Anatomy and Surgical Exposure of the Vascular System

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A well-planned surgical exposure facilitates even the most difficult operative procedure. Awareness of the relationship of surface anatomy to underlying vascular structure allows precise incision placement. This minimizes tissue trauma and reduces the likelihood of wound infection. Detailed knowledge of vascular anatomy helps to prevent injury to vital structures in the operative field. In this chapter, anatomic relationships and variations that may be encountered during common vascular exposures are highlighted. Several alternate surgical approaches are also described. Sources given in the reference list supply the reader with additional detailed information.

Exposure of the carotid bifurcation is discussed first. This is followed by a systematic discussion of anatomy and surgical exposure of the peripheral vascular system ending with commonly used approaches for the arterial circulation in the leg and foot.

EXPOSURE OF THE CAROTID BIFURCATION

The common carotid artery bifurcates approximately 2.5 cm below the angle of the mandible. Normally, the sternocleidomastoid muscle, the posterior belly of the digastric muscle, and the omohyoid muscle bound the carotid bifurcation. Thus, a skin incision placed along the anterior border of the sternocleidomastoid muscle facilitates exposure of the carotid sheath.

The surgeon must be aware of the location of important cranial and somatic nerves during carotid endarterectomy. The mandibular ramus of the facial nerve is vulnerable to injury during this operation. Nerve damage by retraction or surgical dissection can cause temporary or permanent dysfunction. Turning the head toward the opposite side draws the mandibular ramus well below the mandible and increases the possibility of facial nerve injury.

The great auricular nerve (C-2 and C-3 dermatomes) should be protected in its location on the sternocleidomastoid muscle just anterior to and below the ear. Damage to this nerve results in numbness of the posterior aspect of the auricle and may cause distressing ipsilateral postoperative occipital headaches.

The common facial vein comes into view as the incision is deepened. This vessel courses superficial to the carotid bifurcation to join the internal jugular vein. It serves as an important landmark during the dissection. Several small vessels coursing toward the sternocleidomastoid muscle are nutrient branches from the superior thyroid artery and vein. These vessels should be ligated and divided to avoid troublesome postoperative bleeding. In the typical carotid dissection, the common carotid artery should be exposed above the level of the omohyoid muscle. Once this vessel is isolated, further distal dissection along its medial aspect facilitates exposure of the superior thyroid and external carotid arteries. Dissection in the “V” of the carotid bifurcation should be avoided because this area is extremely vascular. It is wise to encircle the internal carotid artery well above the level of gross atherosclerotic disease. This dissection is usually 1 to 2 cm above the bifurcation and thereby avoids the highly vascular carotid sinus tissue.

The descending branch of the hypoglossal nerve (ansa cervicalis) is located anterior and parallel to the sternocleidomastoid muscle. If this branch is followed upward, the main hypoglossal nerve trunk can be located. Division of the descending branch of the hypoglossal nerve near its origin allows the main nerve trunk to be displaced upward and forward, thus providing higher exposure of the internal carotid artery. A nutrient vein and artery to the sternocleidomastoid muscle course in immediate relation to this nerve at this level. Care should be taken to avoid injury to the underlying hypoglossal nerve when these vessels are ligated and divided. This maneuver allows the nerve to retract superomedially and out of harm’s way. Division of this artery/vein “sling” about the hypoglossal nerve facilitates exposure of the internal carotid artery under the posterior belly of the digastric muscle.

The surgeon must also be constantly aware of the loca-
tion of the vagus nerve and its branches. It lies within the carotid sheath between the common carotid artery and the internal jugular vein. Normally, it is directly behind the internal carotid artery at its origin. Care must be taken to prevent injury to the nerve at this vulnerable location. Additional care is required to prevent vagus nerve injury during redo carotid exposure. This is owing to the fact that in these cases the nerve, which can be encased in scar tissue, frequently courses anterior to the carotid bifurcation. The superior laryngeal nerve arises from the vagus nerve above the carotid bifurcation, passes behind the internal carotid artery, and descends medial to the superior thyroid artery. Care must be taken during mobilization of this vessel not to injure the superior laryngeal nerve or its external branch (Fig. 4–1). The external branch of the superior laryngeal nerve may sometimes pass between branches of the superior thyroid artery or be adherent to it. Table 4–1 lists the locations and tests for function of the important nerves encountered during carotid endarterectomy and includes special remarks about each.

An arteriotomy should be created just proximal to the carotid bulb and lateral to the carotid flow divider. This incision is then lengthened distally through the diseased internal carotid artery (ICA) under direct vision to a point at which there is normal-appearing intima. It is critical not to make this arteriotomy on the anterior aspect of the ICA near the carotid sinus because this is a relatively fixed area that is hard to reapproximate without creating a focal narrowing that is at risk for restenosis. It is wise to find the correct endarterectomy plane at the level of the carotid bulb. Thereafter, endarterectomy first proceeds proximally, and the specimen is excised sharply with Potts scissors at the level of the common carotid artery. Evert the external carotid artery into the carotid bulb facilitates endarterectomy at this level. Then, one must carefully find the plaque transition point between the atherosclerotic plaque to be removed and the remaining nondiseased ICA. This is the critical step in the performance of a technically sound carotid endarterectomy and, if done correctly, tacking sutures are rarely required. Meticulous care is then taken to ensure that no loose areas of media remain through the endarterectomized surface. In our practice, Dacron patch angioplasty reapproximates the arteriotomy, and intraoperative duplex ultrasound scanning completes the procedure. The reader is referred to Wylie's Atlas of Vascular Surgery for color illustrations of the steps in performing carotid endarterectomy.

The value of cranial nerve protection during carotid surgery is emphasized by the reports of Evans and coworkers and Hertzler and colleagues. The vagus nerve is the cranial nerve most commonly injured during carotid endarterectomy. Evans and associates prospectively studied the incidence of cranial nerve injury during carotid surgery. Observations were made by surgeons and by a speech pathologist before and after carotid endarterectomy. There was a 4% incidence of preoperative vagus nerve dysfunction when a surgeon made the evaluation. However, a 30% incidence of preoperative dysfunction of cranial nerve X was noted when the evaluation was made by a speech pathologist. Two days after the endarterectomy, the surgeon's evaluation demonstrated a 14.6% incidence of vagal nerve deficit, whereas the speech pathologist's evaluation reported a 35% incidence of superior laryngeal or recurrent nerve dysfunction.

These data support the wisdom of a thorough vocal cord evaluation before performing carotid endarterectomy because of the high incidence of unrecognized vagal nerve dysfunction. Examination of vocal cord function is of particular importance when reoperation is planned or when operating on the contralateral side soon after the first, at which time paresis of cord function may still persist.

**EXPOSURE OF THE HIGH INTERNAL CAROTID ARTERY**

One of the most difficult vascular surgical exposures is that of the high internal carotid artery. The surgeon must contend with many vital nerve structures within a confined space. This is frequently made more difficult by a space-occupying vascular lesion or the presence of vascular injury with hemorrhagic staining and displacement of the tissues. Structures that overlie the high internal carotid artery in the neck include the facial nerve, the parotid gland, the ramus of the mandible, and the mastoid and styloid processes. The hypoglossal nerve, glossopharyngeal nerve, digastric and stylohyoid muscles, and occipital and posterior auricular arteries cross it. The distal cervical internal carotid artery courses progressively deeper to enter the petrous canal of the temporal bone.

Exposure routinely begins at the level of the common carotid artery proximal to the carotid bifurcation. The omohyoid muscle serves as a landmark for the proximal extent of this exposure. The dissection continues distally, protecting the vagus nerve, which lies immediately behind the internal carotid artery. The hypoglossal nerve is exposed, and the descending branch is divided to displace the hypoglossal nerve forward. The digastric and stylohyoid muscles
## Table 4-1

