Title

Continuous peripheral nerve blocks in the ambulatory setting

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Continuous peripheral nerve blocks in the ambulatory setting: an update of the published evidence

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Purpose of review
To review the evidence recently published involving the use of continuous peripheral nerve blocks (cPNBs) in the ambulatory setting.

Recent findings
New evidence exists involving the risks and benefits of cPNB in ambulatory patient populations such as pediatric ambulatory and postmastectomy patients. In addition, new related equipment is now available to facilitate ambulatory cPNB.

Summary
Recent advancements in equipment for cPNB facilitate the usage in the ambulatory setting. Research-supported ambulatory cPNB indications have expanded to include pediatric subpopulations and major breast surgery, while further evidence mounts for its efficacy in patient populations with previously demonstrated benefits, such as foot, ankle and shoulder surgery.

Keywords
ambulatory continuous peripheral nerve block, ambulatory postoperative analgesia, home perineural infusion, ambulatory perineural local anesthetic infusion, perineural catheters, portable infusion pumps

INTRODUCTION

Continuous peripheral nerve blocks (cPNBs) involve the percutaneous placement of a catheter adjacent to a peripheral nerve followed by the infusion of local anesthetic through the catheter. First described in 1946 using a percutaneous needle stabilized with a cork taped to the skin [1], cPNBs have been in use in the ambulatory surgical setting since 1998 [2]. Numerous studies support its utility in facilitating efficacious analgesia via prolonged neural blockade, permitting surgeries associated with moderate-to-severe pain to be conducted in the ambulatory setting without an overnight stay [3–11].

INDICATIONS

Ambulatory cPNB is indicated for operations involving moderate–to-severe pain not easily controlled by other methods. In these selected patient populations, the favorability of benefit to risk ratio in aiding an expeditious discharge without an overnight hospital stay is well supported by many randomized-controlled trials [12,13]. These include – but are not limited to – interscalene continuous peripheral nerve block (cPNB) for clavicle, shoulder and proximal humerus surgery; supraclavicular and infraclavicular cPNB for elbow, forearm and hand surgery; femoral and adductor canal cPNB for knee surgery; and, sciatic cPNB for lower leg, ankle and foot surgery [14]. Recent research has focused on refining existing indications as well as examining areas less investigated in the past. For example, Salviz *et al.* [15] performed a randomized trial comparing single injection interscalene brachial plexus block with interscalene cPNB for patients having outpatient rotator cuff repair and found an extended analgesic benefit beyond the duration of infusion and quality of life benefits through

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KEY POINTS

- cPNB is now a well-accepted and research-supported technique for the well tolerated and efficacious treatment of moderate-to-severe pain related to surgery in the ambulatory setting.
- Recent advancements in equipment facilitate the use and optimize the efficacy of cPNB.
- New research regarding cPNB further supports well-accepted indications and supports previously less investigated ones, while refining techniques, improving knowledge of infusions and providing guidance for patient selection and management.

postoperative day 7 for interscalene cPNB in comparison to single injection interscalene block or general anesthesia alone.

One area of broadening interest is the use of ambulatory thoracic paravertebral continuous catheters following major breast surgery. Ilfeld *et al.* [16▪] conducted a prospective, randomized, triple-masked, placebo-controlled study investigating the benefits of a multiple-day ambulatory paravertebral continuous block compared with single-injection ropivacaine paravertebral block for mastectomy. Sixty individuals undergoing unilateral or bilateral mastectomy were randomized to receive an initial ropivacaine paravertebral block and a 60-h 0.4% ropivacaine or 0.9% saline infusion (basal rate 5 ml/h, no bolus function). Results revealed improved analgesia and decreased functional deficit the day after surgery. Moreover, cPNB resulted in markedly less pain-related physical and emotional dysfunction during the infusion period. This is in contrast to the results of a study by Buckenmaier *et al.* [17] in which patients received primarily breast conservation surgery rather than mastectomy and a benefit was not found. Ilfeld *et al.* [18▪] then conducted a prospective follow-up study of the same postmastectomy participants to evaluate chronic pain and pain-related physical and emotional dysfunction. Although there was no statistical difference in individuals experiencing pain at 3 months postoperatively, there was a large difference in the number of individuals experiencing any pain at 12 months: 13 versus 47%. The difference in pain at 12 months and not at 3 months correlates with current theory of the development of acute – inflammatory versus chronic – neuropathic pain, and this correlation suggests a potential beneficial role for ambulatory paravertebral catheters in both short-term and long-term outcomes [19].

