Regional Anesthesia for Vascular Surgery

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KEYWORDS

- Regional anesthesia • Cervical plexus blockade • Brachial plexus blockade
- Transversus abdominis plane block • Lumbar and lumbosacral plexus blockade
- Vascular surgery • Perioperative outcomes

KEY POINTS

- Cervical plexus blockade can be performed safely as the primary anesthetic in patients undergoing carotid endarterectomy.
- Medically complex patients undergoing open abdominal aortic aneurysm (AAA) repair are at significant risk of postoperative complications and systemic side effects from intravenous analgesia.
- Endovascular repair of abdominal aortic aneurysms allows repair of AAA in patients too medically complex for open repair.
- Regional anesthesia for lower extremity bypass may reduce graft failure rate, and prolonged perineural infusion may reduce phantom limb pains in lower extremity amputation.
- Regional anesthesia produces sympathectomy, leading to venodilation, improving fistula planning and potentially increasing postoperative fistula flow.

INTRODUCTION

The patient population undergoing vascular surgery presents a challenge because of systemic comorbidities, including hypertension, diabetes mellitus, congestive heart failure, and renal impairment. Ninety-two percent of patients with peripheral vascular disease have angiographic evidence of coronary artery disease (CAD), and likely a high rate of CAD exists in patients with carotid and abdominal aortic atherosclerotic disease. Some degree of myocardial ischemia may occur in up to 28% of patients undergoing major vascular surgery.[1] In addition, the high prevalence of active smoking in the patient population increases the risk of perioperative pulmonary complications.[2] Regional anesthesia is appealing for surgical anesthesia and postoperative pain management in these patients to decrease side effects of systemic medication administration, avoid endotracheal intubation, and reduce hemodynamic fluctuations from sympathetic activation.

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Procedures from arteriovenous fistula (AVF) creation to open AAA repair have been performed safely under regional anesthesia alone or as combined general-regional anesthesia. Still, the risks and benefits of regional anesthesia for a particular patient must be carefully weighed. A fundamental concern with the use of regional anesthesia for vascular surgery is the high rate of anticoagulant use in these patients. Table 1 summarizes the 2010 American Society of Regional Anesthesia (ASRA) guidelines for anticoagulation management for patients receiving neuraxial anesthesia. There is risk of bleeding and epidural hematoma formation with both insertion and removal of an epidural catheter. In addition, ASRA suggests following these guidelines for the performance of deep plexus or peripheral nerve blockade.[3] These guidelines state that it is safe to administer intravenous heparin to the vascular surgery patient as little as 1 hour after performance of regional anesthesia.

Several newer anticoagulants (GIIb-IIIa inhibitors, thrombin inhibitors, rivaroxiban, argatroban, or fondaparinux) have shown great efficacy and represent new challenges for the use of regional anesthesia. ASRA is preparing new regional anesthesia guidelines for their use.

Table 1
ASRA guidelines for nerve anticoagulant management before nerve blockade

Anticoagulant[a]	Discontinuation Before Neuraxial Block/After Removal of Catheter	Administration After Neuraxial Block/Catheter Withdrawal
Unfractionated heparin, subcutaneous		
$\leq$5000 units twice a day for $\leq$3 d	No contraindication	1 h
$\leq$5000 units for $\geq$4 d	Assess platelet count	1 h
>10,000 units twice a day or any 3 times a day dosing	Safety not established	Safety not established
Unfractionated Heparin, Intravenous	4 h, consider ACT	1 h
Low-Molecular-Weight Heparin		
Prophylactic dose/single daily dosing	12 h	6–8 h after insertion, 2 h after removal
Therapeutic dose/twice daily dosing	24 h	Indwelling catheter not recommended. Hold dose 24 h before block placement, remove catheter at least 2 h before administration
Warfarin	4–5 d and normalization of INR for insertion, INR <1.5 for removal	Can be initiated, INR should not exceed 1.5 with indwelling catheter
Nonsteroidal antiinflammatory drugs/aspirin	No contraindication	No contraindication
Ticlopidine	14 d	No recommendation
Clopidogrel	7 d	No recommendation
Herbals (gingko, garlic, ginseng)	No contraindication	No contraindication

Abbreviations: ACT, activated clotting time; INR, international normalized ratio.
[a] Refers to single modality of anticoagulation. Multimodal anticoagulation and regional anesthesia safety not well established.

In this article, regional anesthesia for carotid endarterectomy (CEA), abdominal aortic aneurysm (AAA) repair, AVF formation, lower extremity bypass surgery, and lower extremity amputation are discussed.

GENERAL CONCEPTS FOR BLOCK PERFORMANCE

Patient Preparation

Before performing all blocks, a thorough review of the patient's history, focusing on use of anticoagulant medications, existing neuropathies, and concomitant respiratory disease, should be obtained. An international normalized ratio (INR) should be reviewed if the patient is taking warfarin or suffering from liver disease. Risks, benefits, and alternatives to regional anesthesia are discussed with patient. Intravenous access should be established, and standard monitors applied. Apply oxygen by nasal cannula or face mask. Light sedation can be administered to decrease patient anxiety.

Avoiding Complications

The complications listed in **Table 2** are common to all blocks covered in this article. Block-specific complications are addressed in each individual section.

CEA

Regional anesthesia was originally described as the primary anesthetic for CEA in 1962[4] as an effort to improve neurologic monitoring during carotid cross-clamping. Since then, regional anesthesia has been associated with decreased risk of stroke[5,6] and immediate postoperative cognitive dysfunction,[7] myocardial infarction (MI),[8,9] perioperative hemodynamic instability and vasopressor use,[10–12] and postoperative opioid use.[13] Other investigations have shown that regional anesthesia reduces the rate of shunt placement,[11] operating time,[11,14] and hospital length of stay.[8] A systematic review by Guay[15] in 2007 analyzed prospective and retrospective trials comparing regional and general anesthesia and found statistically significant reductions in stroke, death, and MI. However, there remains debate about optimal anesthetic technique for CEA, given the retrospective nature of most data included in this study.

