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Peripheral Nerve Blocks and Continuous Catheter Techniques

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The provision of extended analgesia after painful surgery continues to be a major challenge in health care. This challenge must also be met in a changing environment that emphasizes shorter hospital stays, cost-effective use of resources, and a continued shift toward outpatient surgery. The peripheral nerve block (PNB) is an analgesic modality with unique characteristics that meet this challenge and complement multimodal therapies. Newer continuous catheter techniques can also sustain the benefits of postoperative pain control while single injection blocks regress 10 to 18 hours after the injection of long-acting local anesthetic (LA). This article reviews and highlights the potential advantages of individual PNBs and summarizes the data related to the use of continuous PNBs for postoperative pain control.

Interscalene brachial plexus block

The interscalene block is performed at the level of C6 where the roots of the brachial plexus (C5 through T1) pass between the anterior and middle scalene muscles. This proximal brachial plexus block is ideal for postoperative analgesia for shoulder and upper arm surgery [1]. The superficial nature of the plexus at this

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location, the easily identifiable landmarks, and high success rate of this block as well as the preponderance of shoulder surgery contribute to making this one of the most commonly performed regional anesthesia techniques [2,3].

The interscalene block is highly effective at managing the intense postoperative pain that results from shoulder surgery; consequently, many authors consider this the gold standard in shoulder analgesia. A number of studies have documented the superior pain relief provided by this block when compared with opioid analgesia for arthroscopic and open shoulder surgery. Greater than 50% reduction in the pain verbal analog scale (VAS) scores [4–6], delayed time until first analgesic use [5], and reduced total opioid requirements [4–7] result from this technique. An example of this approach was provided by Kinnard et al [6] in a comparison of bupivacaine interscalene block versus opioids for postoperative analgesia in patients who had general anesthesia (GA) for acromioplasty or rotator cuff repair. During the first 24 hours after surgery, the mean postoperative pain VAS score was 1.8 on 10 in the treatment group versus 5.2 in the control group, and the hydromorphone consumption was 0.1 and 2.5 mg per patient, respectively. Other investigators have compared interscalene block versus subacromial bursa block [8] or the intra-articular administration of LA [9] and have demonstrated similarly superior analgesic efficacy from this PNB. Postoperative oxycodone consumption after interscalene block was one fourth that after subacromial bursa block [8], and pain VAS scores were 2 to 5 times higher with intra-articular LA compared with interscalene block [9].

The decreased incidence of pain and use of postoperative opioids lead to further beneficial effects, including a reduced incidence of postoperative nausea and vomiting (PONV) by 65% to 81% [4,5], improved postoperative mood [6], and up to 2 hours more sleep on the night after surgery [6]. Additional results include a faster discharge of the ambulatory patient [5], reduced in-patient length of stay [7], and lower rates of unanticipated hospital admission [4,10,11]. In an attempt to further improve on these effects, adjuvants to LA such as clonidine [12–14], ketamine [15], and morphine [16] have been examined. Although some studies have demonstrated that clonidine prolongs the analgesic effects of short-acting LA, controversy exists as to whether this is systemically or peripherally mediated.

In an effort to prolong the duration of postoperative analgesia, continuous interscalene nerve blocks have been investigated. Several authors have documented the safety and efficacy of this technique for painful procedures such as open rotator cuff repair and arthroplasty [17–26]. Two prospective studies by Borgeat et al [23,26] are representative. In both studies, patients had GA and an interscalene block for open shoulder procedures. The investigators compared postoperative analgesia with intravenous patient-controlled analgesia (IVPCA) versus patient-controlled interscalene block with ropivacaine [26] or bupivacaine [23]. Patient-controlled interscalene block with a basal infusion and patient-administered boluses was associated with a greater than 50% reduction in postoperative pain VAS scores from 12 to 48 hours, reduced PONV, and higher patient satisfaction.

Several interscalene catheter infusion strategies have been successfully implemented: continuous infusion alone [20,22], infusion with patient-administered boluses [22,23,25–27], and patient-controlled boluses alone [22]. Singelyn et al [22] compared these three modalities over a 48-hour period in patients who underwent open shoulder surgery. They found that the continuous infusion achieved excellent analgesia and minimal opioid consumption but was associated with the greatest use of LA. Infusion with patient-administered boluses provided excellent analgesia with intermediate consumption of LA. A regimen of patient-controlled boluses was associated with up to four times higher pain VAS scores and greater opioid consumption; however, this strategy did result in the lowest overall LA consumption.

