Peripheral Nerve Block Techniques for Ambulatory Surgery

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Peripheral nerve blocks (PNBs) have an increasingly important role in ambulatory anesthesia and have many characteristics of the ideal outpatient anesthetic: surgical anesthesia, prolonged postoperative analgesia, and facilitated discharge. Critically evaluating the potential benefits and supporting evidence is essential to appropriate technique selection. When PNBs are used for upper extremity procedures, there is consistent opioid sparing and fewer treatment-related side effects when compared with general anesthesia. This has been demonstrated in the immediate perioperative period but has not been extensively investigated after discharge. Lower extremity PNBs are particularly useful for procedures resulting in greater tissue trauma when the benefits of dense analgesia appear to be magnified, as evidenced by less hospital readmission. The majority of current studies do not support the concept that a patient will have difficulty coping with pain when their block resolves at home. Initial investigations of outpatient continuous peripheral nerve blocks demonstrate analgesic potential beyond that obtained with single-injection blocks and offer promise for extending the duration of postoperative analgesia. The encouraging results of these studies will have to be balanced with the resources needed to safely manage catheters at home. Despite supportive data for ambulatory PNBs, most studies have been either case series or relatively small prospective trials, with a narrow focus on analgesia, opioids, and immediate side effects. Ultimately, having larger prospective data with a broader focus on outcome benefits would be more persuasive for anesthesiologists to perform procedures that are still viewed by many as technically challenging.

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As ambulatory surgery continues to grow in scope, more invasive and painful surgeries are being performed. These include procedures such as shoulder arthroplasty, multi-ligament knee reconstruction, and ankle arthrodesis. The challenge for ambulatory anesthesiologists is to provide anesthesia that achieves home readiness within hours of surgery concurrent with prolonged postoperative analgesia after discharge home. The use of modern, fast-acting anesthetics has facilitated the efficient discharge of an alert outpatient; however, analgesia may still be insufficient. Apfelbaum et al. (1) quantified the frequent inadequacies of outpatient pain management in a nationwide survey. They noted that 78% of all respondents experienced pain. This pain was rated as moderate by 52%, severe by 22% and extreme by 7% of those surveyed.

Peripheral nerve blocks (PNBs) possess many characteristics of the ideal outpatient anesthetic. They provide site-specific surgical anesthesia and minimize the need for general anesthesia (GA). By providing dense analgesia, opioid requirements are reduced, as are opioid-related side effects. A comfortable, symptom-free patient can be discharged home in a timely fashion. As part of a multimodal approach to postoperative pain management, PNBs with long-acting local anesthetic (LA) can provide prolonged analgesia. The placement of a perineural catheter and subsequent continuous LA infusion at home can further lengthen the period of postoperative analgesia.

Despite these benefits, regional anesthesia is relatively under-used in the ambulatory environment. In a study examining data from the National Center for Health Statistics, Dexter and Macario (2) noted that regional anesthetics were used in only 8% of ambulatory cases. Issues such as technique selection, additional time for block performance, delayed onset time, variable reliability, and perceived lack of outcome benefit may all influence anesthesiologists to avoid PNBs. Further, many investigations of PNBs have

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been performed without attention to the special anesthetic considerations of outpatients.

In this article, we discuss clinical applications of common PNB techniques and continuous perineural infusions. Patients discharged the day of surgery, within 23 h, or those that could meet these criteria have been included. The literature available on the use of each technique in the ambulatory environment will be summarized and analyzed with respect to the potential benefits and deterrents to the use of regional anesthesia in busy ambulatory practices.

Upper Extremity Techniques

Interscalene Brachial Plexus Block

The interscalene block is a proximal approach to the brachial plexus performed at the level of the C6 nerve root. Its popularity and utility stem from the excellent anesthesia it provides for painful orthopedic and vascular procedures of the shoulder and upper arm and the analgesia it supplies after discharge.

Advantages of the interscalene block have been extensively studied in inpatients and many of these benefits can be extrapolated to outpatients. Nevertheless, given the frequent use of this anesthetic technique in outpatients and the special considerations unique to this patient population, it is surprising how few prospective studies and randomized controlled trials exist (Table 1). To address this deficit in the literature, Hadzic et al. (3) recently conducted a prospective study in which patients having open rotator cuff repair were randomized to interscalene block or “fast-track” GA. A number of benefits were attributed to the interscalene block in the immediate postoperative period. Patients who received an interscalene block more frequently bypassed the phase 1 postanesthesia care unit (PACU) and were less likely to have moderate or severe pain or to require analgesia interventions. This group also had less frequent postoperative nausea and vomiting (PONV) and sore throat. Patients in this group had a faster time to ambulation, oral intake, home readiness, and actual discharge all by more than 2 h when compared with the GA group. Despite these benefits and the use of ropivacaine, a long-acting LA, no difference was observed between groups in pain visual analog scale (VAS) scores or opioid consumption at 24, 48, and 72 h.

Two groups have published retrospective reports comparing interscalene block as the sole anesthetic technique versus GA for shoulder surgery. Brown et al. (4) documented a high degree of patient acceptance with excellent intraoperative analgesia and muscle relaxation in their interscalene block group. More importantly, these patients had less pain, PONV, and urinary retention and fewer unanticipated hospital admissions compared with those who received GA. D’Alessio et al. (5) demonstrated reductions in nonsurgical intraoperative time by 20 min and PACU time by 30 min among patients who received an interscalene block in a preoperative holding area compared to those who received GA. The interscalene block group also had fewer unplanned admissions for treatment of pain, sedation, or PONV.