The GALA (General Anesthetic Versus Local Anesthetic for Carotid Surgery) trial,[12] the premiere prospective trial, enrolled 3526 patients but failed to show a statistically significant improvement in stroke, MI, or death with combined superficial and deep cervical plexus block versus general anesthesia. The investigators did find a trend toward reduced risk of stroke and death, although this was at the cost of a slightly increased risk of MI. In patients with bilateral carotid disease, the composite outcome

Table 2
Complications of peripheral nerve blockade and how to minimize them

Complication	Strategy to Avoid
Infection	Hand washing, sterile preparation, cap, mask, and sterile gloves for single-shot blocks and full draping with sterile gowns for catheter placement
Hematoma	Minimize skin punctures, needle passes, optimize needle visualization
Local anesthetic toxicity/intravascular injection	Frequently aspiration during injection, limit total anesthetic dose
Nerve injury	Do not inject against pressure or if painful

of stroke, death, and MI was twice as frequent in patients under general anesthesia. In the analysis by Leichtle and colleagues,[8] preoperative neurologic dysfunction was associated with a significant increased rate of complications, notably MI, in patients undergoing CEA with general rather than regional anesthesia. At the least, there is a paucity of research showing inferiority with regional anesthesia as the primary anesthetic for CEA. Regional anesthesia is highly successful as the sole anesthetic technique for CEA, with conversion to general anesthesia reported in the range of 0% to 6%.[14,16–18]

Cutaneous innervation of the anterolateral neck originates as the ventral rami of cervical nerves C2, C3, and C4, which combine with C1 to form the deep cervical plexus. Four cutaneous nerves arise from the cervical plexus: the great auricular, lesser occipital, supraclavicular, and transverse cervical nerves. Regional blockade for CEA was historically accomplished with deep cervical plexus block, with or without a superficial cervical plexus block. However, several randomized, controlled trials have shown that a superficial cervical plexus block alone is as effective as when it is combined with a deep cervical plexus block with respect to operative conditions and patient satisfaction.[17,19–21] A systematic review by Pandit and colleagues[22] in 2007 showed that when a combined block is performed, the odds ratio of serious complications is 2.13 and of conversion to general anesthesia 5.15 compared with superficial cervical plexus block alone.

Because of confusion as to the depth of the superficial cervical plexus block, whether superficial or deep to the investing layer of fascia, a distinction in the nomenclature has been proposed. The superficial cervical plexus block is the subcutaneous injection occurring superficial to this investing fascia; the intermediate cervical plexus block is performed deep to the investing fascia but superficial to the deep cervical fascia. The intermediate cervical plexus mimics a deep cervical plexus block with fewer complications, taking advantage of the semipermeable nature of the deep cervical fascia, allowing spread of local anesthetic through the deep cervical fascia.[17] Although fewer side effects were observed with this block compared with the deep block, superiority of intermediate cervical plexus block to superficial cervical plexus block alone has not been established.[23,24]

Block supplementation by surgical injection of local anesthesia is frequently required with traditional approaches to cervical plexus blockade. Block failure or incomplete block is at least partially attributable to failure to provide anesthesia to the carotid sheath, which has contributions from the vagus nerve and the superior branch of ansa cervicalis.[18] Recently, Rossel and colleagues[25] described the technique of an intermediate cervical plexus block combined with ultrasound-guided perivascular injection, which reduced the rate of need of surgical injection to less than 20%. Ultrasound-guided perivascular injection was also used successfully by Martusevicius and colleagues,[18] but a head to head trial comparing these techniques with classic cervical plexus blocks has not been performed. In addition, ultrasound guidance has not been proved to be superior to landmark techniques for execution of the superficial cervical plexus block.[26]

Regional anesthesia can be accomplished with cervical epidural anesthesia; however, this is associated with increased incidence of hypotension, bradycardia, and bilateral phrenic nerve palsy, without improvement in analgesia or operating conditions.[27]

Cervical Plexus Blockade

Equipment

Sterile technique
1-cm to 5-cm short bevel needle

Local anesthetic, 15 to 25 mL
Optional: ultrasound guidance with a high-frequency linear probe

Patient preparation
The patient is positioned in the supine or semirecumbent position, with the head turned away from the site of surgery.

Technique best practices
Deep cervical plexus block

Landmark technique Nerve roots C1–C4 emerge from the gutters between the anterior and posterior tubercles of the tip of the corresponding transverse processes. The deep cervical plexus formed by C1–C4 is located immediately lateral to the tips of the transverse processes. The block can be performed as a single injection at the level of C4 or as multiple injections at C2, C3, and C4. There is no cutaneous contribution from nerve root C1. To perform the block, first draw a line connecting the mastoid process to the transverse process of C6, the latter being the most prominent transverse cervical process palpated just inferior to the cricoid cartilage and posterior to the clavicular head of the sternocleidomastoid muscle (SCM). Along this line, palpate or use ultrasonography to mark the transverse process of C2 located 1.5 to 2 cm caudad to the mastoid process, C3 3 to 4 cm, C4 4.5 to 6 cm. Clean the skin with antiseptic solution. Inject local anesthetic superficially along the entire marked line as the skin wheal. For each level, insert the needle perpendicular to the skin, with slight caudad and posterior orientation. Advance the needle slowly until contact is made with the transverse process, approximately 1 to 3 cm deep. Withdraw the needle 1 to 2 mm and inject 4 to 5 mL of local anesthetic in fractionated aliquots, while frequently aspirating for blood, because the vertebral artery typically is within 1 cm of the target. A single injection technique may alternatively be performed at the level of C4.[17,28,29] A total of 15 mL of local anesthetic as a single injection or spread over 3 levels is typically used.