Dilute bupivacaine [22,23,25], levobupivacaine [27], and ropivacaine [19,20,25–27] have all been used for postoperative infusions. Ropivacaine may offer advantages because it has a favorable safety profile and is associated with minimal motor block. This was quantified in a study by Borgeat et al [25]. After a 24-hour infusion of ropivacaine or bupivacaine, they found a reduction of 48% and 66%, respectively, in hand strength, compared with preoperative values. The most common challenges of the continuous technique include pain experienced during the transition from a dense surgical block to an analgesic block with dilute LA [24,28] and catheter-related problems such as dislodgement [19,23,24], kinking [22], and leaking [28].

Recent literature has focused on the use of continuous interscalene catheter infusions for outpatients [19,29–31]. This has enabled prompt hospital discharge with excellent pain control and few side effects after painful and complex procedures. In addition, this technique diminishes breakthrough pain that outpatients may experience after the resolution of a single-injection block [32]. The added benefits such as reduction in sleep disturbances and preservation of cognitive function are also observed [31]. Appropriate patient selection, education, and follow-up are crucial when prescribing outpatient infusions in an unmonitored environment.

Supraclavicular brachial plexus block

The supraclavicular block is performed at the level of the trunks of the brachial plexus. In this technique, LA is injected where the brachial plexus is most compact, leading to consistent, rapid-onset anesthesia distal to the shoulder [1,33]. Bedder et al [34] documented sensory block onset within 3.6 to 4.0 minutes using bupivacaine; this is faster than onset times reported with infraclavicular or axillary blocks. Up to 17 hours of analgesia result after a single injection of bupivacaine or ropivacaine [35,36], and some studies have shown further prolongation from the addition of clonidine, 150 μg [37], or buprenorphine, 300 μg [38,39]. Although the "plumb-bob" technique has historically been associated with a high incidence of pneumothorax, the safety and efficacy of the subclavian perivascular approach has been demonstrated by Franco and

Vieira [40]. They reported no pneumothoraces or neurologic deficits related to supraclavicular block insertion in a series of 1001 blocks performed by both residents and staff anesthesiologists. Despite these attractive features, few studies have investigated the postoperative analgesic efficacy of this block compared with placebo or IVPCA with opioids. Furthermore, although the authors have used continuous supraclavicular brachial plexus infusions of LA for post-operative analgesia with good success, the literature on this subject is sparse. The rapid onset of sensory block, broad upper extremity coverage, and long-lasting analgesia provided by this block make it invaluable for postoperative pain management after upper extremity procedures.

Infraclavicular brachial plexus block

The infraclavicular block targets the brachial plexus at the divisions and cords, where the plexus is in close proximity to the axillary artery and vein. This block is used for procedures of the elbow, forearm, wrist, and hand. Two large series of infraclavicular blocks [41,42] document efficient block performance in as little as 5 minutes, good analgesic efficacy, and a favorable safety profile with a very low incidence of pneumothoraces or postoperative neurologic deficits. In a prospective study of outpatients who underwent hand and wrist procedures, Hadzic et al [43] compared infraclavicular block versus GA and found lower pain VAS scores on arrival to the postanesthesia care unit (PACU) in the infraclavicular block group. Analgesia was required in the PACU by 48% of those in the GA group and by none of the patients in the infraclavicular block group. The use of the short-acting LA chloroprocaine led to similar pain VAS scores and opioid consumption in both groups at 24 and 48 hours; however, substitution with a long-acting LA could be used to prolong analgesia and improve on these results.

Several studies have reported the use of continuous infraclavicular brachial plexus nerve block catheters for postoperative pain management [44–46]. Ilfeld et al [44] compared 0.2% ropivacaine versus saline for ambulatory infraclavicular brachial plexus infusion and demonstrated greater than 50% decrease in pain VAS scores for the duration of the infusion, reduced opioid consumption, and fewer opioid-related side effects in the ropivacaine group. In addition, no patients receiving the ropivacaine infusion reported difficulty sleeping, in contrast to 60% of those in the saline group. Patient satisfaction was higher in the ropivacaine group, in which all patients were willing to repeat the same technique in the future, compared with 53% of those who received a saline infusion. A subsequent study that evaluated the effect of the addition of clonidine to the LA infusion [45] demonstrated a reduction in overall LA use but determined that this difference was not clinically significant. A comparison of infraclavicular infusion regimens produced results comparable with similar studies involving interscalene brachial plexus infusions. A regimen consisting of a basal infusion with patient-controlled boluses yielded the optimal analgesia of long duration compared with a basal infusion alone or patient-controlled boluses alone [46]. Compared with other upper extremity approaches, the only real advantage of this continuous brachial plexus block may relate to the ability to maintain a secure catheter insertion site.