### Regional Nerves Encountered During Carotid Endarterectomy

<table>
<thead>
<tr>
<th>NERVE BRANCH</th>
<th>LOCATION ENCOUNTERED</th>
<th>TEST FOR FUNCTION</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandibular ramus of facial nerve (cranial nerve VII)</td>
<td>Deep to platysma muscle; can be 5-10 mm below inferior margin of mandible</td>
<td>Ask patient to show teeth—check for paralysis of lower lip</td>
<td>Gentle use of retractors on mandible; nerve is pulled down when head is rotated to opposite side for operative exposure</td>
</tr>
<tr>
<td>Great auricular nerve (C-2 and C-3)</td>
<td>Anteromedial surface of SCM muscle anterior to and below ear</td>
<td>Anesthesia of ear and adjacent scalp</td>
<td>Causes disturbing occipital headache when damaged</td>
</tr>
<tr>
<td>Cutaneous cervical nerve (C-2 and C-3)</td>
<td>Subcutaneous on deep fascia</td>
<td>Anesthesia of skin below mandible</td>
<td>Should warn patient preoperatively regarding possible sensory loss</td>
</tr>
<tr>
<td>Glossopharyngeal nerve branch (cranial nerve IX)</td>
<td>Between external and internal carotid arteries (carotid sinus nerve, also known as &quot;nerve of Herring&quot;)</td>
<td>None</td>
<td>Manipulation of nerve may cause bradycardia and/or hypotension; atropine IV or local infiltration of nerve with lidocaine relieves circulatory changes</td>
</tr>
<tr>
<td>Vagus nerve (cranial nerve X)</td>
<td>Within carotid sheath, between internal jugular vein and common carotid artery; directly behind internal carotid artery</td>
<td>Indirect laryngoscopy for vocal cord function</td>
<td>Dissect “right on” distal common and internal carotid arteries and avoid “past pointing” with vascular occluding clamps</td>
</tr>
<tr>
<td>External branch of superior laryngeal nerve (branch of cranial nerve X)</td>
<td>Adjacent and medial to superior thyroid artery</td>
<td>Loss of function of cricothyroid muscle</td>
<td>Inability to reproduce high tones</td>
</tr>
<tr>
<td>Hypoglossal nerve (cranial nerve XII)</td>
<td>Main nerve trunk crosses the internal and external carotid arteries 1–2 cm above carotid bifurcation; SCM artery and vein branches sling around nerve</td>
<td>Extended tongue deviates to side of injured nerve</td>
<td>Visualize descending branch first and follow it to main nerve trunk; careful ligation of SCM muscular arterial and venous branches to preserve dry operative field</td>
</tr>
</tbody>
</table>

IV, intravenous; SCM, sternocleidomastoid.

are divided to facilitate this exposure. In addition, the styloid process and the stylohyoid ligament are excised. The glossopharyngeal and the superior laryngeal nerves must be identified and preserved. It becomes evident that one is now working in a progressively narrowing triangle with inadequate space for performing any major vascular reconstructive procedure.

Anatomic dissection in human cadaver specimens demonstrates that division of the posterior belly of the diastigmatic muscle facilitates exposure of the internal carotid artery to the middle of the first cervical vertebra. Anterior subluxation of the mandible improves exposure to the superior border of the first cervical vertebra. The addition of styloideotomy to the maneuvers described here extends the exposure cephalad approximately 0.5 cm.4

Fisher and associates5 described a unique technique of wire fixation of the mandible to hold its subluxed position during the operative procedure. The 12 to 15 mm of space obtained converts the triangle described earlier into a narrow rectangle (Fig. 4–2). It is important to avoid dislocation of the mandible, because serious injury can occur to the temporomandibular joint and even to the contralateral internal carotid artery. In the discussion of Fisher and associates’ paper, Stanley suggested that a towel clip placed on the angle of the mandible through two small stab incisions would allow the subluxation to be fixed by minimal retraction. Doss and associates6 also suggested that temporary mandibular subluxation can be accomplished in a safe and expeditious manner using diagonal interdental/Steinmann pin wiring. Figure 4–3 shows a diagram of the relationship of the mandibular condyle to the auricular eminence and infratemporal fossa.

In situations requiring more room for vascular reconstruction, transection of the mandibular ramus with either translocation or temporary removal of the condyle and ramus fragment affords wider exposure. Wylie and associates7 described this approach with detailed color illustrations of the involved anatomy.

Following induction of anesthesia, arch bars and wires immobilize the mandible. The usual carotid endarterectomy incision is extended posteriorly to a point behind the ear. The carotid bifurcation and internal carotid artery are exposed as described previously. The mandibular ramus of the facial nerve is protected. The angle of the mandible is exposed and the periosteum elevated toward the mandibular notch anteriorly and posteriorly. The mandibular ramus is divided vertically using a power saw posterior to the foramen of the inferior alveolar artery and nerve. The posterior bone fragment is gently rotated out and upward as the pterygoid muscles are divided, thus allowing its removal. The bone fragment is preserved in chilled lactated Ringer’s solution until it is replaced after arterial reconstruction.

Once the mandibular ramus is removed, the diastigmatic and stylohyoid muscles are divided and the dissection is continued to the skull base. Care should be taken to protect the hypoglossal, glossopharyngeal, and vagus nerves, which are in immediate relation to the high internal carotid artery.
The mandibular fragment is returned to its anatomic location after completion of internal carotid artery reconstruction and interrupted nonabsorbable sutures close the temporomandibular joint capsule. A thin titanium plate is used to fix the mandibular fragment in place. The cervical fascia and platysma muscle are closed in layers, followed by routine skin closure.

EXPOSURE OF AORTIC ARCH BRANCHES AND ASSOCIATED VEINS

The most widely accepted direct route employed for surgical exposure of the innominate and proximal left common carotid arteries, as well as the superior vena cava and its confluent brachiocephalic veins, is through a full median sternotomy. However, we have recently described a less invasive surgical exposure for the direct treatment of these aortic arch branch vessels and associated major veins. Similar to a median sternotomy, this surgical approach provides excellent exposure of the aortic arch branch vessels with the exception of the left subclavian artery. This is owing to the fact that the aortic arch passes obliquely posterior and to the left after its origin from the base of the heart, thus making the first portion of the left subclavian artery inaccessible from this anterior approach.

Mini-sternotomy is effected by first making a limited skin incision measuring 7 to 8 cm in the midline. This should extend from the sternal notch to just past the angle of Louis. The manubrium and upper sternum are divided in the midline down to the third intercostal space with a narrow blade mounted on a redo sternotomy oscillating saw (Stryker, Kalamazoo, MI). The sternum is then transected transversely at the third intercostal space, creating an upside down “T” incision (Fig. 4-4). Care is taken to not injure the internal mammary vessels, which are adjacent to the sternum. After accurate hemostasis along the periosteal edges, a Rienhoff or other similar pediatric sternal retractor is placed to open the upper sternum. The skin incision can be extended upward along the anterior border of either sternoclavdomastoid muscle, with division of the strap muscles to expose the proximal right common carotid artery or the more distal left common carotid artery. This extension can also be used to expose the carotid bifurcation.

The two lobes of the thymus gland are separated in the midline, and if the surgeon carefully observes the pleural bulge during positive pressure inspiration, entry into either pleural space can be avoided. Nutrient vessels to the thy-
mus gland are carefully ligated and divided, keeping a dry field for visibility. These vessels arise from the internal thoracic artery and drain into the internal thoracic or brachiocephalic veins. The upper pericardium is then opened vertically and the edges are sewn to the skin with silk suture.

The left brachiocephalic vein can be visualized in the upper portion of the wound. A thymic vein may join this vessel inferiorly, and an inferior thyroid vein may require ligation and division as it joins the brachiocephalic vein superiorly. After complete mobilization of the left brachiocephalic vein, the anterior surface of the aortic arch can be visualized, as well as the origin of the innominate artery. The base of the heart and the innominate and left common carotid arteries are thus exposed (Fig. 4–5). The recurrent laryngeal nerve must be protected during exposure of the innominate artery bifurcation. It courses from the vagus nerve anteriorly around the origin of the subclavian artery to return in the tracheoesophageal groove to its termination in the larynx.

Innominate and/or left common carotid artery endarterectomy, patch angioplasty, or bypass can then be performed in the usual fashion (Fig. 4–6). After the procedure, a 19 French Blake drain (Johnson & Johnson, Cincinnati, Oh)
is placed in the mediastinum and brought out laterally through one of the intercostal spaces. This is connected to a Heimlich valve grenade suction device. Chest tubes are not used. Two wires are used to bring the upper and lower sternal edges of the "T" together and two more are placed in the manubrium. If needed, another wire placed as a "figure-of-eight" at the level of the second intercostal space completely rejoins the divided upper sternum. After approximating the muscular and subcutaneous planes in two layers, the skin is closed in a subcuticular fashion.

**Origin of the Right Subclavian Artery and Vein**

The origin of the right subclavian artery is exposed through a sternotomy incision with extension above and parallel to the clavicle. The right sternohyoid and sternothyroid muscles are divided, followed by exposure of the scalene fat pad. Branches of the thyrocervical trunk are divided and the dissection is deepened to expose the anterior scalene muscle. The phrenic nerve should be identified and protected as it courses from lateral to medial across the surface of the anterior scalene muscle to pass into the superior mediastinum. The proximal right subclavian artery comes into view with division of the anterior scalene muscle just above its insertion on the first rib.

Traumatic vascular injury at the confluence of the subclavian artery and internal jugular and subclavian veins is difficult to manage solely through a supraclavicular approach. Ideally, sternotomy for proximal vascular control should be followed by supraclavicular extension of the incision. However, in the event that the injury is exposed without proximal control, the incision should be promptly extended via a sternotomy while an assistant maintains compression of the vessels against the undersurface of the sternum to temporarily control hemorrhage (Fig. 4–7). Alternatively, temporary percutaneous balloon occlusion of the distal innominate artery from a femoral artery approach can be life saving and greatly facilitate this exposure.