An interscalene block can also be used with GA to provide intraoperative and postoperative analgesia for shoulder surgery. This has been supported by several prospective studies. In a placebo-controlled trial involving outpatient shoulder arthroscopy, Al-Kaisy et al. (6) documented the efficacy of an interscalene block for analgesia. They found lower pain VAS scores between 20 and 120 min after completion of surgery, less morphine use in the PACU, delayed first dose of analgesic by more than 2 h, and shorter time to reach discharge criteria in the treatment group compared with placebo. After block resolution after 2 h, no difference in analgesic requirements over 24 h was noted. In a similar study, Laurila et al. (7) demonstrated the advantage of an interscalene block over a subacromial bursa block and placebo for early postoperative pain control. In a group of patients having arthroscopic acromioplasty, Singelyn et al. (8) randomized patients to interscalene block, suprascapular nerve block, intraarticular LA, or parenteral opioids for postoperative analgesia. An evaluation of pain scores and opioid consumption showed the interscalene block was most effective, the suprascapular block was an appropriate alternative, and intraarticular LA injection offered no benefit compared to parenteral opioids.

The reported incidence of technique failure for interscalene block ranges from 0% to 9.5% (4–6,9) and conversion to GA in up to 16% (4). Transient Horner’s syndrome, hoarseness, and dyspnea, although frequent (4,10), rarely impede discharge. And although there are few data for outpatients, studies involving inpatients have demonstrated a low risk of neurologic injury (11). Overall, the use of interscalene block for shoulder surgery is supported by the favorable safety profile, clinical efficacy, and data consistently demonstrating positive results.

Although a single-injection interscalene block provides effective intraoperative anesthesia, this technique is limited by the finite period of analgesia provided and the onset of pain as block resolution occurs. During this transition oral opioids alone may not replicate the same level of analgesia for painful procedures. Wilson et al. (9) prospectively followed 50 patients and demonstrated the challenge of providing analgesia at home after interscalene block for shoulder procedures. When the block resolved, 33% had a pain VAS score of 4 or 5 of 5 and 2 patients subsequently contacted a health care provider for further analgesia.

Table 1. Summary of Selected Randomized Trials Involving Interscalene Block in Outpatient Surgery

			Results ISB vs. Comparison Group		
Author	Population	Protocol	Analgesia	Side Effects	Discharge
Hadzic et al. (3)	n = 50 Open rotator cuff repair	ISB 40 mL 0.75% ropivacaine vs. fast-track GA	VAS > 3: 0 vs. 64% ($P < 0.001$) Treatment for pain: 0 vs. 80% ($P < 0.001$)	Nausea: 12% vs. 44% ($P = 0.02$) Sore throat: 16% vs. 48% ($P = 0.03$)	Phase 1 PACU bypass: 76% vs. 16% ($P < 0.001$) Home readiness: 113 ± 55 min vs. 270 ± 101 min ($P < 0.001$) Unanticipated admissions: 0 vs. 16% ($P < 0.05$)
Al-Kaisy et al. (6)	n = 30 Shoulder arthroscopy	All receive GA ISB 10 mL 0.125% bupivacaine vs. ISB 10 mL placebo	Lower VAS 20–120 min ($P < 0.05$) Morphine consumption in PACU: 2.7 ± 2.6 mg vs. 9.5 ± 5.2 mg ($P < 0.05$)		Home readiness: 139 ± 34 min vs. 193 ± 59 min ($P = 0.005$)
Laurila et al. (7)	n = 45 Shoulder arthroscopy	All received GA 15 mL 0.5% ropivacaine Interscalene block vs. Subacromial bursa block vs. placebo	Early postop VAS lower at rest ($P < 0.05$) and with movement ($P < 0.02$) Oxycodone use 1st 6 h: 6 mg ISB vs. 24.1 mg subacromial block vs. 27 mg placebo ($P \leq 0.001$)		
Singelyn et al. (8)	n = 120 Shoulder arthroscopy	All received GA 0.25% bupivacaine for ISB 20 mL vs. suprascapular nerve block 10 mL vs. Intraarticular block 20 mL vs. no block	ISB lower VAS at 4 and 24 h ($P < 0.01$) ISB less morphine in PACU ($P = 0.0008$) and 24 h ($P = 0.004$)	ISB less PONV ($P < 0.05$)	

ISB = interscalene block; GA = general anesthesia; VAS = visual analog pain scale; PACU = postanesthesia care unit; PONV = postoperative nausea and vomiting.

To address these problems and extend the duration of analgesia postoperatively, several groups have reported the use of continuous interscalene block in outpatients. This technique provides the greatest benefit after painful ambulatory shoulder procedures. In a prospective, randomized, placebo-controlled trial, Klein et al. (12) studied patients having open rotator cuff repair and/or biceps tenodesis during 1 24-h admission. All patients received an interscalene block as the sole intraoperative anesthetic and were then randomized postoperatively to receive continuous infusion of ropivacaine or saline through an interscalene catheter. Pain scores and opioid use were low in both groups until the surgical block resolved. Subsequently, morphine consumption was 50% less and pain VAS scores were reduced in the group that received the ropivacaine infusion. A comparable study by Ilfeld et al. (13) on patients at home had similar favorable results. This group also found that patient satisfaction was higher in the ropivacaine group. In

Table 2. Summary of a Randomized Trial Involving Infraclavicular Block in Outpatient Surgery

			Results Infraclavicular vs. Comparison Group		
Author	Population	Protocol	Analgesia	Side Effects	Discharge
Hadzic et al. (23)	$n = 50$ Hand or wrist surgery	Infraclavicular block 40 mL 3% 2-chloroprocaine vs. "Fast-track" GA	VAS > 3 on arrival in PACU: 3% vs. 43% ($P < 0.001$)	PONV: 8% vs. 32% ($P = 0.001$) Sore throat: 4% vs. 36% Inability to concentrate in PACU: 8% vs. 56% ($P < 0.001$)	Phase 1 PACU bypass: 76% vs. 24% ($P = 0.001$) Home readiness: 100 ± 44 min vs. 203 ± 91 min ($P = 0.001$)

GA = general anesthesia; VAS = visual analog pain scale; PACU = postanesthesia care unit; PONV = postoperative nausea and vomiting.

another prospective investigation, Nielsen et al. (14) studied a series of patients who had an interscalene block for open rotator cuff surgery. This was followed by continuous ambulatory interscalene block for 72 h for analgesia. They documented an increase in the mean number of hours of sleep per night from 5 h preoperatively to 7 h over the first 3 days. There was also evidence that cognitive function was maintained at or better than baseline levels. Infrequent neurologic complications, as documented in the inpatient population, also lends support to the use of continuous perineural infusions (11). Extrapolating this safety to unmonitored patients at home, however, is premature.