Axillary brachial plexus block

This technique blocks the terminal branches of the brachial plexus as they surround the axillary artery. This is the most commonly performed PNB in the United States [2,3] likely because of its favorable safety profile [47], ease of performance, high patient acceptance [48], and broad applicability for hand, wrist, and forearm procedures [1]. Variations of the axillary block have been investigated for postoperative pain management for nearly 100 years; hence, the literature base is broad.

In the axilla, the terminal nerves of the brachial plexus are contained within a fascial sheath [49,50]. The presence of septae within the sheath [49,50] and the exclusion of the musculocutaneous, intercostobrachial, and medial antebrachial cutaneous nerves from the sheath at this level may affect the spread of LA as well as the consistency and extent of anesthesia achieved. These anatomical features contribute to the variability in success rates and onset times reported with single-stimulation techniques [51–53] and the improved results obtained with multiple-stimulation techniques [54,55]. The multiple-stimulation technique can also be used to provide selective incisional analgesia of long duration with the early return of partial sensorimotor function in areas outside the surgical field [56]. This is accomplished by blocking the nerves that supply the surgical field with long-acting LA and the remaining nerves with short-acting LA.

Further attempts to prolong postoperative analgesia and minimize motor block have focused on the addition of adjuvant solutions to the LA. The $\alpha 2$ agonist, clonidine, in a dosage range of 0.1 to 2 μg/kg, has been shown to double the duration of postoperative analgesia when added to short-acting LA [57,58]. Hypotension, bradycardia, and sedation, however, may limit the use of perineural clonidine in certain patient populations. There is also evidence that the perineural administration of tramadol [59,60], buprenorphine [61], fentanyl [62,63], and morphine [64] may prolong the duration of analgesia or reduce opioid requirements postoperatively. The controversy continues as to whether these additives act locally at the peripheral nerve or more systemically.

Two prospective studies have compared axillary block with short-acting LA versus GA in patients undergoing hand surgery [65,66]. The benefits attributed to the axillary block include greater than 50% reduction in pain VAS scores, from 30 to 120 min after surgery [66], lower in-hospital opioid requirements [65,66], and longer time until the first analgesic [66]. Additional postoperative advantages include a 75% reduction in the incidence of immediate PONV [65,66] as well as a more expedient discharge from both the PACU and the hospital [66]. However, when long-term benefits were investigated, there was no difference in pain, opioid consumption, adverse effects, or patient satisfaction on the first, seventh, or fourteenth postoperative day [66]. When an axillary block was compared with intravenous regional anesthesia for hand surgery [65], the intravenous regional anesthesia technique was associated with similar postoperative analgesia but a 30% reduction in intra- and postoperative costs, a shorter duration of recovery, and fewer PACU nursing interventions.

Axillary blocks have also been used for the creation of vascular access grafts for dialysis and for the reimplantation of traumatic amputations. The sympathectomy that occurs from this plexus block enhances distal blood flow and perfusion [67] and is of particular benefit for these procedures.

Continuous axillary brachial plexus infusions have further lengthened the duration of analgesia and sympathectomy after upper extremity procedures. A large descriptive series by Bergman et al [68] documented successful axillary catheter insertion in more than 90% of patients, with very few complications. Among 405 catheter insertions, there was one infection that resolved with antibiotic therapy and four new postoperative neurologic deficits. Two of these deficits were attributed to surgical technique, and only one of the four deficits was noted to have incomplete recovery. Given the location of catheter placement, the challenges of continuous axillary catheter management include maintaining a clean, sterile site and avoiding catheter dislodgement from this very mobile area.

In a study of patients undergoing hand microsurgery, a continuous basal infusion was compared with patient-controlled bolus administration of 0.25% bupivacaine [69]. Investigators found that both regimens produced low pain VAS scores and opioid requirements; however, lower plasma bupivacaine levels were measured with the bolus strategy despite similar hourly LA consumption in each group. In an early report on the use of ambulatory continuous axillary infusions for patients undergoing outpatient hand surgery, Rawal et al [70] described a regimen involving patient-controlled boluses of 0.125% bupivacaine or ropivacaine administered as often as once every hour. This technique achieved reductions in pain VAS scores after every bolus and a high rate of patient satisfaction.