**Origin of the Left Subclavian Artery**

The left subclavian artery arises from the aortic arch posteriorly and from the left side of the mediastinum. Therefore, it cannot be adequately exposed for vascular reconstruction through a sternotomy incision. Traumatic injuries and aneurysms of the proximal left subclavian artery should be approached through the left side of the chest. The preferred exposure is an anterolateral thoracotomy through the fourth intercostal space or the bed of the resected fourth rib.

If the vascular injury or aneurysm is extensive, it is wise to prepare the left upper extremity for inclusion in the operative field so that it can be positioned for a second supraclavicular incision. This allows ready access to the second portion of the subclavian artery to gain distal vascular control. Anterolateral exposure of the left side of the chest also facilitates partial occlusion of the aortic arch for lesions involving the origin of the subclavian artery. The phrenic and vagus nerves must be identified and preserved after the pleura is opened and before the dissection of the first portion of the subclavian artery.

![Figure 4–7. Exposure of the anterior aortic arch branches through a median sternotomy incision. Note the location of the phrenic, vagus, and recurrent laryngeal nerves, which must be identified and protected. Ao, Aorta. (From Ernst C: Exposure of the subclavian arteries. Semin Vasc Surg 2:202, 1989.)](image-url)
In situations in which there is exigent bleeding into the pleural space from a traumatic injury of the proximal left subclavian artery, prompt vascular control can be obtained by an anterior thoracotomy in the third or fourth intercostal space. This exposure facilitates placement of a vascular clamp across the origin of the bleeding subclavian artery (Fig. 4–8). An inframammary incision is preferred in females, with the breast mobilized superiorly for the exposure just described.

Subclavian and Vertebral Arteries

Exposure of the second portion of the subclavian artery is accomplished through a supraclavicular incision beginning over the tendon of the sternocleidomastoid muscle and extending laterally for 8 to 10 cm. The platysma muscle is divided and the scalene fat pad mobilized superolaterally. Thyrocervical vessels are ligated and divided as encountered, with exposure of the anterior surface of the anterior scalene muscle. The phrenic nerve can be seen coursing in a lateral to medial direction over this muscle and should be gently mobilized and preserved. The thoracic duct must also be protected at its termination with the confluence of the internal jugular, brachiocephalic, and subclavian veins. Unrecognized injury may result in a lymphocele or lympho-cutaneous fistula.

The anterior scalene muscle is divided just above its point of insertion on the first rib to facilitate exposure of the subclavian artery. Division of this muscle should be done under direct vision and without cautery as the brachial plexus is immediately adjacent to the lateral aspect of the anterior scalene muscle. The origin of the left vertebral artery arises from the medial surface of the subclavian artery medial to the anterior scalene muscle and behind the sternoclavicular joint. The internal thoracic artery, which originates from the inferior surface of the subclavian artery opposite the thyrocervical trunk, should be protected as the subclavian artery is dissected free of surrounding tissue. Figure 4–9 depicts the essential anatomy of this exposure.

Resection of subclavian artery aneurysms and emergency exposure for vascular injury involving the second and third portions of this vessel require wide exposure. This can be accomplished by resecting the clavicle, including the periosteum. The latter structure, when preserved, results in reossification of a deformed clavicle.

The surgical exposure of the vertebral artery is described in detail in Chapter 32 of this text and in the surgical literature. Injuries to the intrasosseous portion of the vertebral artery with associated hemorrhage are best managed by embolic occlusion proximal and, if possible, distal to the area of injury.

AXILLARY ARTERY EXPOSURE

The proximal axillary artery is exposed by a short incision made between the clavicular and sternal portions of the pectoralis major muscle. Branches of the thoracoacromial vessels are divided to expose the axillary vein first and then the axillary artery above and posterior to the vein. Dissection medial to the pectoralis minor muscle provides appropriate exposure of the axillary artery for axillofemoral bypass graft origin. If additional exposure is required laterally, a portion of the pectoralis minor muscle can be divided near its insertion into the coracoid process of the scapula.

The second portion of the axillary artery is more difficult to expose because it lies directly behind the pectoralis major muscle. Extension of the previously mentioned incision continues across the distal portion of the pectoralis major muscle at the anterior axillary fold and out onto the midline of the proximal medial surface of the arm (Fig. 4–10). The tenuous portion of the muscle is divided near its insertion to expose the axillary contents. The pectoralis
minor muscle can also be divided if more medial exposure is desired.

**THORACIC OUTLET EXPOSURE**

Either a supraclavicular or a transaxillary approach facilitates decompression of the thoracic outlet. Roos has described the transaxillary approach for first rib resection in the management of thoracic outlet syndrome.\(^9\) However, evolution of thought regarding thoracic outlet syndrome has led us to favor supraclavicular exposure of the superior thoracic aperture. Essential anatomic elements of this approach have been detailed in Wylie's *Atlas of Vascular Surgery*.\(^{10}\)

A transverse supraclavicular incision based 1.5 cm above the medial half of the clavicle is deepened to develop subplatysmal flaps and to expose the scalene fat pad. Reflection of the fat pad superolaterally facilitates exposure of the anterior scalene muscle. This exposure also requires ligation and division of the transverse cervical artery and vein and resection of the omohyoid muscle.

Identification and careful manipulation of the phrenic nerve are essential to avoid excessive traction or injury. Complete removal of the anterior scalene muscle begins at the level of the first rib and ends at the transverse processes of the cervical vertebrae. Subtotal removal of the scalenus medius muscle in a plane parallel and just inferior to the long thoracic nerve exposes all five roots and three trunks of the brachial plexus.

This unencumbered exposure of the brachial plexus facilitates neurolysis and complete mobilization of the nerve roots. Additional myofibrous bands or bony anomalies are removed at this time. If the course of the lower trunk and C-8 to T-1 nerve roots are deviated by the first rib, the rib should be partially or totally removed to free the path.

Incision of Sibson's fascia and displacement of the dome of the pleura inferiorly help to fully expose the inner aspect of the first rib. Gentle anteromedial retraction of the plexus ensures adequate posterior division of the first rib. Anteriorly, the rib is transected distal to the scalene tubercle. A counterincision just below the clavicle can be used to facilitate anterior transection of the first rib. This approach is useful for rib resection in association with axillosubclavian vein thrombosis. Final removal of the first rib requires division of intercostal muscle attachments to the second rib and division of any other soft tissue.

The scalene fat pad can be wrapped around the plexus if split in a sagittal plane. Repositioning of the fat pad decreases dead spaces and may help to prevent incorporation of the brachial plexus into the healing scar tissue. The wound is closed in layers after secure hemostasis and reapproximation of the sternocleidomastoid muscle.

**EXPOSURE OF THE DESCENDING THORACIC AND PROXIMAL ABDOMINAL AORTA**

No single approach lends itself so well to extensive exposure of the thoracic and abdominal aorta as a properly
intercostal or proximal lumbar artery until the aorta has been opened so that an assessment of arterial back-bleeding can be made under direct vision.

Closure of this extensive aortic exposure begins by reapproximating the diaphragm with 2-0 Prolene suture. A posterior (No. 28 French or No. 32 French) chest tube is placed under direct vision, and the ribs are then reapproximated with interrupted No. 1 Vicryl suture. Occasionally, a segment of the cartilaginous costal arch is excised to provide stable rib approximation. Thoracic musculature is reapproximated in layers with 1-0 Vicryl suture. In the abdomen, the posterior rectus sheath is reapproximated and then the anterior rectus sheath is closed with a running No. 1 PDS suture. Finally, skin is reapproximated with a running 3-0 subcuticular suture.

**RETROPERITONEAL EXPOSURE OF THE ABDOMINAL AORTA AND ITS BRANCHES**

Transperitoneal aortic exposure is generally regarded as the standard operative approach to the abdominal aorta. However, retroperitoneal aortic exposure has gained wider acceptance among vascular surgeons because it affords a more direct route to the aorta and facilitates complex aortic reconstruction above the level of the renal arteries. We and others have demonstrated that in comparison to transperitoneal aortic exposure, the retroperitoneal approach is associated with decreased perioperative morbidity, earlier return of bowel function, fewer respiratory complications, decreased intensive care and hospital stay, and lower overall cost.14-16

For this aortic exposure, the patient is positioned on the operating table with the kidney rest at waist level. After pulmonary artery and radial arterial line placement and tracheal intubation, the patient is turned to the right lateral decubitus position, with the pelvis rotated posteriorly to allow exposure of both groins. The kidney rest is elevated and the operating table gently flexed to open the space between the left anterior superior iliac spine and the costal margin (Fig. 4-14). The free left upper extremity is positioned as described earlier.