When considering the most appropriate perineural LA infusion regimen, prescription must be individualized based on patient physiology and surgical procedure. Although there are clinical studies of infusion strategies, these can be difficult to compare because investigators often use disparate measures of success, and the accuracy of catheter placement is rarely confirmed. The specific needs of the outpatient require that infusion regimens balance analgesic efficacy, undesired motor block, and duration of infusion (based on the volume of the LA reservoir) (15).

Further investigation into the ideal management of home continuous peripheral nerve blocks (CPNBs) is needed. Initial practices have been extrapolated from inpatient management and there are limited data confirming outpatient efficacy. Strategies to maximize analgesic benefits and prevent secondary failures, injury to the blocked limb, and catheter infection are essential. In a recent case report, Sardesai et al. (16) identified some challenges inherent in outpatient interscalene CPNB. They described a patient who developed phrenic nerve palsy and lobar collapse after interscalene CPNB. When the patient was readmitted for presumed pneumonia, the anesthesiologists had to educate the other physicians about continuous interscalene block and its effects on the diaphragm.

The prevalence of shoulder surgery and the beneficial effects of interscalene block support the use of this technique in ambulatory surgery. Nevertheless, large, prospective studies evaluating the use of this PNB in outpatients are required.

Supraclavicular Brachial Plexus Block

The supraclavicular block is performed at the trunks of the brachial plexus. Here the plexus is tightly bundled and invested in dense fascia before diverging under the clavicle and over the first rib. Anesthesia of the upper extremity is achieved although inconsistent blockade of the axillary nerve limits routine use for shoulder procedures (17). Timely onset (18) and reliable anesthesia make this block appealing for use for elbow, forearm, wrist, and hand procedures in a rapid-paced ambulatory setting. Yet despite these advantages, the supraclavicular block has been inadequately studied in outpatients. This may be because of anecdotal reports of pneumothorax with the plumb-bob technique; nevertheless, no data substantiate this risk or illustrate further risk if a patient is discharged after a stable perioperative course. Furthermore, Franco and Vieira (19) documented safety in a series of 1001 supraclavicular blocks performed by both consultants and residents. No clinical pneumothorax or major complications occurred and the success rate was 97.2%. The final patient disposition was not specified. Single injection and continuous supraclavicular blocks may be under-used in ambulatory surgery and could be valuable techniques to include in routine practice.

Infraclavicular Brachial Plexus Block

The infraclavicular block is performed at the level of the divisions and cords of the brachial plexus where they envelope the subclavian artery. As with supraclavicular and axillary blocks, this block is suitable for elbow, forearm, wrist, and hand procedures. Like the supraclavicular block, there is frequent success and rare incidence of pneumothorax (20–22).

Hadzic et al. (23) prospectively compared infraclavicular block alone to fast-track GA for outpatient hand and wrist surgery (Table 2). The infraclavicular block reduced in-hospital pain scores and allowed more frequent phase 1 PACU bypass. Analgesia requests and PONV were rare among block patients.

Table 3. Summary of Selected Randomized Trials Involving Axillary Block in Outpatient Surgery

			Results Axillary vs. Comparison Group		
Author	Population	Protocol	Analgesia	Side Effects	Discharge
McCartney et al. (32)	$n = 100$ Hand surgery	AxB 10 mg/kg 1.5% lidocaine vs. GA	Lower pain VAS scores 0–120 min Lower IV and oral opioid use in hospital ($P < 0.01$) No difference pain or opioid use days 1, 7, or 14	PONV: 6% vs. 24% ($P < 0.05$)	Fast-track eligible: 98% vs 54% ($P < 0.001$) Faster home readiness ($P < 0.05$)
Chan et al. (33)	$n = 126$ Hand surgery *Prospective Not randomized	AxB 50 mL 3% 2-chloroprocaine/ 2% lidocaine vs. IVRA vs. GA	Treatment for pain: 43% AxB vs. 51% IVRA vs. 85% GA ($P < 005$)	PONV: 12% AxB vs. 18% IVRA vs. 62% GA ($P < 0.05$)	Time to discharge: 244 ± 68 min AxB vs. 180 ± 58 min IVRA vs. 240 ± 75 min GA ($P < 0.05$) 30% cost savings with IVRA

AxB = axillary block; GA = general anesthesia; VAS = visual analog pain scale; PONV = postoperative nausea and vomiting; IVRA = intravenous regional anesthesia.

The nerve block reduced time to oral intake and nearly halved the time to home readiness, but analgesic consumption in the first 48 h was unaffected because of the use of 3% 2-chloroprocaine.

In a large, prospective, descriptive series of primarily outpatients, Desroches (24) demonstrated a 91% success rate and a 0.7% incidence of pneumothorax. The risk of non-compressible vascular puncture (up to 17%) may limit this approach in certain patient populations (25).

Continuous infraclavicular blocks can prolong postoperative analgesia after distal upper extremity procedures. Several prospective studies have documented the successful application of this technique in ambulatory patients (26,27). Ilfeld et al. (26) studied patients who had an infraclavicular block with short-acting LA for procedures involving or distal to the elbow. They randomized patients to receive a continuous infraclavicular infusion of 0.2% ropivacaine or saline. The ropivacaine group had reduced pain scores and smaller opioid requirements for the duration of the infusion as well as a decreased incidence of PONV and sedation on the day of surgery. They also had fewer sleep disturbances after surgery. These advantages resulted in higher patient satisfaction in the ropivacaine group and a greater willingness to repeat this technique in the future.