Because the axillary block requires multiple injections to achieve complete distal upper extremity analgesia, prolonged performance and onset time may result, and efficacy similar to other approaches to the brachial plexus may not be achieved. Despite this, the ease of performance and low incidence of side effects associated with the axillary block have made it the most commonly performed PNB.

Lumbar plexus block

The ventral rami of the spinal nerve roots L1–4 combine to form the lumbar plexus within the substance of the psoas muscle. A number of methods of lumbar plexus block are described. Each provides reliable anesthesia of the three main terminal nerves of the lumbar plexus—the femoral, lateral femoral cutaneous, and the obturator nerves [71]; however, anesthesia of the more proximal plexus nerves (ilioinguinal, iliohypogastric, and genitofemoral nerves) is inconsistent.

The extent to which sensory analgesia is achieved makes lumbar plexus block suitable for knee and hip procedures. This block has been used safely and effectively for outpatient knee arthroscopy. Jankowski et al [72] compared a mepivacaine lumbar plexus block versus subarachnoid block (SAB) versus GA and found that the two regional anesthetics were associated with three times more frequent PACU bypass, lower pain VAS scores from 30 to 120 minutes after surgery, and 53% to 69% fewer patients requiring analgesics in the hospital before same-day discharge. Hadzic et al (Admir Hadzic, MD, PhD, personal communication, 2004) contrasted chloroprocaine lumbar plexus and sciatic nerve blocks versus GA and documented early postoperative benefits from the PNBs, including a reduced incidence and severity of PONV, sore throat and concentration difficulties, and a shorter time to both oral intake and discharge readiness by 1 hour. However, reflecting the low incidence of severe postoperative pain that occurs with this procedure and the use of short-acting LA in these studies, neither report demonstrated long-lasting benefit from the lumbar plexus block compared with GA.

Greater postoperative analgesic benefit is evident when a lumbar plexus block is used for invasive and more painful procedures such as anterior cruciate ligament (ACL) repair or total knee arthroplasty (TKA). In a study of patients undergoing arthroscopic ACL repair, Matheny et al [73] found 89% lower opioid requirements and a reduced incidence of opioid-related side effects in the group that received continuous lumbar plexus block versus those who had IVPCA. In an investigation of TKA patients by Luber et al [74], a subset of patients described an easier and more comfortable recovery with lumbar plexus and sciatic nerve blocks compared with previous experience with GA and IVPCA. Kaloul et al [75] compared continuous lumbar plexus block versus continuous femoral nerve block versus IVPCA in TKA patients and found that the PNB techniques reduced 48-hour morphine consumption by 48% to 50%. This benefit was most apparent in the first 12 hours after surgery but was less obvious after 12 to 24 hours when the surgical block resolved and less intense analgesia was provided with an infusion of dilute LA. Pain originating from the sciatic nerve contributions to the knee may also have been a factor. As expected, investigators found more frequent obturator nerve block in the lumbar plexus group than the femoral group; however, this failed to translate into any clinical advantage, again, possibly related to overriding discomfort from the territory of the unblocked sciatic nerve.

Several studies have described the use of a lumbar plexus block for hip fractures and total hip arthroplasty [76,77]. Overall results have been excellent. Hevia-Sanchez et al [78] evaluated patients having total hip arthroplasty under SAB and found that a lumbar plexus block provided low pain VAS scores and infrequent use of opioids in the postoperative period. Most impressively, no patients required morphine in the first 12 hours postoperatively, and only 15% of patients used morphine after 12 to 24 hours. When patients evaluated their experience on the first day after surgery, 90% described their pain as mild or moderate, and only 10% reported pain as intense. Two other groups [77,79] have investigated patients undergoing total hip arthroplasty, and both groups found that a lumbar plexus block reduced pain VAS scores and opioid use for 6 to 12 hours, respectively, after surgery, compared with the use of parenteral opioids alone.

Prolongation of analgesia after total hip arthroplasty can be achieved using a continuous lumbar plexus catheter [80]. Using this technique, Capdevila et al [81] documented low pain VAS scores for over 48 hours. In a study by Turker et al [82], the block was as successful as a lumbar epidural in providing analgesia, minimizing opioid use, and enhancing patient satisfaction. More importantly, patients who received the continuous lumbar plexus block experienced a reduction of more than 80% in the incidence of orthostatic hypotension, urinary retention, and PONV, as well as earlier ambulation than those who received the epidural.