The incision begins over the lateral border of the rectus muscle approximately 2 cm below the level of the umbilicus and is carried laterally over the tip of the 12th rib. This decreases the chance of injury to the main trunk of the intercostal nerve within the 11th intercostal space. In males, resection of a significant portion of this rib facilitates retroperitoneal aortic exposure. However, in females, 12th rib resection is not always required. The anterior rectus sheath is opened to allow transection of the left rectus abdominis muscle. Inferior epigastric vessels are divided between silk ligatures to avoid troublesome postoperative bleeding. The incision is carried laterally through the external and internal oblique muscle fibers. Careful incision of the most lateral aspect of the posterior rectus sheath facilitates development of an extraperitoneal plane. The remaining posterior sheath is divided toward the midline, and, laterally, transversus abdominis muscle fibers are split toward the 12th rib.

The peritoneum is gently swept off the posterior rectus sheath, the transversus abdominis fibers, and the diaphragm to allow safe entry into the left retroperitoneal space. This space is best entered laterally. The peritoneum and its contents are swept medially off the psoas muscle toward the diaphragm along with Gerota's fascia with the contained left kidney. With careful manual control of the left kidney/peritoneal contents and countertraction upward


**Figure 4-13.**

![Positioning for exposure of the retroperitoneal aorta. Top, Flexion of table increases exposure. Bottom left, The hips are positioned at a 45-degree angle with the table, and the left arm is passed across the chest. Bottom right, The position unwinds the torso for greater exposure. Incisions for exposure of the right iliac and common femoral arteries are shown in the bottom left. (From Shepard A, Scott G, Mackey W, et al: Retroperitoneal approach to high-risk abdominal aortic aneurysms. Arch Surg 126:137, 1973.)](image-url)

**Figure 4-14.**
positioned thoracoabdominal incision. After pulmonary artery and radial arterial line placement and dual-lumen tracheal intubation, the patient is placed in a modified right lateral decubitus position, with the hips rotated 45 degrees from horizontal. This allows exposure of both groins. A beanbag device is helpful to support the patient’s position on the operating table. The free left upper extremity should be passed across the upper chest and supported on a cushioned Mayo stand. In this way, thoracoabdominal aortic exposure is gained by unwinding the torso as described by Stoney and Wylie.\textsuperscript{12}

The rib interspace to enter depends primarily on the extent of thoracic aorta to be exposed. The fourth or fifth intercostal space is used when the entire thoracoabdominal aorta from subclavian artery origin through abdominal aorta is to be exposed, whereas the seventh or eighth intercostal space allows mid- to terminal thoracic aortic exposure plus wide abdominal aortic visualization. Dividing the respective lower rib posteriorly facilitates this exposure. On occasion, two interspaces (for instance, fourth and ninth) may be entered under one thoracoabdominal incision to facilitate proximal descending thoracic and abdominal aortic exposure. The thoracic incision is continued across the costal margin in a paramedian plane to the level of the umbilicus (Fig. 4–11). If the terminal aorta and iliac vessels are to be exposed, the incision is extended to the left lower quadrant.

With the left lung deflated, the origin of the left subclavian artery and proximal descending thoracic aorta can be gently dissected free of surrounding tissue to facilitate cross-clamping. The vagus and recurrent laryngeal nerves are densely adherent to the aorta just proximal to the subclavian artery. Meticulous care should be taken not to injure these structures. Division of the inferior pulmonary ligament exposes the middle and distal descending thoracic aorta. The diaphragm is radially incised toward the aortic hiatus, and the left diaphragmatic crus is divided to expose the terminal descending thoracic aorta. Alternatively, just the central tendinous portion of the diaphragm can be divided, or it can be incised circumferentially at a distance of approximately 2.5 cm from the chest wall.

The left retroperitoneal space is developed in a retroperitoneal extraperitoneal plane because surgical exposure of the thoracoabdominal aorta is greatly facilitated by forward mobilization of the left kidney. Division of the median arcuate ligament and lumbar tributary to the left renal vein allows further medial rotation of abdominal viscera and left kidney. Clearing the posterolateral surface of the thoracoabdominal aorta facilitates aortotomy. With this exposure, the origins of the left renal, celiac, and superior mesenteric arteries can then be visualized and dissected free as indicated by the disease process present (Fig. 4–12).

Preservation of the blood supply to the spinal cord is critical in this extensive operation. Brockstein and associates\textsuperscript{13} have stressed the importance of the arteria radicularis magna (artery of Adamkiewicz) in providing circulation to the anterior spinal artery (Fig. 4–13). This vessel is a branch of either a distal intercostal or a proximal lumbar artery. It has been identified as proximal as T-5 and as distal as L-4.\textsuperscript{13} However, the artery generally arises at the T-8 to L-1 level. Therefore, it is unwise to ligate any large

**Figure 4-11.** Incision options for thoracoabdominal aortic procedures are based on extent of thoracic aorta to be exposed and desire to stay in an extraperitoneal plane. (From Rutherford RB: Thoracoabdominal aortic exposures. In Rutherford RB [ed]: Atlas of Vascular Surgery: Basic Techniques and Exposures. Philadelphia, WB Saunders, 1963, p 233.)

**Figure 4-12.** Thoracoabdominal aortic exposure from the origin of the left subclavian artery to the common iliac arteries. (From Rutherford RB: Thoracoabdominal aortic exposures. In Rutherford RB [ed]: Atlas of Vascular Surgery: Basic Techniques and Exposures. Philadelphia, WB Saunders, 1963, p 233.)
on the diaphragm, further medial rotation of the left kidney and viscera allows exposure of the aorta from the left diaphragmatic crus to its bifurcation. The Omni-Tract retraction system (Omni-Tract Surgical, Minneapolis, Minn) is critical for maintaining this exposure.

The left renal artery is readily identified and serves as the main landmark for suprarenal as well as infrarenal aortic exposure (Fig. 4-15). Just above this level, division of the median arcuate ligament and left diaphragmatic crus facilitates exposure of the suprarenal aorta (Fig. 4-16). The celiac and superior mesenteric arteries can be dissected free for a significant length after careful incision of the enveloping neural tissue that surrounds both vessels. The distal thoracic aorta is readily accessible if the dissection is carried proximally between the crura and in an extrapleural plane. This extended exposure facilitates repair of suprarenal aortic disease and transaortic renal or mesenteric endarterectomy as well as antegrade bypass to these vessels.

**Visceral and Renal Artery Exposure**

This left flank approach is ideal for visceral and renal artery exposure. The celiac artery and proximal aspects of its major branches are readily accessible. In addition, the splenic artery can easily be mobilized off the posterior aspect of the pancreas to facilitate extra-anatomic splenorenal bypass. Hepatorenal bypass requires a right retroperito-

![Figure 4-15. Left renal artery serves as landmark for this dissection. Note iliacomum venous tributary just distal to the left renal artery. (From Rutherford RB: Thoracoabdominal aortic exposures. In Rutherford RB [ed]: Atlas of Vascular Surgery: Basic Techniques and Exposures. Philadelphia, WB Saunders, 1995, p 201.)](image)

![Figure 4-16. Division of the median arcuate ligament and left diaphragmatic crus facilitates suprarenal and suprarenal exposure. (From Rutherford RB: Thoracoabdominal aortic exposures. In Rutherford RB [ed]: Atlas of Vascular Surgery: Basic Techniques and Exposures. Philadelphia, WB Saunders, 1995, p 207.)](image)

neal approach. There are no major branches that emanate from the superior mesenteric artery for a distance of up to 5 cm distal to its origin. Therefore, bypass or endarterectomy of the superior mesenteric artery well beyond its orifice is possible without ever entering the peritoneal space. The first major branch is usually the middle colic artery, which arises from the anterior and right lateral surface of the superior mesenteric artery as it emerges from the pancreas. This branch is the usual site for an embolus to lodge. It is important to remember that in addition to a possible replaced right hepatic artery, the common hepatic artery occasionally arises from the superior mesenteric artery. In both circumstances, the replaced artery arises from the proximal aspect of the superior mesenteric artery just past its origin and courses back toward the right upper quadrant.

Dissection at the origin of the left renal artery and along the posterolateral aspect of the infrarenal aorta exposes the large communicating vein connecting the renal to the hemiazygous vein. Once this venous tributary (often two tributaries are encountered) is divided, the left renal vein can be elevated off the infrarenal aorta to facilitate cross-clamping. This maneuver facilitates right renal artery exposure as the origin of this vessel comes into view with suprolateral retraction of the left renal vein. This retroperitoneal surgical exposure also allows dissection of either renal artery to its branch vessels in preparation for endarterectomy or bypass.

In order to carry out transaortic renal endarterectomy with direct visualization of a clean end point, it is necessary to dissect the renal arteries well beyond their respective origins. In addition, the segment of aorta to be isolated must be completely mobilized with control of any adjacent lumbar arteries. This eliminates troublesome back-bleeding that can obscure vision after creation of an aortotomy. Proximal exposure of the suprarenal aorta should include
at least the origin of the superior mesenteric artery so that an aortic clamp can be placed above this level. This is necessary if there is little distance between the origins of the renal arteries and mesenteric vessels. Transaortic endarterectomy is accomplished either by transecting the aorta below the level of the renal arteries or by making a longitudinal aortotomy posterolateral to the left renal artery and/or superior mesenteric artery. Aortotomy can also be carried to the suprarenal aorta to facilitate visceral endarterectomy. Any of these visceral vessels can also be transected well beyond the disease process to facilitate direct end-to-end bypass. The ability to extensively mobilize the renal and mesenteric arteries is a major advantage of this retroperitoneal surgical exposure.