Continuous infraclavicular block has the advantage of an immobile insertion point. This limits the risk of dislodgement and facilitates insertion site cleanliness and sterility, issues that are concerns in outpatients. An additional benefit includes the ability to perform this block with the patient's arm in a neutral position. Ultimately, however, the usefulness and popularity of interscalene and axillary blocks and the minimal advantage over the supraclavicular block may preclude the widespread use of the infraclavicular block in outpatients.

Axillary Brachial Plexus Block

The terminal nerves of the brachial plexus are contained with the axillary artery in a common sheath (28,29). The artery is easily palpable and serves as a useful landmark for the axillary block. The paresthesia, transarterial, and nerve stimulator techniques have all been used successfully for elbow, forearm, wrist, and hand procedures. Ease of performance, favorable safety profile, and prevalence of hand surgery contribute to making this the most commonly performed PNB in the United States (30,31). Despite this popularity, it is interesting that there are not more randomized, controlled trials devoted to outpatients. As with many PNBs, the perceived benefits are often extrapolated from the inpatient literature.

McCartney et al. (32) demonstrated the advantages of an axillary block with lidocaine compared with fast-track GA in a randomized trial involving 100 hand surgery patients. Combined anesthesia and surgery time was almost 20 min shorter in the axillary block group. Efficiency advantages extended into the postoperative period when axillary block patients were more likely to be fast-tracked and had shorter postoperative hospital length of stay by 40 min. In the axillary block group there was a longer time to first requested analgesic by 68 min, less opioid use, and decreased pain VAS scores. The axillary block group also had less frequent PONV. Perhaps related to the use of a short-acting LA for the axillary block, there was no difference between groups in pain, analgesic consumption, PONV, or satisfaction at 24 h, 7 days, or 14 days.

In a similar prospective study, this group (33) compared axillary block with IV regional anesthesia (IVRA) and GA. Both the axillary and IVRA groups required less opioid and had a decreased incidence of PONV compared with the GA group. Interestingly, induction time, overall discharge time, and cost were least in the IVRA. As described above, the use of short-acting LA for the axillary block may have limited further benefit of this technique over the IVRA.

The clinical utility, efficacy and complications of the axillary block have also been described in two large retrospective series involving outpatients. Among 530 blocks, Davis et al. (34) documented frequent success with infrequent complications. Cooper et al.'s group (35) established high patient satisfaction with this technique.

Individual nerve sparing and delayed onset are the greatest deterrents to use of the axillary block in a rapid-paced ambulatory practice. Block placement in a designated block area before surgery provides more time for onset and contributes to operating room efficiency (36). Another strategy to hasten block onset and minimize the likelihood of an incomplete block involves multiple stimulation of individual nerves at the midhumeral level (37). Bouaziz et al. (38) prospectively studied this technique. They used 0.5% bupivacaine for ulnar and median nerve blocks and 2% lidocaine for the remaining nerves to produce selective palmar incisional anesthesia of long duration and early return of function in the area outside of the surgical field. Although routine adoption of the multiple stimulation technique over the single injection technique remains controversial, Koscielniak-Nielsen et al. (39) showed that multiple stimulation is well tolerated by unpremedicated outpatients.

Continuous axillary brachial plexus block was one of the first perineural catheter sites investigated to prolong analgesia at home (40). Rawal et al. (40) prospectively evaluated the feasibility of continuous axillary block for hand surgery. They had patients self-administer 10-mL boluses of LA when they experienced pain. They documented few technical problems and high satisfaction. In another randomized, double-blind study (41), this group compared dilute bupivacaine versus ropivacaine for axillary infusions and demonstrated similar analgesic benefit with both drugs as well as minimal opioid-related side effects. Of advantage to the ambulatory patient, these solutions resulted in limited motor block after the initial dose resolved.

The ease of performance and safety profile of the axillary block supports the use of this technique in outpatients. Nevertheless, strategies will have to be developed to deal with issues such as prolonged onset, incomplete block resulting from nerve sparing, and risk of catheter dislodgement and infection with continuous techniques.

Lower Extremity Techniques

Lumbar Plexus Block

The lumbar plexus is formed from the L1-4 nerve roots and gives rise to the ilioinguinal, iliohypogastric, genitofemoral, femoral (saphenous), obturator, and lateral femoral cutaneous nerves. These nerves provide sensation to the lower abdomen, groin, anteromedial and lateral thigh, and medial calf. The femoral and obturator nerves also supply the knee joint. Motor innervation is supplied to the lower abdomen, hip flexors, thigh adductors, and quadriceps muscles. Three recent articles provide an extensive review of the anatomy and approaches to the lumbar plexus (42–44).

Psoas Compartment Block (Posterior Approach to the Lumbar Plexus)

The psoas compartment block provides consistent coverage of the femoral, obturator, and lateral femoral cutaneous nerves (45). In the lateral decubitus position, the needle is inserted in a paramedian direction at the L3-5 level.

Two prospective trials have compared psoas compartment block and GA or subarachnoid block (SAB) in patients having knee arthroscopy (Table 4). Hadzic et al. (46) randomized patients to receive either a combined psoas compartment block and sciatic nerve block or a GA. They found an incidence of moderate to severe PONV of 12% with combined psoas compartment and sciatic blocks versus 62% with fast-track GA that included prophylactic dolasetron. The combined nerve blocks reduced sore throat, increased ability to bypass phase 1 PACU, and reduced time to meet discharge criteria. Although the PNBs increased induction time by 7 min, no difference in total operating room time was observed. In a similar study, Jankowski et al. (47) randomized patients to receive psoas compartment block (but no sciatic block), GA, or SAB. They found that supplemental analgesics were required in 45% of patients receiving a GA compared with only 14% receiving SAB and 21% receiving psoas compartment block. In addition, the GA group had higher pain scores at 30, 60, 90, and 120 min. However, because the median pain scores were low in all groups, they concluded that a lumbar plexus block for