Quantitative summaries regarding overall efficacy of lumbar plexus block for painful hip and knee procedures are difficult to make because the existing studies have numerous variations in methodology. Although the benefits of this technique are shown repeatedly, the extent and duration of analgesia vary depending on whether single-injection or continuous blocks are used and whether a sciatic nerve block is also used.

Femoral nerve block

The largest terminal nerve of the lumbar plexus, the femoral nerve, is formed from the posterior divisions of the ventral rami of the L2–4 nerve roots. The femoral nerve block provides excellent anesthesia in the femoral nerve distribution. Increasing LA injectant volume and application of pressure distal to the needle insertion are used in attempt to attain a "3-in-1" block, which includes coverage of the lateral femoral cutaneous nerve and the anterior portion of the obturator nerve. Numerous studies, however, have documented inconsistent results with the 3-in-1 block [83,84]. Nevertheless, it is a simple technique and offers excellent analgesia after knee surgery.

When used for knee arthroscopy, the femoral nerve block has high patient acceptance, a reduced incidence of pain requiring treatment in the PACU from 36% to 1.7%, and decreased length of hospital stay compared with GA [85]. Two studies comparing femoral nerve block with intra-articular LA injection have found that both methods provide good analgesia and similar pain VAS scores for up to 24 hours [86,87]. A combined femoral-sciatic nerve block using mepivacaine has been compared with propofol-remifentanil GA [88] and unilateral [89] and bilateral [90] SAB for knee arthroscopy. Reflecting the minimally painful nature of this procedure, patients in all groups reported low pain VAS scores at discharge, and fewer than 37% of patients required opioid analgesia in the first 24 hours after surgery. In these studies, the recovery advantages of the femoral-sciatic nerve block included earlier micturition by 95 minutes and sooner ambulation by 50 minutes.

A femoral nerve block with long-acting LA can provide up to 23 hours of analgesia after ACL repair and can assist with the comfortable and timely transition of ambulatory patients out of the hospital [91,92]. There is evidence that, when compared with placebo, femoral nerve block improves immediate postoperative analgesia [91,93], prolongs the time to first requested analgesic [93], and reduces 24-hour morphine consumption by 45% [93]. A continuous femoral nerve block provides the option to further prolong postoperative analgesia after ACL repair [94]. In a series comparing continuous femoral nerve versus fascia iliaca blocks, both techniques provided low postoperative pain VAS scores and opioid requirements [95].

Some studies, however, have failed to show significant postoperative analgesic benefit from a femoral nerve block after ACL reconstruction [96,97]. Investigators have hypothesized that this is the result of pain originating from the geniculate contributions of the sciatic nerve distribution [98,99]. Consequently, a combination femoral-sciatic nerve block is particularly useful for ACL repair using a hamstring graft, in which there is significant pain in the sciatic nerve distribution [100]. In a comparison of femoral-sciatic nerve block versus femoral nerve block alone for ACL repair, Williams et al [100] found that the combined femoral-sciatic nerve block was associated with reduced pain and analgesic requirements. More importantly, these benefits have facilitated ACL repair as an outpatient procedure [99,100] with a projected annual cost savings of $98,613 in an institution performing 250 procedures per year [101].

Investigators have reported the beneficial effects of femoral nerve block (without additional sciatic block) for patients undergoing TKA and other painful open knee procedures [102]. Because of the intensity and duration of pain that occur with these procedures, many reports involve the use of a continuous femoral nerve block. A number of studies have documented dense analgesia with up to 50% reduction in pain VAS scores for 48 hours [103,104], up to 64% lower postoperative opioid requirements [103,105–107], a reduced incidence of side effects [106], and a 20% shorter hospital stay [104] with femoral nerve catheters when compared with IVPCA. An additional benefit includes improved short-term postoperative rehabilitation and joint mobilization [104,106]. The continuous femoral nerve infusion of LA has been found to provide similar analgesia but fewer side effects than a single dose of intrathecal morphine [108], a single dose of epidural morphine [109], or a continuous infusion of epidural LA [104,106]. In an attempt to determine the best LA infusion regimen for continuous femoral nerve blocks used for TKA, Singelyn and Gouverneur [110] compared continuous infusion alone versus continuous infusion with intermittent boluses versus intermittent boluses alone. Reduced IVPCA opioid consumption was noted in the continuous infusion group that had a mean of 0 PCA attempts over 48 hours compared with 44 to 66 attempts in the other groups. The consumption of LA, however, was 32% to 58% lower with the intermittent bolus strategy. The continuous infusion with intermittent bolus modality provided intermediate LA consumption but was associated with the highest opioid consumption, contrasting with results from similar studies involving upper extremity infusions [22].