Ultrasound guided To perform an ultrasound-guided block, a high-frequency linear probe can be positioned transversely at the level of the cricoid cartilage between the cricoid cartilage and SCM. From here, the probe is moved lateral to identify the prominent anterior tubercle characteristic of the C6 transverse process. Scanning cephalad, identify transverse processes and roots of C4, C3, and C2 and mark as sites of injection (**Fig. 1**).[30] Caudad tilt of the ultrasound probe may aid in identifying nerve roots. After cleansing skin and creating a skin wheal, the needle is advanced until

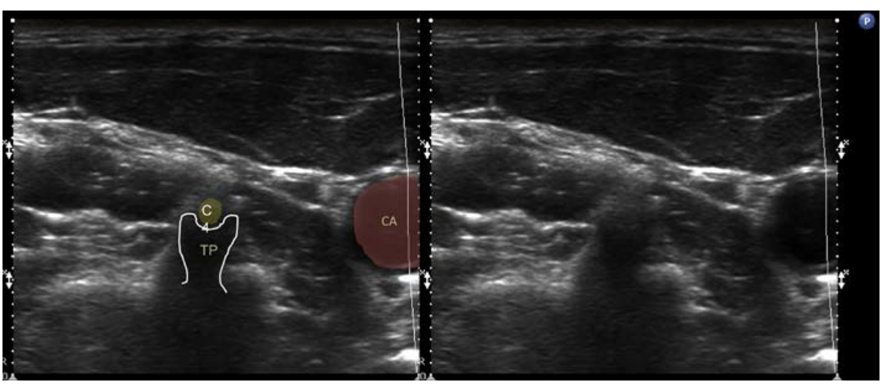

Fig. 1. Cervical nerve root 4 (C4) visualized between the anterior and posterior tubercle of the C4 transverse process (TP). The carotid artery (CA) is also visualized.

contact is made with the transverse process or the tip is seen close to the nerve root, and after negative aspiration, 5 mL local anesthetic is injected at each level.

Superficial cervical plexus block

Landmark technique The cutaneous branches of the cervical plexus converge just deep to the lateral border of the SCM, near the level of the cricoid cartilage. The superficial cervical plexus block is performed as a subcutaneous field block, with the needle inserted at this level. After cleaning with antiseptic solution and creating a skin wheal, the needle is inserted and guided just deep to the posterior border of the SCM (0.5 cm) and 5 mL of local anesthetic delivered. After this process, the needle is fanned superiorly and inferiorly; with each motion, an additional 5 mL of local anesthetic is delivered.[29]

Ultrasound guided To perform an ultrasound-guided block, place the ultrasound probe in transverse orientation at the midpoint of the posterior border of the SCM at approximately the level of the cricoid cartilage, visualizing the tapering edge of the SCM (Fig. 2). After cleaning the skin and producing a skin wheal, advance the needle from the posterior aspect just deep to the skin and platysma muscle until adjacent to the edge of the SCM. Five milliliters of local anesthetic is injected here after negative aspiration for blood. After initial injection, fan superiorly and inferiorly and inject as described earlier.

Intermediate cervical plexus block

Landmark technique The intermediate cervical plexus is performed by injecting local anesthetic just deep to the superficial cervical fascia. In identical fashion to the superficial cervical plexus block, the needle is inserted posterior to the SCM. The needle is advanced until a loss of resistance is felt, approximately 1 to 2 cm, and 15 to 25 mL of local anesthetic distributed in this space.[24]

Ultrasound guided To perform the ultrasound-guided block, place the ultrasound probe in transverse orientation at the midpoint of the posterior border of the SCM. The superficial cervical plexus may appear as a honeycomb orientation of hypoechoic structures at this level (see Fig. 2). If it is not visible, scan caudad or cephalad to identify the greater auricular nerve as it wraps around to the superficial aspect of the SCM. If the plexus is not visible, target the intermuscular plane deep to the tapering edge of

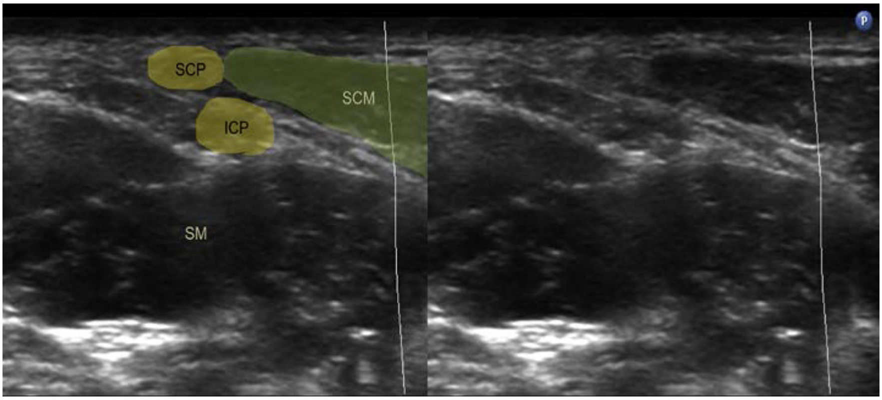

Fig. 2. The superficial cervical plexus (SCP) is visualized adjacent to the SCM. Deep to the superficial cervical fascia lies the intermediate cervical plexus (ICP). SM, anterior scalene muscle.

the SCM and superficial to the anterior and middle scalene muscles. Once the target is identified, clean the skin with antiseptic and create a skin wheal. The needle can be advanced until adjacent to the target. Ten to 15 mL of local anesthetic is injected in this location to complete the block.[29]