Table 4. Summary of Selected Randomized Trials Involving Lumbar Plexus Block in Outpatient Surgery

			Results Lumbar Plexus Block vs. Comparison Group		
Author	Population	Protocol	Analgesia	Side Effects	Discharge
Hadzic et al. (46)	$n = 50$ Knee arthroscopy	LP 30 mL 3% 2-chloroprocaine and SNB 20 ml 3% 2-chloroprocaine vs. fast-track GA	VAS > 3: 16 vs. 48% ($P = 0.02$)	Nausea: 12% vs. 62% ($P = 0.001$) Sore throat: 28% vs. 60% ($P = 0.045$)	Phase 1 PACU bypass: 72% vs. 24% ($P < 0.002$) Home readiness: 131 ± 62 min vs. 205 ± 94 min ($P = 0.002$)
Jankowski et al. (47)	$n = 60$ Knee arthroscopy	LP 40 mL 1.5% mepivacaine vs. SAB vs. GA	LP and SAB lower VAS than GA 30–120 min ($P < 0.001$) LP and SAB median pain score 0 30–120 min		PACU bypass: 95% LP vs. 100% SAB vs. 35% GA ($P < 0.001$)

LP = Lumbar plexus block; SNB = sciatic nerve block; GA = general anesthesia; VAS = visual analog pain scale; PACU = postanesthesia care unit; SAB = subarachnoid block.

postoperative analgesia might not have been necessary for knee arthroscopy.

A lumbar plexus block can also be used for more invasive and painful ambulatory hip and knee procedures such as knee ligament reconstruction (48). Surprisingly, there are few studies investigating the use of single injection lumbar plexus blocks for these procedures. This may reflect the lack of popularity of this technique for outpatients for two reasons. First, iliopsoas muscle block creates weak hip flexors, making crutch walking difficult or requiring the use of a walker. Second, there is a 1.8%–8.9% risk of epidural spread (49,50) attributed to the paravertebral needle insertion point. These complications can potentially impede discharge.

The use of a lumbar plexus CPNB can provide intense postoperative analgesia for outpatients having major lower extremity surgery. It is in this patient population that home CPNBs have the greatest potential, yet few studies in this area exist. A single case series describes the use of continuous lumbar plexus and sciatic nerve blocks for ambulatory multiligament knee reconstructions (51). Profound analgesia enables outpatient care for procedures that otherwise require hospital admission; consequently, significant cost savings can result.

Femoral Nerve Block

The femoral nerve can be blocked at the inguinal ligament using a femoral nerve block or a fascia iliaca block. In the supine position, the femoral nerve is superficial and the femoral nerve block landmarks are simple. This PNB provides anesthesia to the anteromedial thigh, anterior knee, and medial calf, resulting in broad utility for knee procedures and making the femoral nerve block the most common lower extremity single injection block (31). Increasing volume and applying distal pressure have been attempted to direct LA cephalad to block the three main nerves of the lumbar plexus (described as the "3-in-1" block) (52). This technique, however, inconsistently blocks the lateral femoral cutaneous and obturator nerves (45,53–55).

Investigators have studied the femoral nerve block for knee arthroscopy and, depending on the comparison group and LA, success has been variable (56,57). Patel et al. (57) randomized subjects into three groups: 1) GA, 2) femoral nerve block with a lateral femoral cutaneous nerve block, or 3) femoral nerve block with a sham lateral femoral cutaneous nerve block (Table 5). The nerve blocks reduced the incidence of postoperative pain from 27% to 3% compared with GA. In addition, the PNB groups achieved faster discharge times. Broader anesthesia resulted from the addition of the lateral femoral cutaneous nerve block when compared with the femoral nerve block alone and this provided improved intraoperative conditions. In a study of similar design, Goranson et al. (56) randomized patients to receive an intraarticular injection of LA alone, a femoral nerve block alone, or both an intraarticular and femoral nerve block. Interestingly, all techniques provided acceptable intraoperative anesthesia, excellent surgical conditions, and similar postoperative analgesia. Patient satisfaction was universally high.

The analgesic potential of femoral nerve blocks may be even greater when they are used for more painful surgical procedures, such as anterior cruciate ligament (ACL) reconstruction. In a prospective trial, Mulroy et al. (58) examined 55 patients having ACL repair with

Table 5. Summary of Selected Randomized Trials Involving Femoral Nerve Block in Outpatient Surgery

			Results FNB vs. Comparison Group		
Author	Population	Protocol	Analgesia	Side Effects	Discharge
Patel et al. (57)	$n = 90$ Knee arthroscopy	1.5% Lidocaine/1.5% Mepivacaine FNB and LFCN block vs. FNB and placebo LFCN block vs. GA	Treatment of pain: 3% vs. 27% ($P < 0.05$)		Discharge time shorter for FNB groups: 57.3 ± 9.2 min vs. 55.2 ± 9.6 min vs. 95.3 ± 10.3 min GA ($P < 0.05$)
Goranson et al. (56)	$N = 60$ Knee arthroscopy	FNB (2% 3-chloroprocaine) and placebo portal and IA injections vs. FNB and portal and IA injections vs. portal and IA injections and placebo FNB	Similar VAS and opioid use		No difference discharge times
Mulroy et al. (58)	$n = 55$ Knee ACL reconstruction	All had epidural and IA injection FNB 0.25% bupivacaine vs. FNB 0.5% bupivacaine vs. Sham FNB	FNB lower early VAS ($P = 0.03$) FNB lower early opioid use ($P = 0.04$) Analgesia duration similar with FNBs: 23.2 ± 7 h 0.25% vs. 25.7 ± 22 h 0.5%	Halted enrollment in sham group due to increased pain	
Iskandar et al. (59)	$n = 80$ ACL with hamstring graft	All had GA 20 mL 1% ropivacaine FNB vs. IA injection	PACU VAS: 31 ± 6 vs. 50 ± 15 ($P = 0.001$) Rehab VAS: 32 ± 6 vs. 55 ± 10 ($P < 0.001$) Morphine use: 4.7 ± 2 mg vs. 3.7 ± 4.5 mg ($P < 0.001$)	PONV: 7.5% vs. 27.5% ($P = 0.037$) Sedation: 2.5% vs. 20% ($P = 0.03$)	