In addition, pediatric patients have benefitted from cPNB in the ambulatory setting for greater than 10 years, though few large studies have been conducted of the feasibility and efficacy in this population [20–23]. Visoiu *et al.* [24▪▪] conducted a retrospective study of 403 pediatric patients who underwent ambulatory upper and lower extremity orthopedic and plastic surgery procedures. They found that patients and their caregivers were very satisfied with pain control provided by cPNB. Patients had lower pain scores in the recovery room and at home relative to equivalent populations, and they had lower opioid consumption in the recovery room. The rate of complication in this study was 14%, 35% of which was related to catheter leakage. The cPNB failure rate was 7% in this study.

CATHETER INSERTION TECHNIQUES

Multiple techniques including ultrasound, nerve stimulation, paresthesia and landmark-based are validated for catheter insertion and have been reviewed elsewhere [13]. Time constraints of ambulatory surgery centers largely favor the method for which practitioners are most familiar and ultrasound-guided techniques [12,25–29]. Recent equipment and technique research largely focuses on refining existing techniques and addressing ongoing controversies.

One subject which continues to receive attention is the role of nerve stimulation versus ultrasound guidance versus combination approaches [13]. Many randomized-controlled trials have investigated the variety of techniques including nerve stimulation via insulated needles, nonstimulating catheters and stimulating catheters in addition to or instead of ultrasound-based techniques. Although most studies have found comparable analgesia, improved patient comfort and decreased insertion times with ultrasound techniques with respect to nerve stimulation techniques, other studies show conflicting results. To elucidate this issue, Farag *et al.* [30▪▪] conducted a prospective randomized-controlled trial in 453 patients that tested the hypothesis that ultrasound alone when compared with ultrasound and electrical stimulation through the needle and ultrasound and electrical stimulation through the needle and catheter is noninferior on both postoperative pain scores and opioid requirements and superior in at least one regard for continuous femoral nerve block for total knee arthroplasty. They found that neither type of stimulation improved either primary outcome; furthermore, ultrasound alone was both more time and cost-efficient. Although the outcomes may be specific to continuous femoral blocks, this study suggests little benefit of nerve stimulation to ultrasound in experienced hands.

In addition to the method of insertion, different types of catheters have been investigated in the effort to improve the efficacy and quality of cPNB. For example, the echogenicity of catheters varies among different commercially available catheters. Mariano *et al.* [31▪] compared 19 ga Arrow StimuCath (Teleflex, Morrisville, NC, USA), 19 ga multiorifice nonstimulating Perifix (Braun, Bethlehem, PA, USA), multiorifice 20 ga nonstimulating Contiplex (Braun) and a single-orifce 21 ga nonstimulating wire-reinforced catheter in development (Epimed, Farmers Branch, TX, USA) for their overall visual echogenicity, visibility, scanning time, catheter length seen and ultrasound-related artifacts using a porcine-bovine in-vitro model. Their proof-of-concept study confirmed the heterogenic echogenic qualities of currently available commercial catheters and suggests that a catheter incorporating an internal wire braid may improve the visibility of the catheter under ultrasound.

Different configurations of catheters have been used for ambulatory cPNB as a result of successful configurations of catheters for epidural usage: end-hole, triple-hole and six-hole. In a randomized trial of 156 patients receiving interscalene cPNB for major shoulder surgery, the three types of catheters were compared [32▪]. Although end-hole catheters were more difficult to thread (19 versus 6 versus 0%), no major differences were found among the catheters in regard to pain scores, catheter function, opioid consumption, side-effects or adverse effects. However, the comparison of the catheters in this study is limited to the operative and immediate postoperative experiences, as endpoints for cPNB infusion on postoperative days 1 and 2 were not obtained [33].

One common problem during ambulatory cPNB is inadvertent catheter dislocation. Recent studies have examined whether catheter-over-needle techniques may improve this issue or prevent it from happening [34–37,38▪]. This technique attempts to address the hypothesis that leakage and dislocation result from the fact that in most cPNB systems, the catheter has a smaller diameter than that of the needle, leaving space for leakage to occur and inappropriate displacement a possibility. Although promising, further study is required to support the efficacy of catheter-over-needle techniques.