As discussed in relation to ACL repair, some authors have been unable to reproduce these beneficial results using femoral nerve block for TKA and have suggested that this may be because of the unblocked sciatic or obturator nerve contributions to the knee [111]. Cook et al [112] have documented improved postoperative analgesia as well as a 39% reduction in opioid consumption in the first 24 hours from a combined femoral-sciatic nerve block compared with femoral nerve block alone. When used with a continuous femoral nerve block, intermittent boluses or continuous infusion of LA through a sciatic nerve catheter can further extend postoperative analgesia in 67% [113] to 83% [114] of patients and reduce pain VAS scores by 67% [114]. Compared with SAB followed by postoperative parenteral opioids, femoral-sciatic nerve blocks are associated with a 2- to 8-hour prolongation in the time to first analgesic [115], decreased total opioid consumption of 53% to 63% in the first 24 hours [115,116], and reduced pain VAS scores of 42% to 54% [115,116]. Chelly et al [117] compared combined femoral-sciatic nerve block versus epidural analgesia and found a 20% reduction in the amount of opioid consumed, a 50% lower incidence of PONV, and an earlier discharge from the hospital in the femoral-sciatic nerve block group.

The safety and ease of performance of this technique make this one of the most commonly performed lower extremity PNBs. The femoral nerve block can provide excellent postoperative analgesia for major knee procedures, is a less invasive alternative to lumbar plexus block, and is a technique that preserves hip flexion. In the literature there is variability in the extent and duration of analgesia provided after major knee surgery. This variability likely reflects the different techniques used (single injection versus continuous infusion, with or without sciatic or obturator nerve block) and interpatient variability in the importance of the sciatic innervation of the knee.

Sciatic nerve block

Formed from the rami of L4–S3, the sciatic nerve is composed of three anatomically and functionally distinct components: the posterior femoral cutaneous, tibial, and common peroneal nerves. Numerous approaches have been described to achieve analgesia along the length of this nerve. These approaches can be divided into proximal (classic, Raj, anterior, lateral, and subgluteal) and distal (popliteal fossa) techniques.

The majority of publications on sciatic nerve block describe its use as an adjunct to femoral or lumbar plexus blocks for knee and hip procedures (see above). Other studies evaluate the use of a proximal sciatic nerve block as the primary technique for foot and ankle surgery, although the paucity of studies on this topic reflects the more common use of distal sciatic nerve block for these procedures. Long-acting LA can provide safe and effective pain relief for up to 16 hours after foot and ankle surgery [118]. Casati et al [119] documented a high success rate, low postoperative opioid requirements, and excellent patient satisfaction in a series of patients who underwent sciatic nerve block for foot and ankle procedures. Cooper et al [120] studied patients who had open calcaneal fracture repair and compared postoperative analgesia from sciatic nerve block versus IVPCA. They documented reduced pain VAS scores for 24 hours in the block group and found equal analgesic efficacy in blocks administered pre- or postoperatively.

Continuous proximal sciatic nerve block can extend the duration of analgesia after painful orthopedic procedures on the distal lower extremity, although the number of studies investigating its use seems low given the excellent results it can provide. Significant analgesic benefit has been proven when continuous sciatic nerve block is provided pre- and postoperatively for patients undergoing below-knee amputation [121]. Both surgical and phantom limb pain can be reduced with this technique, with a resulting improvement in sleep. In a study examining continuous sciatic nerve block with 0.2% ropivacaine, di Benedetto et al [122] compared a continuous infusion regimen versus a strategy involving a continuous infusion with patient-controlled boluses. Both regimens provided similarly effective analgesia, with pain VAS scores lower than 30 mm for 24 hours; however, there was 42% less LA consumed in the continuous infusion with patient-controlled boluses group.

Overall, the lower number of studies on the use of proximal sciatic nerve blocks for distal lower extremity surgery is surprising given its efficacy. This block has the potential to provide potent postoperative analgesia after major foot and ankle procedures and continuous catheter techniques can safely prolong the duration of pain relief.