FNB = femoral nerve block; LFCN = lateral femoral cutaneous nerve block; GA = general anesthesia; VAS = visual analog pain scale; PACU = postanesthesia care unit; PONV = postoperative nausea and vomiting; IA = intraarticular.

epidural and intraarticular anesthesia. In the PACU they were randomized to receive femoral nerve block with 0.25% or 0.5% bupivacaine or a sham femoral block when the epidural resolved. There was superior postoperative analgesia in the block groups, whereas 6 of 12 patients in the sham group reported pain VAS scores ≥5 of 10, halting enrollment in this arm of the study. Iskandar et al. (59) also found better pain control as well as reduced opioid use and fewer opioid-related side effects associated with femoral nerve block when compared with intraarticular LA for patients having ACL repair with hamstring graft. Nevertheless, when hamstring graft is used for ACL repair, a significant component of postoperative pain can arise from the sciatic nerve distribution. In these circumstances, some investigators have found that femoral nerve block alone may not provide a significant advantage over placebo (60).

Strong support for the use of a femoral nerve block and the addition of a sciatic nerve block for more extensive knee surgery is evidenced in a large retrospective study by Williams et al. (61). They examined 1200 consecutive outpatients having knee surgery and categorized patients according to surgical intensity.

Table 6. Summary of Selected Randomized Trials Involving Proximal Sciatic Nerve Block in Outpatient Surgery

			Results Proximal Sciatic Block vs. Comparison Group		
Author	Population	Protocol	Analgesia	Side Effects	Discharge
Casati et al. (64)	$n = 120$ Knee arthroscopy	FSB (2% mepivacaine) vs. GA vs. SAB1	Treatment for pain: 0 vs. 10% ($P = 0.07$)	Time to urination greatest with SAB ($P < 0.0005$)	Home readiness: 265 min vs. 170 min vs. 230 min ($P < 0.026$)
Casati et al. (63)	$n = 40$ Knee arthroscopy	All had intraarticular LA FSB (2% mepivacaine) vs. Fast-track GA	PACU VAS: 0 vs. 7 mm ($P = 0.005$)	Intraop hypotension: 0% vs. 36% ($P = 0.013$)	PACU bypass: 50% vs. 5% ($P = 0.003$)
Cappelleri et al. (65)	$n = 50$ Knee arthroscopy	FSB (2% mepivacaine) vs. Unilateral SAB		Time to urination: 145 ± 36 min vs. 240 ± 90 min ($P = 0.0001$)	Time to ambulation: 217 ± 49 min vs. 166 ± 44 min ($P = 0.002$)

FSB = femoral sciatic block; GA = general anesthesia; SAB = subarachnoid block; LA = local anesthesia; PACU = postanesthesia care unit; VAS = visual analog pain scale.

Although they found that femoral nerve blocks alone provided little benefit for simple procedures like arthroscopy, they documented improved analgesia and reduced unanticipated hospital admissions when this technique was used for more invasive and painful procedures, such as ligament repairs. Regression analysis demonstrated that, in this subgroup, the addition of a sciatic nerve block conferred even better postoperative analgesia and fewer hospital admissions. More importantly, patients who had complex knee surgery without PNBs had a 4–6 times increased chance of requiring hospital admission. More recently, this group concluded that if nerve blocks were used for all ACL repairs (250 per year in their institution), if 82% of patients bypassed PACU and if 4% had an unplanned admission this would equate to $98,600 in annual cost savings (62).

There are few investigations that evaluate the use of continuous femoral nerve blocks in ambulatory surgical patients. This technique can provide postoperative analgesia for major knee procedures while preserving hip flexors and enabling crutch walking. Catheter dislodgement and insertion site infection remain concerns in the outpatient population.

Although a femoral nerve block provides effective intraoperative anesthesia for minor procedures (such as knee arthroscopy), advocating its use based on superior postoperative analgesia may not be warranted given the small degree of postoperative pain and the effectiveness of alternative analgesics. However, for more extensive knee surgery, the data do demonstrate analgesic benefit from this block.

Sciatic Nerve Block

The sciatic nerve is formed from the L-4, L-5 and S1, 2, 3 ventral rami and has three functional and anatomical parts: the posterior cutaneous nerve of the thigh, the tibial nerve, and the common peroneal nerve. Proximal sciatic nerve block techniques (e.g., classic) provide motor block of the hamstring muscles as well as ankle and toe flexors and extensors. Sensory block is accomplished for the posterior thigh, posterior knee, anteroposterolateral calf and foot, as well as part of the knee joint. Distal approaches to the sciatic nerve block (e.g., popliteal fossa block) spare the hamstrings and sensation to the back of the thigh.

For leg and foot surgery, sciatic nerve block consistently provides excellent analgesia. Despite this, a survey of Society of Ambulatory Anesthesia members showed only 10.5% of respondents would routinely perform an outpatient sciatic nerve block with long-acting LA (31). Interestingly, respondents were more likely to be younger and work at a teaching hospital, perhaps reflecting advantages relating to acquisition and maintenance of regional anesthesia skills.

Proximal Sciatic Nerve Block

A proximal sciatic nerve block is often used to supplement a psoas compartment or femoral nerve block for procedures of the knee and those requiring a thigh tourniquet. Prospective studies have evaluated the utility of a combined femoral-sciatic block for knee arthroscopy when compared with fast-track GA (63,64) and unilateral (65) or bilateral (64,66) SAB (Table 6).