The inferior mesenteric artery is the primary blood supply to the left colon and is located by carrying the infrarenal dissection inferiorly along the posterolateral aspect of the aorta. In some large aneurysms, the thickened wall of the aorta obscures the actual origin of the inferior mesenteric artery. Division of this mesenteric vessel flush with the aorta is generally well tolerated. However, its inadvertent division distal to the left colic branch may result in sigmoid colon infarction. This complication is much more likely to occur when there is arteriosclerotic occlusion of the marginal artery of Drummond. In patients with visceral artery occlusive disease, the left colic artery communicates with the left branch of the middle colic artery to become the meandering mesenteric artery (also known as the central anastomotic artery). This artery provides collateral circulation between the superior and inferior mesenteric arteries and vice versa (Fig. 4-17).

Beyond the pelvic brim, the left common and external iliac arteries are readily accessible for vascular control. Ligating and dividing the inferior mesenteric artery flush with the aorta facilitates exposure of the distal anterolateral surface of the infrarenal aorta and the right common and external iliac arteries. It is wise to remember that the common iliac veins and vena cava are densely adherent to the posteromedial aspect of the left common iliac artery and the posterolateral aspect of the right common iliac artery. Vascular control of these vessels is safest after gently elevating them off their respective underlying major vein. This maneuver also facilitates transection of the distal common iliac artery under direct vision so that end-to-end aortoiliac reconstruction can be accomplished. If the iliac anastomosis cannot be performed at this level, it is wise to graft end to end to the internal iliac artery and then jump a separate graft to the external iliac artery. With this graft configuration, even an aneurysmal internal iliac artery may be simultaneously excluded (by opening it) and bypassed to the level of its first branch vessel. This helps to maintain vital pelvic perfusion.

Wound closure is accomplished in layers using No. 1 Vicryl suture for the posterior rectus sheath, transversalis fascia, transversus abdominis, and internal oblique muscle layers. The anterior rectus sheath and external oblique aponeurosis are closed with No. 1 PDS suture. Subcuticular skin closure with 3-0 Vicryl suture completes this multilayer wound closure.

**ALTERNATE RENAL ARTERY EXPOSURE**

The distal right renal artery can be exposed through a right-sided flank incision, which is a “mirror image” of the incision described in the section on retroperitoneal exposure of the aorta. With the patient on the operating table in a modified left lateral decubitus position, the retroperitoneal space is entered laterally after division of the abdominal wall muscles. The peritoneum and contents are gently mobilized anteriorly and medially, including the right kidney enclosed in Gerota's fascia. The renal artery is palpated distally and carefully dissected free of surrounding tissue. The inferior vena cava is also identified and mobilized after ligation of two or three paired lumbar veins. The vena cava can be gently elevated to expose the right posterolateral aspect of the aorta. Partial aortic occlusion with a side-biting vascular clamp is employed for anastomosis of the proximal bypass graft. Thereafter, a distal end-to-end anastomosis completes renal artery revascularization.

An extra-anatomic revascularization procedure for the right kidney is described by Moncure and associates. This exposure employs a right subcostal incision extending into the right flank. The hepatic flexure of the colon is mobilized and rotated to the left. The duodenum is Kocherized toward the midline to expose the right kidney. The renal artery is located behind and just above the right renal vein. Next, the hepatic artery is palpated in the hepatoduodenal ligament and the gastroduodenal artery identified. The common hepatic artery proximal to the gastroduodenal artery is dissected free. An end-to-side anastomosis of the bypass graft to the hepatic artery is constructed first. The bypass graft is then routed over the hepatoduodenal ligament and anastomosed to the transected end of the renal artery to revascularize the kidney. Figure 4-18 demon-

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**Figure 4-17.** Angiogram from a patient with occlusion of the celiac and superior mesenteric arteries. Note the large inferior mesenteric artery with a central anastomotic artery (arrow) and a large marginal artery (lateral position) providing collateral circulation.
Figure 4-18. Illustration of hepatic-to-right renal artery bypass. The duodenum is Kocherized (open arrow) for exposure. The reverse saphenous vein bypass is identified (solid arrow). Note the retraction of the right renal vein for exposure.

strates the essential anatomy and a side-to-side distal anastomosis. However, end-to-end reconstruction is easier to accomplish.

The left renal artery can be exposed peripherally for extra-anatomic bypass by using the same incision described earlier in this section for retroperitoneal exposure of the abdominal aorta. Once the pararenal aorta is exposed, the tail of the pancreas is separated from the left adrenal gland to expose the splenic artery for bypass to the left renal artery (Fig. 4-19). Infow can also be obtained from the aorta proximal or distal to the renal artery. This bypass can originate from the side of the aorta with destination to the transected left renal artery.

**ALTERNATE EXPOSURE OF THE ABDOMINAL AORTA AND ITS BRANCHES**

A helpful modification of the standard midline abdominal incision that can be used to expose the proximal abdominal

Figure 4-19. Flank exposure of the left renal artery. See text for details.
aorta without entering the chest is illustrated in Figure 4-20. An inverted hockey-stick incision is employed beginning at the left midcostal margin. The left rectus muscle is transected and the oblique and transversus muscles are divided in the direction of the skin incision. The incision is continued down the lines alba to the symphysis pubis. The left side of the colon is mobilized by incising the peritoneum along the white line of Toldt from the pelvis to the lateral peritoneal attachments of the spleen. The spleen is gently mobilized and brought forward toward the midline by incising the splenorenal and splenophrenic ligaments.

Dissection is continued by forward mobilization of the spleen, pancreatic tail, and splenic flexure of the colon between the mesocolon and Gerota's fascia, with care not to damage the adrenal gland medially or the adrenal vein at its junction with the left renal vein. This left-to-right transperitoneal medial visceral rotation affords excellent exposure of the supraceliac and visceral aorta, including the renal arteries (Fig. 4-21). This exposure is facilitated by forward displacement of the left kidney along with the rest of the mobilized viscera. Division of the median arcuate ligament and diaphragmatic crura exposes the distal thoracic aorta without entering the left chest.

**TRANSPERITONEAL EXPOSURE OF THE ABDOMINAL AORTA AT THE DIAPHRAGMATIC HIATUS**

Exposure of the supraceliac aorta at the diaphragmatic hiatus is life saving for early control of exsanguinating hemorrhage in the case of a ruptured abdominal aortic aneurysm. It is also useful for temporary control of the aorta during repair of aortocaval or aortoenteric fistulas and infected aortic grafts. Less frequently, this exposure is suitable for revascularization of the celiac trunk and its proximal branches or the superior mesenteric artery.

![Figure 4-20. Modified abdominal incision for greater left upper quadrant exposure during transperitoneal medial visceral rotation. (From Despartine MK, Ballard JL: Correspondence re: "Transperitoneal medial visceral rotation." Ann Vasc Surg 6:607, 1995.)](image)

This exposure through the lesser sac is facilitated by downward retraction of the stomach and lateral retraction of the esophagus. The aortic pulse is palpated, and the arching fibers of the diaphragm at the aortic hiatus are divided directly over the aorta. The periaortic fascia is opened and the index and middle fingers are passed medially and laterally to the aorta. Gentle blunt finger dissection between the diaphragmatic fibers and the aorta creates space on either side of the aorta. This maneuver is critical, because any overriding muscle fibers would allow a vascular occluding clamp to slide up and off the aorta. No effort is made to completely encircle the aorta because an intercostal or proximal lumbar artery or vein can be avulsed with troublesome bleeding. At this point, a partially opened aortic clamp is advanced over the dorsal hand and fingers that have been appropriately positioned to cross-clamp the aorta and interrupt blood flow. This exposure is illustrated in Figure 4-22.

Celiac artery reconstruction requires more exposure. A generous incision is made in the posterior parietal peritoneum, and the diaphragmatic crura are completely divided. The inferior phrenic arteries should be isolated, ligated, and divided. The aortic branch to the left adrenal gland is also usually visualized and sacrificed. Dissection is continued distally to expose the celiac artery, which can be palpated at its origin from the anterior surface of the aorta. Dense fibers of the median arcuate ligament are divided along with the neural elements forming the celiac plexus. This tissue is quite vascular; thus, stick ties and cautery are useful for hemostasis. Once the celiac trunk has been exposed, the common hepatic artery is dissected free of surrounding tissue as it courses toward the liver hilum. Sympathetic nerve fibers can be seen to entwine on the surface of this vessel. There is usually a 3- to 4-cm segment of the hepatic artery that is free of branches and therefore
useful as a site for vascular anastomosis. The splenic artery is palpable at the superior border of the pancreas and courses to the left toward the splenic hilum. Here, again, there is a 4- to 5-cm segment free of branches that can be used for placement of a vascular anastomosis. The left gastric artery is the smallest of the three main branches of the celiac artery. It courses anteriorly to follow the lesser curvature of the stomach and should be protected during this exposure.