Perivascular injection

Position the ultrasound probe transversely just above the clavicle to identify the common carotid artery in cross section. Follow this cephalad to the bifurcation. After cleaning the skin and creating a skin wheal, advance the needle from the lateral border of the SCM until abutting the bifurcation point. After negative aspiration, local anesthetic is injected in this plane to achieve a half-moon shape spread.[18,25]

Postprocedure care

The onset time of the described blocks is approximately 10 to 20 minutes, depending on type, concentration, and volume of local anesthetic used. To test for adequate anesthesia, assess for loss of sensation to pinprick in the C2, C3, and C4 dermatome. Monitor the patient for signs of intrathecal, epidural, or intravascular injection, as well as phrenic nerve blockade, especially if a deep cervical plexus block is performed on patients with coexisting pulmonary disease. If regional anesthesia is performed for CEA at a center unfamiliar with its use, a discussion should be had with the surgical team about the expectation of requiring local supplementation, particularly to the carotid sheath.

Avoiding complications

The overall complication rate for all types of cervical plexus block is low. The composite of serious complications (including spinal anesthesia, respiratory distress, intravascular injection, and local anesthetic systemic toxicity) occurred in approximately 1% of patients receiving deep cervical blockade in a 2007 meta-analysis.[22] Virtually no serious block-related complications were reported in patients receiving a superficial cervical plexus block. A table of complications specific to cervical plexus blockade is provided (see **Table 2**).

OPEN REPAIR OF AAA

Open AAA repair has been performed in high-risk patients using combination spinal-epidural anesthesia without general anesthesia.[31,32] Although there has been success with this technique, neuraxial blockade is more commonly used in combination with a general anesthetic. Aside from superior analgesia, the benefits of this neuraxial analgesia for AAA versus intravenous pain control are controversial. Initial studies touted a reduction in postoperative hypertension[33] and time to extubation,[34] but absent were improvements in major cardiopulmonary morbidity or mortality. Although 1 group of investigators reported a 15% mortality reduction in patients with adjunctive epidural analgesia,[35] others have failed to replicate this finding. A 2012 meta-analysis found epidural superior to intravenous analgesia, with improved postoperative pain scores as well as a reduction in postoperative intubation times, acute respiratory failure rates, intensive care unit (ICU) stay duration, and rates of cardiac, gastrointestinal, and renal complications.[36] The counterpoint to these benefits is concern for postoperative coagulopathy, given large volume intraoperative blood loss and resuscitation, leading to increased risk of epidural hematoma.

Overall, the evidence for the use of adjunctive epidural analgesia for AAA repair is modest and must be weighed against the risk of postoperative coagulopathy for an individual patient. If an epidural is used, low thoracic, T8 to T10, is most appropriate.

The ideal anesthetic regimen is unclear, with some investigators[37] advocating use of epidural local anesthetic only after the aortic cross-clamp has been removed and hypotension resolved, or only postoperatively, or avoided all together in favor of epidural opioid alone.

An alternative adjunct to general anesthesia in patients at high risk for or refusing neuraxial blockade is the transversus abdominus plane (TAP) block. This block provides anesthesia only to the parietal peritoneum and abdominal wall, not to the viscera, and therefore cannot be used as the primary anesthetic.[28] Abdallah and colleagues[38] reported a case series of 6 patients undergoing open AAA with TAP blocks performed at the level of the iliac crest compared with their counterparts who refused TAP block. With a preoperative bilateral single-shot injection of 20 mL bupivacaine in the TAP, a 41.5% reduction in intraoperative opioid consumption, 42.2% reduction in us of postoperative morphine patient-controlled analgesia, decreased antiemetic requirements, and reduced pain scores for the first 48 hours were observed. Although the traditional approach to TAP blockade provides reliable analgesia only below the level of the umbilicus, a subcostal version is purported to extend this level to the upper abdomen. A study by Niraj and colleagues[39] compared subcostal TAP catheters versus epidural analgesia for upper abdominal surgery and found no difference in pain scores at 8 or 72 hours. Further research efforts are required to refine our knowledge of subcostal TAP block spread.

TAP Block

Sensation to the anterior abdominal wall is provided by ventral rami of T6-L1. In the lateral abdomen, these nerve roots lie in the fascial plane between transversus abdominus and internal oblique muscles, called the TAP.

Equipment

Sterile preparation
10-cm, 21-G needle
Local anesthetic, 20 to 30 mL per side
Ultrasound guidance with high-frequency linear probe

Patient preparation

This block can be performed with the patient either awake or asleep. The patient is positioned supine.

Technique best practices

A traditional TAP block is performed at the level of the iliac crest. The ultrasound probe is placed at this level in the midaxillary line, parallel to the muscles of the abdominal wall. The needle is advanced and guided deep to the fascia of the internal oblique just superficial to the transversus muscle (**Fig. 3**). Injection in this plane should create a clear fluid pocket dividing the 2 muscles. If the fluid pocket appears blurry, intramuscular injection should be suspected and the needle redirected slightly. To perform the subcostal block, simply complete these steps in the same plane just below the costal margin. A combination of blocks at both levels may be performed with care not to exceed safe doses of local anesthesia, because high plasma levels are expected after TAP block.[40] For either block, a perineural catheter may be threaded after localization of the needle in the TAP.

Postprocedure care

Postoperatively, the patient may be assessed for block success and visual analog pain scores. If a catheter was placed, the ideal regimen is unclear, with some advocating

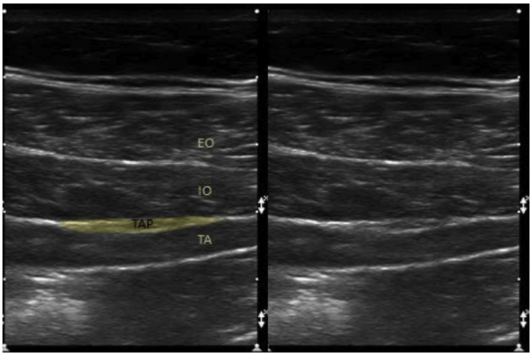

Fig. 3. TAP lies between the internal oblique (IO) and transversalis (TA) muscles, all deep to the external oblique (EO) muscle.

continuous infusion and others intermittent high-volume boluses. Confirmation of catheter injectate spread in the TAP can be performed under ultrasound guidance.

