and use of drugs such as diuretics or antibiotics, which can potentiate blockade.	
Blood and fluid requirements	IV: 18–20 ga × 1 NS @ 1–2 mL/kg/h	IV access may be difficult; avoid iv placement in operated arm. Minimize fluids in renal-failure patients.
Monitoring	Standard monitors (p. B-1)	Avoid BP cuff placement on operated arm.
Positioning	and pad pressure points. eyes.	
Complications	Local anesthetic toxicity	

Postoperative

Complications	Nerve damage Hematoma	These are rare complications of brachial plexus blocks.
Pain management	PO analgesics	

(Print pagebreak 443)

Suggested Readings

1. Bour ES, Weaver AS, Yang HC, et al: Experience with the double lumen Silastic catheter for hemoaccess. *Surg Gynecol Obstet* 1990; 171(1): 33–9.

2. Monk J: Hemodialysis catheters and ports. *Semin Nephrol* 2002; 22:211–20.

3. Murphy GJ, White SA, Nicholson ML: Vascular access for hemodialysis. *Br J Surg* 2000; 87:1300–15.

4. Silberman H, Berne TV, Escandon R: Prospective evaluation of a double-lumen subclavian dialysis catheter for acute vascular access. *Am Surg* 1992; 58:443–5.

Venous Surgery—Vein Stripping and Perforator Ligation

Surgical Considerations

Description: Chronic venous insufficiency results from static blood flow in the deep, superficial, and perforating veins of the lower extremities. Clinical manifestations include pathologic changes in the skin and subcutaneous tissues, such as pigmentation, dermatitis, induration, and ulceration around the lower portion of the leg. The condition is most commonly caused by defective venous valves and less often by obstruction to the venous return or impaired pumping action of the muscles in the leg. The disorder is sometimes the residual of previous iliofemoral thrombophlebitis. Varicose veins of the primary type, particularly those of long duration, are a common cause of chronic venous insufficiency of milder degrees. Most symptoms respond well to conservative management, which includes compression stockings, elevation of the extremity, and topical treatment of ulcerations. Failure of medical management is an indication for surgical intervention. Split-thickness skin grafting is indicated for large ulcers to accelerate healing and shorten hospitalization time. **Ligation of perforators** is best performed when the ulcer has completely healed. The classic approach of **Linton** is rarely used today. If the quality of the skin overlying the perforators prevents a direct approach, **subfascial ligation** of the perforators may be performed through a short, posterior midline incision. The incompetent greater or lesser saphenous veins are resected only if patency of the deep system is confirmed. Venous ulcers recur in 30% of patients after surgical therapy, and ulcerations persist for prolonged period in 15% of patients. Adjunctive procedures include: **valvuloplasty, vein transposition**, and **venous valve transplant.**

Alternative procedures: Minimally invasive radiofrequency techniques have been used successfully for ablation of varicose veins

Usual preop diagnosis: Chronic deep venous insufficiency

Summary of Procedures

Position	Supine
Incision	**Vein stripping:** longitudinal or oblique groin incision and transverse incision at medial malleolus; transverse incision over posterior lower leg for lesser saphenous vein stripping. **Perforator ligation:** longitudinal incision along medial aspect of tibia to posterior medial malleolus
Special instrumentation	Vein stripper
Antibiotics	If patient has an associated venous ulcer, preop antibiotics should be based on culture results; generally, cefazolin 1 g iv, if culture results are not available.
Surgical time	3 h
EBL	50–250 mL
Postop care	PACU → ward; antiembolism stockings and SCDs
Mortality	Minimal
Morbidity [5]	Persistence of nonhealing ulcer: 20–53%

Pain score	3

(Print pagebreak 444)

Patient Population Characteristics

Age range	Young adult–elderly (generally older adults, although present in younger patients as well)
Male:Female	1:2
Incidence	6–7 million people in the United States have adverse effects from chronic venous stasis; 500,000 have complications of leg ulceration.
Etiology	Chronic primary varicose veins; defective venous valves; impaired pumping action of muscles in leg; previous iliofemoral thrombophlebitis; obstruction of venous return
Associated conditions	Varicose veins; Hx of DVT/thrombophlebitis

Anesthetic Considerations

See Anesthetic Considerations following Varicose Vein Stripping, p. 446.