The supraceliac aorta can also be used as the bypass origin for superior mesenteric artery reconstruction. The proximal anastomosis is made on the anterior surface of the aorta after the aortic hiatus is opened as described earlier. Using careful finger dissection, a tunnel must then be created behind the pancreas. The bypass graft is passed through the tunnel and anastomosed to the distal patent superior mesenteric artery. Kinking of the bypass, such as can occur with retrograde aortic-to-superior mesenteric artery bypass grafts during replacement of bowel, is unlikely in this tunneled position.

Anterior exposure of the superior mesenteric artery inferior to the transverse mesocolon requires opening the posterior parietal peritoneum lateral to the third and fourth portions of the duodenum (Fig. 4–23). The left renal vein is identified and mobilized as described previously for exposure of the renal arteries. The left renal vein is retracted downward and the dissection carried upward on the aorta until the superior mesenteric artery origin can be palpated. It usually arises from the left side of the anterior surface of the aorta. The artery is immediately encased by the superior mesenteric sympathetic nerve plexus, which must be incised for exposure. Bleeding from the vascular plexus tissue is controlled by cautery and suture ligatures. The

Figure 4–22. Exposure of the abdominal aorta at the diaphragm. See text for details.

Figure 4–23. Infraocolic exposure of the superior mesenteric artery. The pancreas and transverse colon are not shown but are retracted upward and forward. See text for details. IMA, inferior mesenteric artery.

overlying transverse mesocolon and pancreas significantly limit this exposure.

TRANSPERITONEAL EXPOSURE OF THE INFRARENAL ABDOMINAL AORTA

A midline abdominal incision from the xiphoid to the symphysis pubis is commonly used for anterior exposure of the infrarenal abdominal aorta. One major disadvantage of this approach is incomplete visualization of the proximal abdominal aorta and/or renal artery origins. This potential lack of exposure is improved by proximally extending the midline incision around the xiphoid process and completely mobilizing the third and fourth portions of the duodenum. The dissection continues through the posterior peritoneum just lateral to the duodenum and medial to the inferior mesenteric vein to avoid damaging the circulation to the left—or sigmoid—colon. This is particularly important in dealing with ruptured abdominal aortic aneurysms, where landmarks are frequently obscured by an extensive retroperitoneal hematoma. The duodenum can nearly always be visualized and used as a landmark during this exposure.

It is wise to palpate the aortic bifurcation and expose the common iliac arteries from the midline, thereby avoiding injury to the ureters. Fibers of the sympathetic nerves arch over the left common iliac artery in males, and damage to these sympathetic fibers can result in erectile dysfunction and retrograde ejaculation. Figure 4–24 shows the relationship of the infrarenal sympathetic nerve fibers to the terminal aorta and iliac arteries. Incising along the white line of Toldt and mobilizing the sigmoid or proximal ascending colon toward the midline can readily identify the external iliac arteries. Graft limbs coursing out to this
Cautious dissection is advisable in this area, as there is an important large communicating vein arising from the posterior surface of the proximal left renal vein. This vein communicates with the adjacent lumbar vein and thence to the hemiazygos system and superior vena cava. The presence of this venous collateral allows acute ligation of the left renal vein without impairment of renal function. This lumbar venous communication should be preserved if at all possible during this anterior peritoneal approach.

Once the left renal vein is mobilized, attention should be directed to exposing the left lateral surface of the aorta above and below the level of the left renal vein. The left renal artery arising from the posterolateral surface of the aorta is thus exposed. Autonomic nerve elements are encountered on the renal artery but can be divided without concern. Gentle placement of a vein retractor under the left renal vein with upward retraction by an assistant greatly facilitates this exposure. A silastic loop placed about the renal artery origin aids in the mobilization and dissection of this vessel.

The right renal artery is more difficult to expose, because it passes directly behind the inferior vena cava on its course to the renal hilum. The origin of this artery is palpated as it emerges from the right posterolateral aspect of the aorta. Care should be taken not to injure the right adrenal branch, which arises 5 to 10 mm from the origin of the right renal artery. The size of this vessel may be 2 to 3 mm when renal artery stenosis is present because it becomes a very important collateral to the distal right renal artery via capsular branches. In the event that the entire right renal artery and its branches must be exposed, the surgeon must completely mobilize the vena cava above and below the artery by carefully ligating and dividing all adjacent lumbar veins.

The subhepatic space is entered and the duodenum kocherized to allow exposure of the right renal vein as it joins the inferior vena cava. The renal vein is mobilized on a silastic loop to aid in identification of the main renal artery lying beneath the vein. Exposure of the renal artery is complete when this distal dissection joins the medial exposure already described.

**EMERGENCY EXPOSURE OF THE ABDOMINAL AORTA AND VENA CAVA**

Vascular exposure of injured vessels within the abdomen is best carried out through a generous midline abdominal incision. Location of the hematoma determines the exposure to be employed. Because the abdominal circulation arises in a retroperitoneal location, the overlying viscera need to be rotated medially or elevated superiorly in order to expose the aorta and its major branches and the caval and portal venous circulation.

Kudsk and Sheldon have classified the retroperitoneal space into three zones (Fig. 4–25). The presence of a central hematoma (zone 1) indicates injury to the aorta, the proximal renal/visceral arteries, the inferior vena cava, or the portal vein. An expanding, zone 1 retroperitoneal hematoma with extension to the left indicates a proximal aortic or adjacent major branch vessel injury. Transperito-
mobilization of the overlying bowel are continued to the midline.

Lateral hematomas (zone 2) indicate injury to distal visceral and renal vessels. Despite their lateral location, it is wise not to enter a large hematoma to control exsanguineous hemorrhage until central aortic exposure has been secured for possible cross-clamping. Retroperitoneal pelvic hematomas (zone 3) usually indicate torn branches of the iLiac vessels associated with pelvic fractures. These may not require exploration unless the hematoma is expanding or there is evidence of large vessel injury demonstrated by angiography.

EXTRAPERITONEAL EXPOSURE OF THE ILIAC ARTERIES

This exposure begins with an oblique incision in the lower quadrant of the abdomen on the side of involved iliac artery occlusive disease. It is good practice to start the incision near the pubic tubercle with extension obliquely lateral, staying medial to the anterior superior iliac spine of the pelvis. The external oblique aponeurosis is opened in the direction of its fibers, and the incision is continued into the fleshy portion of this muscle. The internal oblique and transversus abdominis muscles are divided in the direction of the incision to enter the preperitoneal space. The peritoneum is gently rotated medially to expose the external iliac artery. The ureter, which is adherent to the peritoneum and usually retracts with the peritoneal contents, is vulnerable to injury as it courses across the iliac bifurcation.

Exposure of the common iliac artery requires extension of the incision proximally and laterally into the flank region. Care should be taken not to injure the iliinguinal or genitofemoral nerves during exposure or retraction. Their location on the anterior surface of the psoas muscle is vulnerable. Combination of this incision with a curvilinear incision over the common femoral artery permits exposure from the terminal common iliac artery to the proximal superficial or deep femoral arteries (Fig. 4–28). The iliac artery exposed in this extraperitoneal fashion is particularly appealing as an inflow source in cases in which there is extensive scarring at the groin from previous peripheral vascular procedures.

EXPOSURE OF THE COMMON FEMORAL ARTERY

A curvilinear incision placed directly over the palpable pulse, with extension above as well as below the groin crease, provides excellent exposure of the common femoral artery and its branches. An incision made just medial to the midpoint of the inguinal ligament suffices in the absence of a palpable pulse. Frequently, the diseased artery can be rolled beneath the index finger, and this guides the plane of deeper dissection. It is important to remember to check for posterior branches, because an aberrant medial femoral circumflex artery can arise anywhere along the posterior surface of the common femoral artery. Failure to control this vessel can result in troublesome bleeding when the common femoral artery is opened.
Gentle dissection about the origin of the profunda femoris artery is important. The lateral femoral circumflex artery arises from the lateral side of the deep femoral artery, and this vessel can be easily injured. Care should also be taken to identify the lateral femoral circumflex vein, which courses from a lateral to a medial direction across the origin of the profunda femoris artery. Division of this vein facilitates arterial mobilization and distal dissection. This maneuver is paramount if the proximal profunda femoris artery is to be used as an inflow source, and it provides excellent exposure for eversion endarterectomy.

**EXPOSURE OF THE DEEP FEMORAL ARTERY**

The profunda femoris artery is located 1.5 cm medial to the femur and lies on the pectineus and adductor brevis muscles. In cases in which the deep femoral artery is being exposed as an initial procedure, the dissection is aided by flexion and external rotation of the thigh to relax the involved muscles. Colborn and associates have described the surgical anatomy of the deep femoral artery. The reader is well advised to consult this excellent and well-illustrated article.