Avoiding complications

Although serious complications of TAP blocks, including liver lacerations and bowel perforation, have been reported, the overall complication rate is low, with most studies citing few to no adverse effects.[41]

ENDOVASCULAR REPAIR OF AAAS

Early endovascular repair of AAAs (EVAR) was performed solely under general anesthesia because of lengthy surgical duration and risk of open conversion. Procedure times and success rates have improved with experience, allowing for exploration of local and regional techniques as the primary anesthetic for EVAR.

Local anesthesia with intravenous sedation has been used with success across many centers,[42–46] primarily when femoral access is used for repair. Several investigators have reported decreased procedure times,[45–47] shorter ICU and hospital stays,[44,45,47–49] less vasopressor use,[43] and fewer cardiopulmonary complications[44,45,48–50] when local anesthesia is used in lieu of general anesthesia. Although theoretically at a disadvantage because of an inability to breath-hold during stent deployment, no difference in endoleak rate has been observed with local anesthesia.[47] Rates of conversion to general anesthesia have been reported as low as 0.5% of patients undergoing EVAR under local anesthesia.[44,45] However, local anesthesia is less feasible when complex dissection for iliac access is required.

Several regional anesthetic techniques have been used, including continuous spinal, epidural, combined spinal/epidural, paravertebral, and ilioinguinal/iliohypogastric blockade. However, most commonly, epidural or spinal has been used. A lack of reliable data exists for peripheral nerve blockade. Epidural or spinal anesthesia has been associated with decreased procedure duration,[43] length of ICU and hospital stay,[44,48] blood loss,[48] and pulmonary complications.[49] Adequate anesthesia is achieved for femoral or iliac approach with titration to a T10 level, often accomplished with blockade at the L3 to L4 or L4 to L5 level.

Although this evidence suggests a potential advantage for locoregional anesthesia compared with general anesthesia, the literature is largely retrospective. A recent meta-analysis by Karthikesalingam and colleagues[47] showed statistically significant improvements in postoperative complications, operative times, and hospital length of stay when general anesthesia is avoided. However, the investigators questioned the clinical relevance of the small absolute differences in the observed advantages. Although most studies have failed to show a mortality benefit with locoregional anesthesia, the EUROSTAR data analysis by Ruppert and colleagues[51] reported a reduction in mortality in the subset of ASA (American Society of Anesthesiologists) III–IV patients. Patients undergoing EVAR with locoregional anesthesia are typically sicker and are able to undergo aneurysm repair with similar mortality to healthier patients undergoing repair under general anesthesia.[44,47,48] However, complex aneurysms or difficult approaches to EVAR have commonly been cited as a reason for opting for general anesthesia.[47] Locoregional anesthesia may be of greatest benefit in high-risk patients undergoing relatively simple EVAR with femoral access.

LOWER EXTREMITY VASCULAR SURGERY: ARTERIAL BYPASS AND AMPUTATION

Regional anesthesia has been used for several decades for lower extremity vascular surgery. The proposed benefits of regional anesthetic techniques are improved hemodynamic stability, decreased catecholamine surge, and sympathectomy; all resulting in improved lower extremity blood flow.

For infrainguinal bypass surgery, hemodynamics may be better maintained with regional anesthesia, because heart rate volatility as well as the incidence of both intraoperative hypertension[52] and hypotension[53] have been shown to be more frequent with general anesthesia. Further, regional anesthesia is associated with decreased incidence of postoperative pneumonia.[54] Generally, however, tangible evidence of improvement in morbidity and mortality is sparse, and general anesthesia remains the technique of choice in more than 70% of procedures. This situation is surprising because, at the least, regional anesthesia is universally reported with at least equivalence of postoperative outcomes.[55–57] Therefore, epidural, spinal, and peripheral nerve blockade are acceptable anesthetic techniques for lower extremity vascular surgery.

A controversial point, but one in which regional anesthesia may have true benefit, is the effect of anesthetic technique on graft patency and return to the operating room. Multiple trials[54,58–60] have shown that general anesthesia is associated with increased likelihood of graft failure requiring regrafting, revision, or embolectomy. Others[57,61] have failed to replicate this result, and further prospective, randomized trials are required to verify this finding.

In the setting of lower extremity amputation, neuraxial anesthesia and peripheral nerve blockade have both been shown to significantly decrease perioperative pain.[62–65] A proposed additional benefit is a reduction in postoperative phantom limb pain, although this is not well supported by the literature with traditional perioperative management strategies. However, 1 promising observational study conducted by Borghi and colleagues[66] maintained sciatic and femoral perineural catheter infusions for a period of 4 to 83 days. Of patients compliant with the catheter protocol, 84% had zero pain at 1 year and only 39% had phantom limb phenomena, compared with the 60% to 70% of patients who experience phantom limb pain with traditional approaches.