Popliteal fossa sciatic nerve block

In the popliteal fossa, the sciatic nerve divides into the tibial and common peroneal nerves. Popliteal fossa sciatic nerve block is accomplished 7 to 10 cm superior to the popliteal skin crease, before the divergence of these nerves. This distal sciatic nerve block is advantageous because it preserves hamstring muscle function, allowing easier ambulation; however, sensation to the posterior thigh remains because the posterior cutaneous nerve is spared.

Popliteal fossa sciatic nerve block with long-acting LA can provide analgesia of 20 hours after foot or ankle procedures [123]. In a series of 652 popliteal blocks performed by trainees and staff anesthesiologists for foot and ankle procedures, Singelyn et al [124] documented a superior success rate, with only 3% of patients requiring conversion to GA, and excellent patient tolerance of the initial block. High patient satisfaction was illustrated when 95% of patients described being completely satisfied with their anesthesia and analgesia, 4% conveyed satisfaction with moderate reservations, and 1% expressed major reservations with the technique. The safety of this block was highlighted in another large series by Provenzano et al [125]. This descriptive study involved 439 popliteal blocks performed primarily on outpatients, and the investigators found no postoperative neurologic sequelae. In a report by Hansen et al [126], a number of patients who had experience with GA for previous foot or ankle surgery volunteered that the popliteal block provided superior postoperative analgesia. None of the patients in this study required opioids in the PACU, and comfortable ambulatory discharge was facilitated. Further evidence of the analgesia provided by this block is found in two studies by McLeod et al [127,128]. In outpatients undergoing foot and ankle procedures, they compared the popliteal fossa sciatic nerve block versus ankle block [127] and versus subcutaneous LA infiltration [128]. The popliteal fossa sciatic nerve block provided 1080 to 1082 minutes of postoperative analgesia, significantly longer than either the ankle block (690 minutes) or subcutaneous infiltration (373 minutes). Four times as many patients experienced severe pain at home in the subset that received subcutaneous LA infiltration, and patient satisfaction was correspondingly lower in this group. In a study of outpatients, Vloka et al [129] described a novel use of popliteal block for patients undergoing short saphenous vein stripping. They compared a popliteal block with chloroprocaine versus SAB and found that the popliteal block facilitated more comfortable and prompt same-day discharge. This occurred because patients experienced less pain immediately postoperatively, spent half as long in PACU as SAB patients, and were discharged from the hospital more than 1 hour earlier than SAB patients. However, the use of a short-acting LA for the popliteal block failed to confer analgesic benefit after discharge.

Extending these analgesic advantages, continuous popliteal sciatic nerve block has been used for hospitalized and ambulatory patients. A continuous block with dilute bupivacaine [130,131] and ropivacaine [132,133] provides better analgesia [130–133] and 70% to 100% lower opioid requirements than placebo [130,131,133,134]. This technique provides such high-quality analgesia that 40% to 80% of patients do not require opioid analgesia for the duration of the LA infusion [130,133]. Fewer opioid-related side effects result [130,131,133,134], which was highlighted by a 90% reduction in the incidence of nausea and vomiting when continuous popliteal sciatic nerve block was compared with parenteral analgesics [131]. Additional benefits include a reduced number of sleep disturbances by 60% to 94% [132,133], a 50% shorter hospital length of stay [130], and a 40% lower incidence of hospital admissions among outpatients [130]. Consequently, this type of block resulted in reduced perioperative costs [130] and high patient satisfaction [130,133]. Challenges related to continuous popliteal sciatic nerve block include catheter kinking, breakage or dislodgement [130–133], and leakage of infusate from the catheter insertion site [132,133].

Despite its slow onset, the popliteal block provides effective analgesia for foot and ankle procedures. Although more proximal sciatic nerve block results in weakened hamstrings, the popliteal block preserves hamstring function and facilitates ambulation.

Paravertebral block

The paravertebral block is accomplished by an injection of LA as the spinal nerve roots exit the central neuraxis. The block is unique in that a single injection can block the ventral and dorsal rami as well as the gray and white rami communicans, thereby providing a dense sensory and sympathetic block. As a result, unilateral segmental analgesia can be provided for a variety of thoracic and abdominal surgical procedures.