The deep femoral artery can be a useful inflow or outflow source in a patient with a hostile groin after previous surgical exposures. Nuñez and associates have described a practical approach to the middle and distal thirds of this artery that avoids a scarred femoral bifurcation. This surgical dissection begins lateral to the sartorius muscle. Figure 4-29 demonstrates the incision over the lateral aspect of the sartorius muscle and branches of the lateral femoral circumflex artery. These branches are followed medially to the profunda femoris artery after the incision is deepened between the vastus medialis and adductor longus muscles. Complete mobilization of the artery at this level requires division of overlying venous tributaries to the deep femoral vein. This dissection can then safely be extended distally or, if needed, proximally to the femoral bifurcation.

Alternatively, the distal third of the profunda femoris artery can be exposed by a surgical plane of dissection that is posterior to the adductor longus muscle in the medial thigh. This exposure is deepened between the gracilis and adductor longus muscles to the medial aspect of the profunda femoris artery. Knee flexion relaxes the involved muscles and aids in this exposure.

**EXPOSURE OF THE POPLITEAL ARTERY**

The popliteal artery is exposed from a medial approach with few exceptions. The proximal and distal portions of this vessel are readily exposed. However, the medial head of the gastrocnemius muscle and the tendinous insertions of the long adductor muscles obscure the midportion of the artery at the joint space of the knee. A posterior
Although not usually necessary, additional exposure can be obtained distally by dividing the tendon of the medial head of the gastrocnemius muscle. Gentle insertion of the left index finger behind its tendinous origin aids in isolating this structure and protecting the underlying neurovascular bundle. Should additional distal exposure be necessary, the tendinous insertions of the sartorius, semimembranosus, semitendinosus, and gracilis muscles may be divided. It is well to mark these tendons with identifying sutures to aid in their subsequent repair.

The terminal popliteal artery and tibioperoneal trunk are exposed through an incision placed approximately 1.5 cm posterior to the medial margin of the tibia. Once again, the surgeon must be aware of the greater saphenous vein and protect it in its subcutaneous location. The thick muscular fascia overlying the gastrocnemius muscle is incised to enter the popliteal space. The popliteal vein is usually encountered first within the neurovascular sheath. Gentle downward retraction of the vein facilitates dissection of the popliteal artery, which lies superolateral to the vein. The origin of the anterior tibial artery arises anteriorly and laterally from the terminal popliteal artery. Further exposure of the tibioperoneal trunk and proximal peroneal and posterior tibial arteries requires the division of the soleus muscle fibers arising from the medial margin of the tibia. Division of overlying venous tributaries between the often-paired popliteal veins facilitates this exposure.

**Lateral Exposure of the Popliteal Artery**

A lateral approach to the popliteal artery can be employed when previous medial exposure has resulted in dense tissue scarring, making repeat procedures extremely difficult. The incision for the above-knee popliteal artery is placed between the iliotibial tract and the biceps femoris muscle as described by Veith and associates. The dissection is deepened through the fascia lata posterior to the junction of the lateral intramuscular septum and the iliotibial tract to enter the popliteal space. The popliteal vein is encountered first within the vascular sheath. It can be mobilized and retracted posteriorly to allow exposure of the popliteal artery. The tibial and peroneal nerves are also posterior and loosely adherent to the hamstrings. They naturally fall out of harm's way with retraction of the biceps femoris, semimembranosus, and semitendinosus muscles.

The lateral approach to the below-knee popliteal artery begins with an incision over the head and proximal one fourth of the fibula. As the incision is deepened, care must be taken to preserve the common peroneal nerve as it courses around the neck of the fibula (Fig. 4-30). The biceps femoris tendon is divided. The ligamentous attachments to the head of the fibula are also divided, and the proximal fibula is removed. The entire below-knee popliteal artery, anterior tibial artery origin, and tibioperoneal trunk are accessible after removal of the bone fragment (Fig. 4-31). The proximal posterior tibial and peroneal arteries can be exposed if more of the distal fibula is resected.

**EXPOSURE OF THE TIBIAL AND PERONEAL ARTERIES**

Management of lower extremity ischemic vascular disease requires accurate knowledge of the arterial and venous

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**Figure 4-30.** Lateral approach to the distal popliteal artery. Note the common peroneal nerve coursing around the neck of the fibula. (From Veith F, Ascere E, Gupta S: Lateral approach to the popliteal artery. J Vasc Surg 6:119, 1987.)
approach to the midpopliteal artery is useful for isolated disorders such as popliteal entrapment or cystic adventitial disease.

The proximal popliteal artery is exposed through an incision placed in the groove between the vastus medialis and sartorius muscles. The greater saphenous vein lies just posterior to this incision and care must be taken to preserve it during the dissection. The sartorius muscle is retracted posteriorly and investing fascia incised longitudinally, preserving the saphenous nerve, which is usually seen lying on the deep fascial surface. Once the fascia is opened, the popliteal artery can be palpated in its location under the adductor magnus tendon.

Figure 4–27. Rotation left of intraabdominal viscera by mobilization of the right colon and by Kocherization of the duodenum. The right kidney can also be mobilized to inspect the posterior surface of the vena cava if necessary. (Reproduced with the permission of Dohrmann M, original illustrator.)

Figure 4–28. Extraperitoneal exposure of the distal common and external iliac arteries. Counterincision at groin facilitates iliofemoral resection.

Figure 4–29. Lateral approach to the deep femoral artery. Upper right. The incision is lateral to the sartorius muscle. Lower left. The exposure of the profunda femoris vessel. See text for details.
circulation of the leg. It is important to keep in mind the relationship of the three major leg arteries to the tibia and fibula as well as the compartments of the leg. Figure 4–32 demonstrates these important relationships. Note the anterior tibial vessels lying on the interosseous membrane in the anterior compartment. The peroneal artery, which is adjacent to the medial margin of the fibula in the deep posterior compartment, lies in close proximity to the trans-

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**Figure 4–31.** Lateral approach to the distal popliteal artery after the removal of the proximal fibula. Note the transected tendon of the biceps muscle and the intact common peroneal nerve. (From Veith F, Aseo E, Gupta S: Lateral approach to the popliteal artery. J Vasc Surg 6:119, 1987.)

**Figure 4–32.** Cross-section of the leg showing the location of the anterior tibial artery in the anterior compartment of the leg and the posterior tibial and peroneal arteries in the deep posterior compartment. (From Briggs S, Seligson D: Management of extremity trauma. In Richardson D, Polk H, Flint M [eds]: Trauma: Clinical Care and Pathobiology. Chicago, Year Book Medical, 1987, p 544.)
verse crural intermuscular septum. The posterior tibial vessels are medial to the peroneal artery and veins, but also above the intermuscular septum and in the deep posterior compartment of the leg.

Surgical exposure of the crural vessels requires patience and great care. There are numerous small muscular branches, and each artery has two accompanying veins with their respective tributaries to protect. Careless dissection leads to bleeding that obscures the operative field and increases the likelihood of injury to these delicate vascular structures.

Anterior Tibial Artery

This vessel travels between the tibialis anterior and the extensor digitorum longus muscles in the proximal portion of the anterior compartment of the leg. The extensor hallucis longus muscle crosses over the artery from lateral to medial in the distal leg above the level of the flexor retinaculum. Surgical exposure of the anterior tibial artery is best afforded either in the proximal leg or just above the flexor retinaculum proximal to the ankle.

A skin incision made approximately 2.5 cm lateral to the anterior border of the tibia facilitates proximal exposure of the anterior tibial artery. Deepening the dissection between the two muscle bellies assists this surgical approach. Dorsiflexion and internal rotation of the foot aid in identification of the groove between These muscles. The muscles are gently separated down to the anterior tibial artery, which lies between the two accompanying veins and anterior to the deep peroneal nerve on the interosseous membrane.

Alternatively, a dissection course that passes between the extensor hallucis longus and extensor digitorum longus laterally and the tibialis anterior muscle medially exposes the artery just above the flexor retinaculum. The upper portion of the flexor retinaculum can be divided to improve distal exposure. However, complete division of this retinaculum is not recommended. If the anterior tibial artery is unsuitable for vascular reconstruction at this level, the dissection should skip down to the dorsalis pedis artery below the inferior portion of the retinaculum.

Posterior Tibial Artery

Extending the incision described earlier for medial exposure of the tibiofibular trunk facilitates proximal exposure of the posterior tibial artery. This requires incising the origin of the soleus muscle from the medial border of the tibia. Tributary veins traveling through this muscle origin may cause troublesome bleeding. These should be ligated to keep the operative field dry. Immediately deep to the soleus fibers, the posterior tibial vessels can be observed coursing between the tibialis posterior and the flexor digitorum longus muscles. The tibial nerve, which crosses the artery posteriorly from medial to lateral, must be protected. This exposure can be challenging, as there is a dense network of venous tributaries overlying the origin of the posterior tibial artery.