Cutaneous innervation of the lower extremity is provided by the lumbar and lumbosacral plexi. The thigh is primarily innervated by the lumbar plexus, whereas the lumbosacral plexus provides innervation below the knee. The nerves of interest for most lower extremity bypass surgery are the femoral, a branch of the lumbar plexus, and sciatic, originating from the lumbosacral plexus. The lumbar plexus is composed of ventral rami from L1–L4, with a variable contribution from T12. The plexus itself is located deep to the psoas muscle adjacent to the transverse processes of lumbar vertebrae. The caudal portion of this plexus divides into the lateral femoral cutaneous, femoral, and obturator nerves responsible for leg innervation. The femoral nerve splits the iliopsoas muscle before coursing down the leg in the plane between the iliopsoas muscle and the fascia iliaca, just lateral to the femoral artery. The distribution of the femoral nerve includes sensory innervation to the anterior and medial thigh. The lumbosacral plexus is formed from ventral rami of L4-S3. From this plexus arises the sciatic nerve, which refers to the tibial and common peroneal nerves that course down the upper leg in a common sheath until they typically split at or near the popliteal fossa.[28]

The traditional means of providing regional anesthesia to the lower extremity is via epidural or intrathecal injection of local anesthetic. The involved dermatomes for bypass surgery are primarily L1–L4; a T10 level of anesthesia is achievable, with minimal hemodynamic compromise. A variety of local anesthetic solutions may be used for this purpose; discussion of these is beyond the scope of this article. Recently, performance of lower extremity bypass under peripheral nerve blockade was described. Yazigi and colleagues[67] provided a case series of 25 patients successfully undergoing infrainguinal bypass with combination femoral and sciatic nerve blockade, supplemented by intravenous midazolam. Astounding hemodynamic stability was observed in these patients, with only 2 requiring vasopressor support, and zero patients required conversion to general anesthesia. The investigators followed with a prospective, randomized study[68] comparing this technique with general anesthesia for infrainguinal bypass, which showed a statistically significant reduction in intraoperative myocardial ischemia, as defined by 1 minute or greater ST segment changes, in the group randomized to peripheral nerve blockade. Other approaches have included combined femoral, sciatic, and obturator blockade or combined psoas, sciatic, and T12-L1 paravertebral blockade.[69] Ultrasound-guided approaches to the femoral and sciatic nerve blocks are discussed here.

Femoral Nerve Blockade

Equipment

Sterile technique
10-cm block needle
20 mL of local anesthetic
Ultrasound guidance with a high-frequency linear probe

Patient preparation

The patient is positioned supine.

Technique best practices

Place the ultrasound probe in the inguinal crease, near the midline of the thigh. Identify the pulsatile femoral artery; the nerve lies laterally to this structure. The nerve should appear as a hyperechoic bundle at this level. The fascia iliaca appears as a thin hyperechoic strip superficial to the nerve and extending medial and deep to the artery (**Fig. 4**). Once the fascia iliaca is identified, the skin is prepared and a skin wheal made. The needle is advanced just deep to the fascia iliaca. Local anesthetic injected in this plane should be visualized coursing above or below the nerve and deep to the femoral artery. A catheter can be threaded to provide continuous analgesia.

Postprocedure care

Success of the block can be confirmed by assessing loss of sensation to pinprick over the anterior thigh and medial calf, as well as by assessing quadriceps femoris

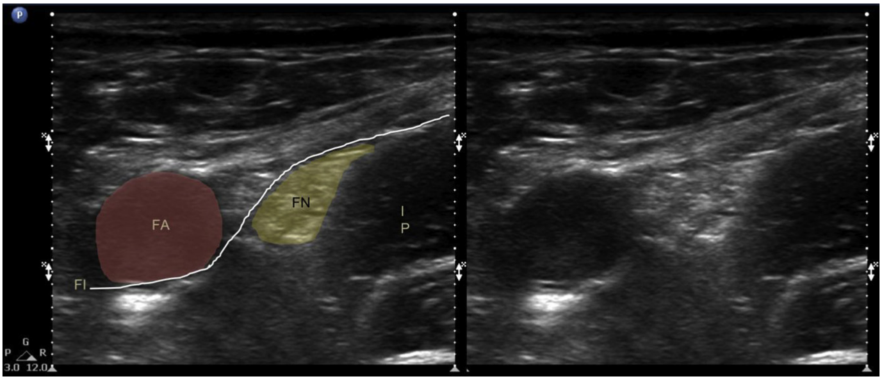

Fig. 4. The femoral nerve (FN) lies immediately lateral to the femoral artery (FA). The 2 are divided by the fascia iliaca (FI), leading to the characteristic spread of local anesthetic from the nerve under the artery. The iliopsoas muscle (IP) is also visualized.

weakness. The catheter should be secured with adhesive dressing. For postoperative pain management, an infusion of bupivacaine 0.125% or ropivacaine 0.2% is appropriate.

Avoiding complications

A 5.7% vascular puncture risk has been reported,[70] avoided best with optimal needle imaging and frequent aspiration. Weakness of the quadriceps muscle is expected, and fall precautions should be closely observed while this block is in place.

Sciatic Nerve Blockade

Several approaches (anterior, parasacral, transgluteal, and subgluteal) are available for ultrasound-guided proximal sciatic nerve blockade. Because the anterior approach is deep and less suitable for catheter techniques, and the parasacral approach without specific benefit, only the subgluteal and infragluteal approaches are described here.

Equipment

Sterile technique
10-cm block needle
20 to 30 mL of local anesthetic
Ultrasound guidance with a linear or curvilinear probe, depending on body habitus

Positioning

The patient may be positioned lateral, prone, or supine with leg elevated.

Technique best practices

The sciatic nerve can be blocked anywhere along its path as it courses down the leg. More proximal approaches are preferred to adequately cover the surgical site. Start the scan by placing the transducer transversely at the infragluteal crease. The sciatic nerve is then identified as an elliptical hyperechoic structure between the greater trochanter and ischial tuberosity under the gluteus maximus at the subgluteal level (Fig. 5). The nerve is found deep to the biceps femoris for more distal approaches. After sterile preparation and skin wheal formation, the needle is advanced toward the edge of the sciatic nerve. Injection around the sciatic nerve produces a circumferential pattern of local anesthetic. A catheter can be threaded to provide prolonged analgesia and sympathectomy.