The continuous paravertebral block has been extensively compared with the thoracic epidural for post-thoracotomy analgesia [135–137]. In a number of studies involving patients who underwent lung resection, paravertebral block provided analgesia of similar or better quality than the thoracic epidural. Paravertebral block was associated with fewer side effects, including a reduction in the incidence of hypotension (up to 67% with epidurals to zero with the paravertebral block), a decrease in the incidence of PONV by 80% [137], and an 85% lower rate of urinary retention [135]. Impressively, measures of pulmonary function were equal to or better than those seen in patients with thoracic epidurals [136,137]. Catala et al [138] investigated continuous thoracic paravertebral block infusion regimens and found that patients who received a continuous infusion of LA experienced 33% to 42% lower pain VAS scores from 4 to 48 hours postoperatively than patients who had intermittent boluses of 0.375% bupivacaine. Additional reports exist on the safe and effective use of single-injection and continuous paravertebral blocks for conventional [139] and minimally invasive [140,141] cardiac surgery as well as major vascular surgery [142].

Additionally, many investigators have documented the safe and effective use of paravertebral blocks for major and minor breast cancer procedures as well as cosmetic and reconstructive breast augmentation [143–149]. Long-acting LA can provide up to 23 hours of analgesia [143]. When compared with GA, paravertebral block results in 50% to 80% lower pain VAS scores [146,149], 48% to 95% reduced opioid consumption [145,146,149], and less painful restricted movement [146]. Further benefits include a 48% to 97% decreased incidence of PONV [145,146,149], a shorter hospital stay [145,149], and the enhanced ability to perform breast procedures on an outpatient basis [143,145]. The potential for cost savings are evident [143]. There are case reports describing the use of continuous paravertebral catheters for analgesia after breast cancer surgery [150], however, pain after resolution of single-injection paravertebral block is usually readily managed with oral analgesics.

Similar positive results have been obtained when paravertebral blocks are used for inguinal [151,152] and ventral [153] hernia repair as well as loop ileostomy closure [154]. When used for inguinal hernia repair, this technique provides up to 14 hours of postoperative analgesia and delays the time to the first dose of opioid by up to 22 hours [151]. A study by Naja et al [155] documents no need for opioid analgesia in the first 24 hours and no PONV among patients who had a paravertebral block for inguinal hernia repair. In this study, the length of hospital stay after paravertebral block was one half that after GA or SAB. This group also compared paravertebral block versus GA for ventral hernia repair [153]. They found that the paravertebral block resulted in lower pain VAS scores, diminished the number of patients requiring postoperative opioids from 90% to 0% in the first 24 hours, decreased incidence of PONV by 88%, and reduced length of hospital stay from 4.1 days to 2.3 days. However, the postoperative benefits of this technique over extended ilioinguinal-iliohypogastric block have not been as compelling [156].

Segmental analgesia achieved with paravertebral block has broad value, ranging from thoracic and breast surgery to inguinal and abdominal procedures. It has been extensively studied and has many advantages compared with thoracic epidural anesthesia and requires less to place. Given its multiple uses and excellent results, it may be one of the most underused PNBs.

Summary

This article reviews the extensive literature base on the use of PNBs for postoperative pain management. The discussion focuses on the advantages of individual blocks used for common surgical procedures. The technical aspects or side effects of each approach are found in standard reference texts.

Intense, site-specific analgesia results from PNBs. These blocks provide superior postoperative analgesia with fewer side effects than most other analgesic techniques, including parenteral opioids. As a result PONV, sedation, concentration difficulties, pruritus, and urinary retention are minimized. In addition, the return to important preoperative functions such as eating, drinking, ambulation, and sleeping is enhanced. These advantages facilitate a prompt recovery and discharge, achieve cost savings, and result in high patient satisfaction.

Nevertheless some benefits achieved from single-injection techniques are limited by the finite duration of the LA. Prolongation of these attributes can be achieved with a continuous catheter. The use of these modalities has also been supported by a number of studies illustrating that continuous lower extremity blocks provide analgesia of equal quality but with fewer side effects than continuous epidural infusions. Further advantages of continuous PNBs include the potential to enhance rehabilitation after major total joint arthroplasty and the potential to improve results of reimplantation procedures. Preliminary work on the use of continuous PNBs in outpatients has been promising and has the potential for significant cost savings and outcome improvement.

Despite these advantages, PNB techniques continue to be underused. This may be because of the limited number of regional anesthesia instructors available in teaching institutions in addition to a focus on GA by United States residency programs. A nationwide survey of third-year anesthesiology residents illustrated this problem [157] when the majority of sampled trainees expressed low confidence in their ability to perform most PNBs. To foster the continued use of these techniques for postoperative analgesia, it is essential to develop improved teaching modalities. Finally, although the beneficial analgesic effects of PNBs are well-demonstrated, additional research showing improved patient outcome may provide further impetus for their expanded use.

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