Casati's group (64) found that knee arthroscopy was associated with little postoperative pain and minimal opioid requirements independent of the anesthesia technique used. The femoral-sciatic block did provide more stable intraoperative hemodynamics with less hypotension compared with GA (63). In addition, the

PNB afforded a greater chance of PACU bypass compared with GA (63), as well as a shorter length of PACU stay compared with both GA (63) and SAB (64). Furthermore, the femoral-sciatic block had less total anesthesia cost compared with GA (64). Nevertheless, in one study (63), 12% of patients (2 patients) who received the femoral-sciatic block had mild pain during surgery (one patient received IV analgesia and one patient required GA). In another study (64), PNB failed to show efficiency advantages. The GA group had a shorter time until hospital discharge criteria were met (170 min) compared with femoral-sciatic block (265 min) or SAB (230 min), possibly related to discharge criteria requiring block resolution. Concerning the SAB group, these patients had a longer time to urination compared with GA (64) and femoral-sciatic anesthesia (64,66) as well as an increased incidence of bladder catheterization (64). Despite these differences, patient satisfaction with the various anesthesia techniques was universally high (64).

Sansone et al. (67) conducted a large retrospective study evaluating the efficacy of combined femoral-sciatic blocks in 601 patients having knee arthroscopy. They also found some patients had incomplete anesthesia with this technique. Additional intraoperative analgesia and sedation were required in 12% and 20%, respectively, but only 0.7% required conversion to GA. Follow-up at 1 mo failed to detect any neurological deficits. It was unclear whether patients were discharged with an insensate extremity.

As with femoral nerve blocks, the analgesic potential of combined femoral-sciatic blocks may be most apparent when more invasive procedures are performed with long-acting LA. Few prospective, randomized trials have investigated this issue; however, there are two retrospective studies. The study by Williams et al. (61) was previously summarized (see section on femoral nerve blocks). These results were further supported by a retrospective trial by Nakamura et al. (68). They studied 67 patients who received either GA or femoral-sciatic block for ACL reconstruction. The femoral-sciatic block allowed the procedure to be performed on an ambulatory basis in 90% of patients. Compared with GA and its associated subsequent hospital admission, regional anesthesia incurred a savings of $2907 per patient because it facilitated outpatient discharge.

The literature is deficient in studies investigating the use of single-injection proximal sciatic nerve blocks for foot and ankle surgery. This technique can provide dense anesthesia and analgesia. However, the hamstring weakness that occurs may lead to the preferential use of distal sciatic nerve blocks for foot and ankle procedures, especially when a thigh tourniquet is not required. Similarly, continuous proximal sciatic nerve blocks have been infrequently evaluated in the ambulatory surgical population.

Distal Sciatic Nerve Block

Posterior (69) and lateral (70,71) popliteal fossa blocks target the sciatic nerve behind the knee, cephalad to its division into the tibial and common peroneal nerves. This technique preserves hamstring function and sensation to the posterior thigh. This enables crutch walking but requires the use of a calf tourniquet or supplemental anesthesia for a thigh tourniquet. As with a proximal technique, distal sciatic nerve block may require supplementation with a femoral or saphenous nerve block for procedures that involve the medial calf or ankle. Popliteal fossa block is safe, easily achieved, and associated with high satisfaction and is therefore ideal for foot and ankle surgery (72).

The use of this technique in outpatients has been relatively well investigated when compared with other PNBs (Table 7). Singelyn et al. (73) prospectively studied 507 patients (14% outpatients) having 625 posterior popliteal fossa blocks with 1% mepivacaine or 0.5% bupivacaine. They found frequent success (92%), minimal discomfort with block performance, and excellent patient satisfaction.

Popliteal fossa block provides analgesia advantages over both ankle block and wound infiltration after foot surgery. McLeod et al. (74) randomized patients having GA to a popliteal fossa block or an ankle block with 0.5% bupivacaine. Although both blocks were safe and efficient, analgesia after popliteal block lasted 1080 min compared with 690 min after ankle block. Using a similar design, the same authors (71) compared popliteal fossa block with subcutaneous wound infiltration. They found the analgesic duration from the popliteal block exceeded that from subcutaneous LA by 709 min. The popliteal fossa block also provided better analgesia and higher patient satisfaction.

Vloka et al. (75) further expanded the application of the popliteal fossa block in a novel, prospective study involving patients having short saphenous vein stripping. They combined this block with a posterior cutaneous nerve of the thigh block and compared it with SAB. The combined PNB was associated with fewer patients requiring analgesia in PACU (21% versus 64%) and a 1-h reduction in hospital length of stay.

Some in busy ambulatory practices find it challenging to achieve timely onset of popliteal fossa block. As discussed with axillary blocks, a multiple-stimulation technique has also been described for sciatic nerve blocks in an attempt to improve block quality and onset time. Taboada et al. (76) used the multiple-stimulation technique in a prospective study involving patients having hallux valgus repair. This study compared the proximal sciatic approach to the popliteal fossa block and highlighted some of the deficiencies of the more distal block. The popliteal fossa block was associated with longer times for complete onset of sensory (11 min) and motor (14 min) block as well as

Table 7. Summary of Selected Randomized Trials Involving Distal Sciatic Nerve Block in Outpatient Surgery

			Results Distal Sciatic Block vs. Comparison Group		
Author	Population	Protocol	Analgesia	Side Effects	Discharge
MacLeod et al. (74)	$n = 40$ Foot osteotomies	All had GA Popliteal and saphenous nerve blocks vs. Ankle block (0.5% bupivacaine)	Similar VAS postoperatively Treatment for pain in PACU: 43% vs. 16% ($P < 0.05$) Postoperative: 1080 vs. 690 min ($P < 0.05$)	No difference in side effects	
MacLeod et al. (71)	$n = 40$ Foot osteotomies	All had GA Popliteal and saphenous nerve blocks vs. Subcutaneous infiltration (0.5% bupivacaine)	Similar VAS postoperatively Postop analgesia: 1082 vs. 373 min ($P < 0.05$) Severe pain at home: 14% vs. 58% ($P < 0.05$)		

GA = general anesthesia; VAS = visual analog pain scale; PACU = postanesthesia care unit.

more frequent block failure requiring conversion to GA (32% versus 4%). In contrast, Fernandez-Guisasola et al. (77) demonstrated timelier onset of popliteal fossa block within 7 min using both 0.5% ropivacaine and 1% mepivacaine.