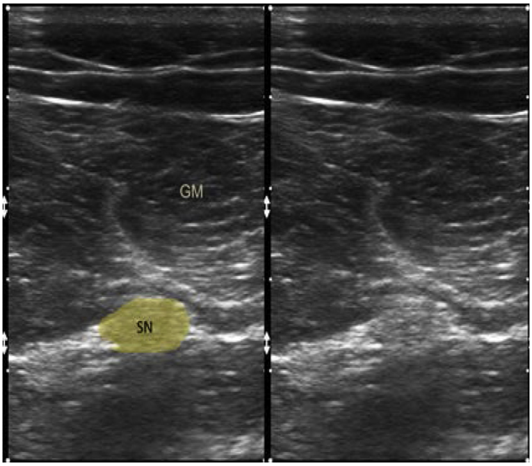

Fig. 5. The sciatic nerve (SN) appears as a hyperechoic bundle just deep to the gluteus muscle (GM).

Postprocedure care

Success of the block can be confirmed by assessing loss of sensation to pinprick on the posterior and lateral aspects of the calf. The catheter should be secured with adhesive dressing. For postoperative pain management, an infusion of bupivacaine 0.125% or ropivacaine 0.2% is appropriate.

Avoiding complications

Intraneural injection may be relatively common in sciatic nerve blockade, reported by Hara and colleagues[71] as occurring in 16% of patients, avoided by optimizing visualization of the needle tip and injecting with low pressure. Sciatic blockade is also associated with a 6.3% vascular puncture risk.[70]

AVF CREATION

A persistent problem with AVF creation is the approximate 25% failure rate.[72] Two important predictors for success of AVF maturation are vein diameter and blood flow.[72] Peripheral nerve blockade creates a sympathectomy, resulting in vasodilation, increased fistula blood flow, and perhaps decreased failure rate. Venodilation with regional anesthesia has been reported in numerous studies,[72–76] with percent dilation ranging from 8.7% to 35%. This vasodilation has been shown to improve site selection[77] and allow fistula creation in patients otherwise scheduled for arteriovenous grafting. Sahin and colleagues[78] performed a randomized, prospective trial comparing local infiltration with infraclavicular blockade for AVF surgery. Fistula flow was statistically significantly greater at 3 hours, 7 days, and 8 weeks after surgery in the infraclavicular patient group. Elsharawy and Al-metwalli,[79] alternatively, were unable to show a difference in graft failure rate comparing general anesthesia with brachial plexus block. Overall, a retrospective review article[72] from 2009 reported reduced vasospasm, shorter fistula maturation times, lower failure rates, and higher patency rates with regional blockade. Further, regional anesthesia has been associated with decreased anesthesia dedicated time for ambulatory upper extremity surgery.[80]

Brachial plexus block can be performed at a variety of levels to provide adequate anesthesia for AVF creation. Most cutaneous sensation to the surgical field for distal fistula creation is provided by the musculocutaneous and medial antebrachial cutaneous nerves. These 2 nerves were selectively anesthetized in case series,[81,82] providing adequate anesthesia for 75% and 83% of patients. The remaining required surgical supplementation when the surgical field drifted into radial nerve territory.

Most investigators perform nonselective brachial plexus block. The surgical field may include radial, axillary, and intercostobrachial nerve territory; the latter of which is not consistently blocked with all brachial plexus block approaches. Niemi and colleagues[83] compared axillary and infraclavicular brachial plexus blocks for AVF creation without significant difference in outcomes, although musculocutaneous blockade set in faster with infraclavicular block. Any approach (supraclavicular, infraclavicular, or axillary) to brachial plexus blockade is appropriate for AVF creation. A comparison of ultrasound-guided approaches to each block performed by Tran and colleagues[84] reported no differences in success rates or serious complication rates. Single and double injection techniques generate similar success with infraclavicular and supraclavicular blockade, whereas a double injection approach is adequate for axillary blockade. Supraclavicular or infraclavicular approaches are preferred to minimize needle passes in this population likely to receive anticoagulation. Overall, ultrasound-guided approaches are superior to blind or nerve-stimulating approaches.[85–87] A single-shot approach is generally adequate for this procedure. If the procedure is performed with a primary anesthetic, a surgical concentration of local anesthetic should be chosen. To block the medial skin of the upper arm for proximal AVF surgery, the infraclavicular block may be sufficient or may be supplemented by the intercostobrachial block.

Supraclavicular Nerve Blockade

Equipment

Sterile technique
5-cm to 10-cm 21-G block needle
20 to 30 mL of local anesthetic
Ultrasound guidance with a high-frequency linear probe

Patient preparation

Patient supine or semirecumbent, head turned away.

Technique best practices

Place the transducer parallel to the clavicle in the supraclavicular fossa. The subclavian artery should be identified in cross section, with the brachial plexus trunks seen as hypoechoic structures surrounding the artery laterally or superiorly (Fig. 6). The first rib is visualized as the hyperechoic line at the inferior margin of the artery. Apply color

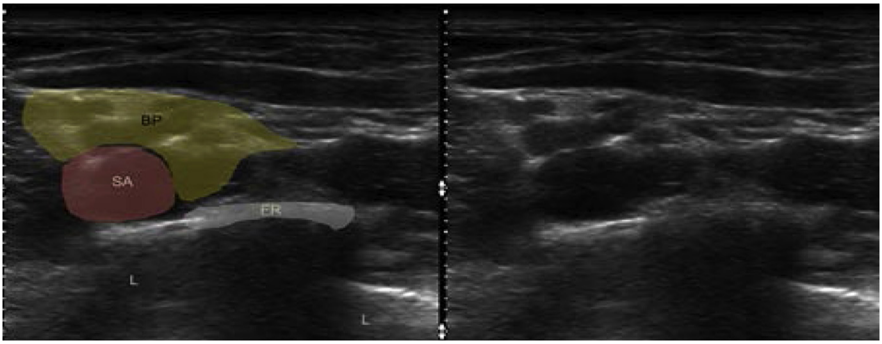

Fig. 6. Brachial plexus (BP) distribution surrounding the subclavian artery (SA). Note the proximity to the first rib (FR) and lung (L).