Suggested Readings

1. Roth SM: Endovenous radiofrequency ablation of superficial and perforator veins. *Surg Clin North Am* 2007; 87(5):1267–84.

2. See Suggested Readings for Venous Surgery—Thrombectomy or Vein Excision, p. 430.

Varicose Vein Stripping

Surgical Considerations

Description: In patients with primary varicose veins, no definite cause has been identified, although age, female sex, pregnancy, obesity, and positive family Hx are predisposing factors. The causes of secondary varicosity include incompetence or obstruction of the deep veins as a result of previous DVT, tumor, trauma, or congenital or acquired arteriovenous fistulas. Usual indications for operative therapy include aching, swelling, heaviness, cramps, itching, cosmesis, stasis dermatitis, pigmentation, burning, and ulcers. Surgical treatment is contraindicated in: pregnant patients; elderly patients who are considered high risk; and patients with arterial insufficiency of the lower extremities, lymphedema, skin infection, or coagulopathy.

There are two principal approaches: the **stab avulsion technique** and **high ligation and stripping**. With **stab avulsion**, the varicosities are marked preop. Small transverse or longitudinal incisions are made directly over these varicosities, which are dissected from the surrounding subcutaneous tissue (with undermining of the skin) and bluntly removed or avulsed. Firm pressure over the region being operated on will achieve hemostasis. After removal of all marked varicosities, sterile dressings are placed and a compression bandage wrapped around the affected leg. The patient is instructed to keep the leg elevated as much as possible while convalescing at home. The chief advantage of the stab avulsion technique is preservation of the saphenous vein when it is not directly involved with varicosities.

If there is valvular incompetence of the saphenous vein, the treatment of choice is **stripping** (**avulsion**) of the incompetent portion of the greater and lesser saphenous veins, together with avulsion of the superficial varicose veins of the thigh and calf. **High ligation and stripping** refers to the removal of the greater saphenous vein from the level of medial malleolus to the saphenofemoral junction. A small transverse incision is made at the level of the ankle and the saphenous vein is dissected free. A longitudinal or oblique incision at the groin permits isolation of the saphenous vein at the saphenofemoral junction. The greater saphenous vein is ligated proximally and distally. After a **venotomy**, *(Print pagebreak 445)* a plastic or metallic vein stripper is passed and the vein is removed or stripped in a distal-to-proximal fashion. Sterile dressings are applied, followed by a compressive dressing.

If all varicose veins are removed and the incompetent segment of the saphenous vein is stripped, 85% of the patients will have good-to-excellent results at late follow-up. These procedures can be performed with regional or GA.

Usual preop diagnosis: Varicose veins; symptoms of venous insufficiency; cosmetic considerations

Summary of Procedures

	Stab Avulsion Technique	High Ligation and Stripping
Position	Supine	
Incision	Varicosities marked preop; short stab incisions made and veins avulsed with small forceps.	Varicosities marked preop; small transverse incision over saphenous vein proximal to medial malleolus; proximal saphenous vein exposed via groin incisions and stripper passed.
Special instrumentation	None	Vein stripper
Unique considerations	May be facilitated by tourniquet.	
Antibiotics	None	
Surgical time	2–3 h	
Closing considerations	Leg compressed with elastic wrap	
EBL	50–250 mL	50–150 mL
Postop care	PACU → ward; support stockings	+ Elevate foot of bed 10°; short periods of ambulation.
Mortality	Minimal	
Morbidity	Recurrence: < 10% Hematoma: Rare Infection: Rare Lymph fistula: Rare Nerve injury: Rare Postop DVT: Rare Femoral artery injury: Nil	 5% Very rare
Pain score	2	2

Patient Population Characteristics

Age range	Wide range, young adult–elderly (average = 48 yr)
Male:Female	1:3
Incidence	24,000 in the United States.
Etiology	Primary varicose veins: no definite cause (Predisposing factors include age, female sex, pregnancy, obesity, and positive family Hx.) Secondary varicose veins: incompetence or obstruction of the deep veins from DVT, tumor, trauma, or high venous pressures due to congenital or acquired arteriovenous fistulas
Associated conditions	Older age; pregnancy; obesity; DVT; tumor; trauma

Anesthetic Considerations

(Procedures covered: vein stripping and perforator ligation; varicose vein stripping)

Preoperative

Patients presenting for varicose vein surgery are a generally healthy patient population (ASA I & II). Preop considerations and tests, therefore, should be guided by the H&P.