Exposure of the middle aspect of the posterior tibial artery is best achieved distal to the lower edge of the soleus muscle fibers in the medial calf. This dissection into the deep posterior compartment of the leg continues above the intermuscular septum to expose the neurovascular bundle. The artery must be carefully dissected free from its accompanying paired veins and tibial nerve.

Peroneal Artery

The proximal and middle aspects of the peroneal artery can be exposed using the same medial leg incisions that were described for exposure of the posterior tibial artery. Once this latter artery is exposed, the dissection continues on the intermuscular septum to a deeper level. The peroneal artery is located adjacent to the medial border of the fibula. This exposure is quite deep and therefore more difficult in a large leg.

Resecting a short segment of the fibula through a lateral incision over this bone can also expose the peroneal artery. This incision should be placed below the entrance of the peroneal nerve into the anterior compartment of the leg. The peroneal vessels lie just deep to the medial border of the fibula. Once this short segment of bone is removed, the vessels are exposed. Careful division and removal of the fibula are essential, as the accompanying venous plexus that surrounds the peroneal artery is easy to disturb and may cause significant bleeding. Surprisingly little postoperative morbidity is associated with this exposure.

Exposure of Pedal Arteries

A detailed understanding of the pedal arterial circulation is important because distal bypass sites in the foot are frequently used for limb-threatening ischemic vascular disease. Ascend and associates have described various surgical approaches as well as results of these distal lower extremity bypass procedures. Figure 4–33 shows the branches and distribution of the distal anterior and posterior tibial arteries in the foot.

Distal Posterior Tibial Artery and Plantar Branches

Exposure of the terminal posterior tibial artery with its concomitant veins and tibial nerve is accomplished by a retromalleolar incision. The dissection is continued distally by division of the flexor retinaculum. The neurovascular bundle is surrounded by fatty tissue and the artery is usually superior to the nerve. Further dissection may require sequential incisions to accurately follow the course of the terminal posterior tibial artery into the plantar surface of the foot. Small self-expanding retractors facilitate this exposure, as the plantar tissues are thick and rigid. The plantar aponoeurosis and the flexor digitorum brevis muscle can be incised to expose the medial and lateral
plantar arteries (Fig. 4–34). This latter vessel continues distally into the foot to form the deep plantar arch.

**Dorsal Pedal Artery and Lateral Tarsal Branch**

These vessels are approached through a longitudinal incision lateral to the extensor hallucis longus tendon. The inferior extensor retinaculum is partially incised just distal to the ankle joint to expose the proximal dorsalis pedis artery and lateral tarsal branch. The lateral tarsal artery usually arises at the level of the navicular bone and beneath the extensor digitorum brevis muscle. This artery communicates with the arcuate artery in the midfoot. Therefore, it is an important collateral blood supply to the dorsum of the foot. Division of the inferior extensor retinaculum is not required for more distal exposure of the dorsal pedal artery. It is necessary to protect the distal deep peroneal nerve coursing medial to this artery.

**Deep Plantar Artery**

This vessel is the main continuation of the dorsal pedal artery at the level of the metatarsal bones. It is best ap-
References


Review Questions

1. Of the following nerves, the one most likely to be injured during carotid endarterectomy is a (a) recurrent laryngeal nerve (b) vagus nerve (c) hypoglossal nerve (d) superior laryngeal nerve (e) glossopharyngeal nerve

2. Structures contributing to thoracic outlet compression syndrome may include (true or false) (a) subclavian muscle (b) first rib (c) scalenus anticus (d) congenital cervical rib (e) sternocleidomastoid muscle

3. Concerning lower extremity circulation (true or false) (a) the deep femoral artery is accessible only by an approach that is lateral to the sartorius muscle (b) it is possible to expose the popliteal artery above and below the knee by lateral or medial approaches (c) the lateral tarsal artery is the largest distal branch of the posterior tibial artery (d) the deep plantar arch is formed by the deep plantar artery and the lateral plantar artery

4. During repair of an infrarenal abdominal aortic aneurysm (true or false) (a) autonomic nerve fibers crossing the left common iliac artery should be protected to preserve erectile function (b) a large anastomotic artery appearing on arteriography between the superior and inferior mesenteric arteries indicates satisfactory perfusion of the left colon with little risk of ischemia if the inferior mesenteric artery is ligated (c) a large lumbar artery near the renal arteries should be preserved because this may represent a significant contribution to the anterior spinal artery (d) the left renal vein may be safely ligated and divided to facilitate aortic exposure if the lumbar and adrenal tributaries are maintained for collateral circulation (e) initial aortic control at the diaphragm safely facilitates infrarenal vascular control in a patient with injured aortic branch vessels or ruptured aortic aneurysm

5. Patients with celiac and superior mesenteric artery occlusive disease would be expected to have (true or false) (a) a large central anastomotic artery (b) retrograde filling of the superior mesenteric artery (c) a large marginal artery of Drummond (d) a low incidence of left colon ischemia following inferior mesenteric artery ligation

6. Renal artery reconstruction (true or false) (a) may be performed via a left or right retroperitoneal approach (b) may be difficult in the obese or previously operated patient if an anterior transabdominal approach is used (c) is facilitated in the high-risk patient using splenic artery-to-left renal artery bypass or hepatic artery-to-right renal artery bypass (d) is more difficult with regard to exposure and revascularization of the right renal artery due to its retro-vena cava position (e) all of the above
approached through a curvilinear incision over the dorsum of the foot lateral to the extensor hallucis longus tendon. The artery is followed distally until it divides into the first dorsal metatarsal and deep plantar branches. The latter vessel descends between the two heads of the first dorsal interosseous muscle to anastomose with the lateral plantar branch. This forms the deep plantar arch of the foot (Fig. 4-35). Adequate exposure of the deep plantar branch requires retraction of the extensor hallucis brevis muscle. The periosteum of the second metatarsal bone is then carefully elevated and a portion of the bone is removed by a rongeur to provide adequate exposure for distal arterial anastomosis (Fig. 4-36). This exposure requires delicate dissection otherwise because injury to adjacent arterial branches and venous tributaries may obscure the operative field or create ischemia to marginally viable tissues.

Figure 4-35. Diagram of the arterial circulation on the dorsum of the foot. The insert shows the origin of the deep plantar branch as it courses between the two heads of the first dorsal interosseous vessel. See text for details. (From Ascer E, Veith F, Gupta S: Bypasses to plantar arteries and other tibial branches: An extended approach to limb salvage. J Vasc Surg 8:437, 1988.)

Figure 4-36. A. Shows the deep plantar arch branch following resection of a portion of the second metatarsal bone. B. Shows the distal anastomosis of a bypass to this vessel. (From Ascer E, Veith F, Gupta S: Bypasses to plantar arteries and other tibial branches: An extended approach to limb salvage. J Vasc Surg 8:437, 1988.)
7. Regarding carotid artery exposure (true or false)
   (a) the distal internal carotid artery is crossed posteriorly by the hypoglossal nerve (XII)
   (b) the vagus nerve (X) passes posterolateral to the carotid bifurcation
   (c) distal exposure is safely facilitated by anterior dislocation of the mandible
   (d) distal exposure may be facilitated by division of the posterior belly of the digastric muscle and the stylohyoid muscle
   (e) anteriorly the distal internal carotid artery is covered by the parotid gland

8. Regarding trauma to the great vessels (true or false)
   (a) exposure of the proximal left subclavian artery is best accomplished via sternotomy
   (b) temporary right third interspace thoracotomy may be used to control exsanguinous hemorrhage from the innominate artery
   (c) right subclavian exposure via a simple supraclavicular incision is adequate for most traumatic injuries in this area
   (d) exposure of either common carotid artery origin is best accomplished via a sternal splitting incision extended along the anterior border of the appropriate sternocleidomastoid muscle

9. Exposure of the infrapopliteal arteries involves the following anatomic relationships (true or false)
   (a) the anterior tibial artery passes posterior to the interosseous membrane
   (b) lateral exposure of the peroneal artery requires segmental fibular resection
   (c) the tibial nerve crosses the posterior tibial artery anteriorly
   (d) the posterior tibial artery lies deep to the transverse crural intermuscular septum

10. The arteria radicularis magna (artery of Adamkiewicz) (a) is important in providing circulation to the anterior spinal artery
      (b) may supply up to two thirds of the spinal cord
      (c) appears as a branch of either a distal intercostal or proximal lumbar artery
      (d) is rarely identified via standard arteriography preoperatively
      (e) all of the above

Answers

1. b  2. (a) T  3. (a) F  4. (a) T  5. (a) T  6. e  7. (a) F  8. (a) F  9. (a) F  10. e
      (b) T  (b) T  (b) F  (b) T  (b) T  (c) F  (c) F  (c) F  (c) T  (d) T  (d) T  (d) T  (e) T