to assess the vessels that traverse the plexus. After sterile preparation and skin wheal formation, the needle is directed to the inferolateral edge of the subclavian artery, the corner pocket.[88] After negative aspiration, 20 mL of local anesthetic is injected. Sometimes, the plexus is separated by a fascial layer or vessel that prevents complete spread of the solution,[89] in which case, the needle should be redirected and solution injected to ensure that all parts of the plexus are exposed to local anesthetic.

Postprocedure care

Onset of the block can be confirmed early by assessing for vasodilation and relative warmth of the blocked limb. Loss of sensation to pinprick in the musculocutaneous and medial antebrachial nerve distribution as well as motor blockade confirms the onset of surgical anesthesia.

Infraclavicular Nerve Blockade

Equipment

Sterile technique
5-cm to 10-cm 21-G block needle
20 to 30 mL of local anesthetic
Ultrasound guidance with a high-frequency linear probe

Patient preparation

Patient supine or semirecumbent, head turned away, arm abducted 90° to displace clavicle.

Technique best practices

Place the transducer inferior to the clavicle, just medial to the coracoid process. Identify the pulsating subclavian artery. Rotate and adjust the angle of the probe to optimize the cross-sectional view of the vessel. Here, the lateral, posterior, and medial cords of the brachial plexus are visible surrounding the artery (Fig. 7). After sterile preparation and skin wheal formation, advance the needle toward the posterior aspect of the neurovascular bundle. A single injection posterior to the artery is adequate, unless initial spread does not create a reassuring U shape around the artery, in which case, the needle must be redirected and additional injection performed to account for this.

Postprocedure care

Onset of the block can be confirmed early by assessing for vasodilation and relative warmth of the blocked limb. Loss of sensation to pinprick in the musculocutaneous and medial antebrachial nerve distribution and motor blockade confirm the onset of surgical anesthesia.

Avoiding complications

Compared with supraclavicular blockade, the risk of phrenic nerve block or Horner syndrome is negligible.

Intercostobrachial Blockade

Equipment

Sterile preparation
5-cm to 10-cm block needle
10 mL of local anesthetic

Patient preparation

Patient supine, arm abducted 90°.

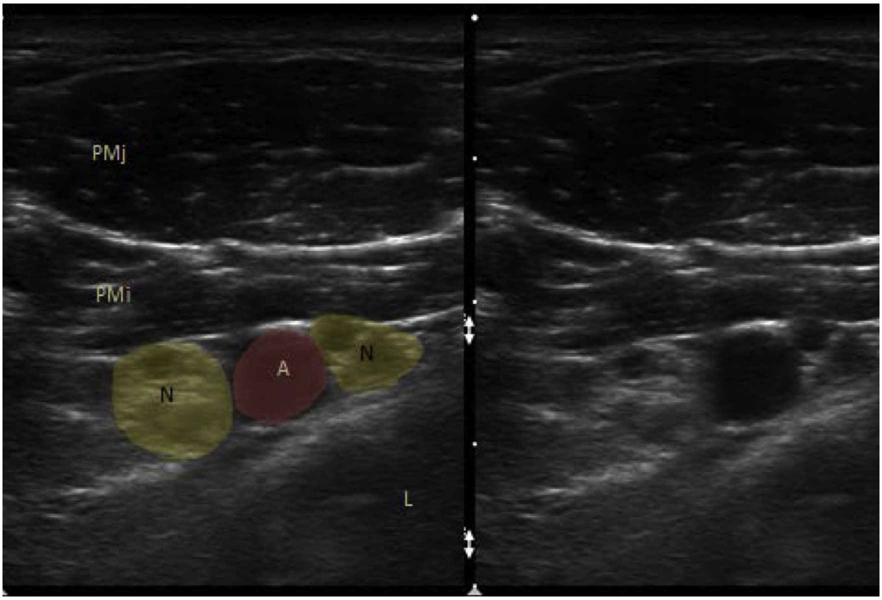

Fig. 7. Infraclavicular nerve block. Deep to pectoralis major (PMj) and minor (PMi) lies the brachial plexus (N) surrounding the axillary artery (A). The medial and lateral cords are clearly shown, whereas the posterior cord, deep to the artery, may be difficult to appreciate. Note the proximity to the lung (L).

Technique best practices
This block is performed as a subcutaneous field block within the axilla. After sterile preparation, the needle is inserted at the proximal aspect of the axilla and advanced subcutaneously to the inferior aspect. Local anesthetic is injected continuously as the needle is removed to form a linear skin wheal.

Postprocedure care
The onset of the intercostobrachial block is rapid and can be assessed by testing loss of sensation to pinprick over the medial upper arm.

Avoiding complications
No block-specific complications. Generalized complications of peripheral nerve blockade are avoided by remaining within the subcutaneous layer during needle advancement.

SUMMARY

Regional anesthesia is an acceptable modality to be used as the primary anesthetic technique or as an adjunct to general anesthesia for vascular surgery. When performed by the experienced anesthesiologist, these techniques may improve morbidity and analgesia and reduce hospital stays in this challenging patient population. Overall, however, data from randomized, controlled trials are lacking, and therefore, general anesthesia remains an appropriate alternative. The decision to use regional techniques should be made by the patient, surgeon, and anesthesiologist after an individualized discussion of the risk benefit profile for each patient and surgery.

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