Hematologic	If regional anesthesia planned, check patient's coagulation status. **Tests:** Plt count; Hct
Laboratory	Tests as indicated from H&P.
Premedication	If necessary, standard premedication (p. B-1).

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Intraoperative

Anesthetic technique: General, regional, or local anesthesia, ± sedation, are all appropriate anesthetic techniques. Choice depends on factors such as extent of surgery, patient physical status, and patient and surgeon preference.

Regional anesthesia:

Spinal	**Single-shot vs continuous:** Patient in sitting or lateral decubitus position (operative site down) for placement of hyperbaric subarachnoid block. Doses of local anesthetic for T10-T12 level: 0.75% bupivacaine in 8% dextrose (7–10 mg); or 0.5% tetracaine in 5% dextrose (10–12 mg). For continuous spinal (multiorifice catheter), titrate local anesthetic to desired surgical level (T12). Large doses of hyperbaric local anesthetic should be avoided as they may cause postop cauda equina syndrome.
Epidural	Patient in sitting or lateral decubitus position for placement of epidural catheter. After locating the epidural space, administer a test dose (e.g., 3 mL of 1.5% lidocaine with 1:200,000 epinephrine) to elucidate whether the catheter is subarachnoid (rapid onset outer block) or intravascular (↑HR, tinnitis, etc.). Titrate local anesthetic until desired surgical level is obtained (3–5 mL at a time) usually < 15 mL.
Local	Requires gentle surgical technique. Surgical field block, plus ilioinguinal and iliohypogastric nerve blocks using 0.5% bupivacaine with 1:200,000 epinephrine. Usually done by surgeon.

General anesthesia:

Induction	LMA/mask vs ETT: Standard induction (p. B-2). LMA or mask GA may be suitable for many patients.
Maintenance	Standard maintenance (p. B-2)
Emergence	No special considerations
Blood and fluid requirements	Minimal blood loss IV: 18 ga × 1 NS/LR @ 5–8 mL/kg/h
Monitoring	Standard monitors (p. B-1)
Positioning	and pad pressure points. eyes.

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Postoperative

Complications	Cauda equina syndrome	The diagnosis of cauda equina syndrome (urinary and fecal incontinence, paresis of lower extremities, perineal hypoesthesias) should be sought in the postop period in patients who have received large doses of intrathecal local anesthetic during continuous spinal techniques. patients for bowel or bladder dysfunction and perineal sensory deficits. If present, consider a neurology consultation and continue followup of the patient's neurologic dysfunction.
	Urinary retention common with regional anesthesia	Patients with urinary retention may require intermittent catheterization until urinary function resumes.
Pain management	PO analgesics: Acetaminophen and codeine (Tylenol #3 1–2 tab q 4–6 h) Oxycodone and acetaminophen (Percocet 1 tab q 6 h)	Regional anesthesia should provide sufficient analgesia postop.

Suggested Readings

1. Hirsch SA, Dillavou E: Options in the management of varicose veins, 2008. *J Cardiovasc Surg (Torino)* 2008; 49(1):19–26.

2. Mackenzie RK, Paisley A, Allan PL, et al: The effect of long saphenous vein stripping on quality of life. *J Vasc Surg* 2002; 35:1197–1203.

3. Merchant RF, DePalma RG, Kabnick LS: Endovascular obliteration of saphenous reflux: A multicenter study. *J Vasc Surg* 2002; 35:1190–6.

4. Vloka JD, Hadzic A, Mulcare R, et al: Femoral and genitofemoral nerve blocks versus spinal anesthesia for outpatients undergoing long saphenous vein stripping surgery. *Anesth Analg* 1997; 84(4):749–52.