Additional analgesic benefits from the popliteal fossa block are realized when home continuous sciatic nerve blocks are used for painful lower extremity surgery, such as ankle fusions and extensive forefoot reconstructions. In a randomized controlled trial of foot and ankle procedures with GA and popliteal fossa block, White et al. (78) compared postoperative continuous popliteal fossa block with 0.25% bupivacaine versus saline. The bupivacaine group had lower pain VAS scores for 48 h and 70% smaller morphine consumption. This facilitated a shorter length of hospital stay. In a similar study, Ilfeld et al. (79) used a mepivacaine popliteal block for surgical anesthesia and randomized patients to receive a continuous popliteal block with 0.2% ropivacaine or saline. In addition to decreased pain, opioid requirements, and opioid-related side effects, they found patients in the ropivacaine group had better sleep with fewer awakenings during the first and second nights. Zaric et al. (80) performed a study of similar design in which all patients received SAB and popliteal fossa block with ropivacaine for foot surgery. Postoperatively, patients were randomized to receive a continuous popliteal fossa block with ropivacaine 0.2% or saline. They found similar benefits but were unable to demonstrate a difference in opioid consumption or PONV in the postoperative period.

In summary, benefits such as dense, long-lasting analgesia and preserved hamstring function support the applicability of the popliteal fossa block for painful foot and ankle surgery. Given this evidence, more frequent use of single injection and continuous distal sciatic nerve blocks in outpatients seems warranted.

Paravertebral Block

Analgesia of specific thoracic or lumbar dermatomes can be accomplished with a paravertebral block. This technique involves injection of LA into the paravertebral space near the spinal nerve roots and the white and gray rami communicantes. The literature includes several studies in which paravertebral nerve blocks are used for inpatient surgery; however, many of these procedures are now performed on an outpatient basis. These studies include small trials and case reports of breast (81–86), inguinal hernia (87–90), and ileostomy revision surgery (91).

Greengrass et al. re-popularized the use of this block for breast (86) and hernia (88) surgery. Subsequently, studies have demonstrated the benefits of this regional technique. One example is a study by Naja et al. (92) in which these investigators prospectively randomized 60 patients having breast cancer surgery to receive either paravertebral nerve blocks or GA. The paravertebral blocks provided lower pain VAS scores both at rest and with activity for 120 h. There was reduced opioid consumption for 72 h, a lower incidence of PONV for 36 h, and the total length of stay was shorter in the paravertebral nerve block group by 1 day.

Lack of a definitive end-point when performing the technique leads to variability in published success rates (83,85,86) and may hinder broader implementation. The proximity of the paravertebral space to the lung leads to a risk of pneumothorax (0%–6.7%) (81–86), which is viewed as another deterrent to outpatient use.

Discharge of the Patient with a Blocked Extremity

Discharging patients with an insensate extremity and lack of protective reflexes remains controversial. Accidental limb damage or injury from falls may occur without protective reflexes. Only a few studies have examined this issue directly (34,93). Our group (93) prospectively studied 2382 ambulatory patients having upper and lower extremity PNBs with ropivacaine. Satisfaction was high and most (>97%) would choose the same anesthetic again. Seven patients (0.29%) had a persistent paresthesia that may have been anesthesia-related. One patient in the series fell while exiting a car but was uninjured. These data suggest that the risk of injury in patients discharged with an insensate extremity is relatively small. The infrequent incidence of complications in this series is likely related to appropriate patient selection and detailed discharge instructions from anesthesiologists and PACU nurses. A retrospective review by Davis et al. (34) lends support to the safe practice of discharging patients with a blocked extremity. They examined 543 axillary blocks performed on 526 outpatients, 361 of whom were discharged with an insensate extremity, and found no patients sustaining a neurologic injury.

Summary

The studies outlined in this review provide support for the role of PNBs in ambulatory surgery. PNBs provide improved postoperative analgesia, opioid sparing, and fewer opioid-related side effects relative to GA and parenteral analgesia. These advantages may have important implications such as reduced nursing interventions, improved patient well-being, facilitated same-day discharge with infrequent hospital readmission, and, ultimately, decreased cost. Outpatient CPNBs offer a mechanism to substantially prolong analgesia. Initial outpatient investigations have demonstrated encouraging preliminary results and offer promise for managing surgeries associated with prolonged pain. Issues such as resources for patient follow-up, mechanisms of reimbursement, and the potential for a failed technique after a painful surgery still need to be addressed. The impact of the introduction of the much-anticipated ultralong-acting LA remains to be seen. The realization of this technological breakthrough would dramatically amplify the effects of single-injection blocks, potentially eliminate the need for perineural catheter infusions, and considerably increase the demand for ambulatory PNBs.

Despite the beneficial effects of PNBs, a number of issues are repeatedly cited in the literature that may be viewed as deterrents in the outpatient environment. The time required for block performance and the prolonged onset seen with long-acting LA are frequent outcome measures and remain challenging issues that many studies have tried to address. As outlined in some reports (36), strategies such as the use of a preoperative block area may mitigate this issue. Alternatively, other studies have demonstrated that this issue may be less important than focusing on diminishing total hospital length of stay and capturing other outcome benefits. Despite the proven advantages of PNBs, most outpatient regional anesthesia studies have been either case series or relatively small prospective trials with a narrow focus on the impact of PNBs on analgesia and opioid consumption. Additional studies that focus on the special needs of outpatients are still needed. Larger prospective investigations demonstrating broader outcome benefits may provide the impetus required to adopt more widespread use of PNBs. In conclusion, anesthesiologists need to anticipate that future scientific and economic analysis will support the broader use of PNBs and CPNBs and be ready to meet the increased demand for regional anesthesia by patients, surgeons, administrators and insurers.

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