INFUSATES/INFUSION

Local anesthesia is the primary analgesic infused in ambulatory cPNB, and ropivacaine, bupivacaine and levobupivacaine are the most commonly used local anesthetics for their favorable duration of action and sensory-to-motor block ratio [13]. Although volume and concentration primarily determine the efficacy of single-injection nerve blocks when dose is held constant, it appears total dose is the primary determinant of block efficacy and effects for many cPNB locations [39]. This finding has been validated at multiple cPNB locations of the lower extremity and was reaffirmed by Madison *et al.* [40▪] in a randomized, triple-masked, active-controlled investigation of the relative effects of dose, concentration and infusion rate for continuous popliteal-sciatic nerve blocks in volunteers [41]. This suggests a decreased rate and increased concentration with conservation of total dose may permit a longer duration of infusion – a useful finding for ambulatory cPNB with a finite reservoir volume. In contrast, results in the upper extremity, such as along the brachial plexus at the infraclavicular position, are variable and may relate to anatomical differences in the relationship of the perineural space and the target nerves/plexus [42]. It is unclear if this variability holds true at the interscalene location of the brachial plexus or if the pharmacokinetics of the infusion for interscalene cPNB resemble lower extremity cPNB [43,44].

In addition to medication choice, volume, concentration and dose, analgesia may be optimized via the delivery regimen of boluses rather than solely a basal infusion. Patient-controlled boluses are frequently used in the clinical setting to optimize analgesia [45]. Previous studies of automated bolus function in place of a continuous infusion have found similar analgesia, sensory and motor effects and a small but significant local anesthetic-sparing effect [46,47]. Two recent studies investigated whether automated bolus could improve infusion characteristics for interscalene cPNB. In a randomized, double blind prospective trial, Hamdani *et al.* compared continuous infusion and PRN bolus with automated bolus and PRN bolus in interscalene cPNB for major shoulder surgery [48▪▪]. No significant difference was found in analgesia or secondary outcomes. In a similar study, Shin *et al.* [49▪▪] investigated interscalene cPNB for ambulatory arthroscopic rotator cuff repair comparing a continuous infusion with automated bolus without PRN bolus. Again, no difference was found in automated bolus versus continuous infusion in regard to analgesia or motor function. These findings are in contrast to studies for epidurals but consistent with prior investigation of automated bolus function in the lower extremity [47].

Because of the heterogeneity of catheter types, insertion techniques and many other factors, no specific concentration or rate combination can be recommended for all anatomic locations [13]. However, the most common concentrations are

bupivacaine 0.1–0.25% and ropivacaine 0.1–0.4%. The most common basal rate is 4–10 ml/h, bolus volume 2–10 ml and lockout period of 20–60 min (Table 1). Similarly, the maximum safe hourly dose of local anesthetic remains unknown. In a classic study, Knudsen [50] determined the toxic plasma concentration of free ropivacaine in healthy volunteers to be between 0.34 and 0.85 mg/l with a mean value of 0.6 mg/l with approximately 94% of the ropivacaine bound to α_1-acid glycoprotein.

A pilot study reported no signs of local anesthetic toxicity when 15 individuals were tested on multiple days while receiving ropivacaine 0.2% at basal rates of 6–14 ml/h with 30–60 ml surgical boluses of ropivacaine of 0.5% and 10 ml analgesic boluses of ropivacaine 0.5% [51]. Two individuals reached the mean plasma level for toxicity and four individuals reached the minimum plasma level for toxicity. The individuals in this study were previously healthy male adults 22–34 years old. This pilot study was succeeded by a similar study of 49 individuals age 19–59 who each received a ropivacaine 0.2% infusion with boluses of ropivacaine 0.5% resulting in a mean total dose of 22 mg/h (range 13–50 mg/h) [52▪▪]. No individual reached toxic plasma levels in this study. The highest plasma concentration of ropivacaine was 0.19 mg/l, and all other values were less than 0.09 mg/l – considerably lower than the toxic threshold established by Knudsen *et al.* [50]. It is unknown whether these results are applicable to elderly patients or individuals with comorbid conditions.

Adjuvant medications have also been examined in the effort to improve the quality of perineural infusions, such as clonidine, opiates and epinephrine; however, each has failed to demonstrate clinically relevant benefits in randomized-controlled trials (as opposed to single-injection PNBs in which some benefits have been demonstrated) [53–59,60▪]. Other possible adjuvants, such as dexmedetomidine and pregabalin, have been reported, but none is approved for perineural use and the side-effects may be unacceptable [61▪,62,63].

INFUSION PUMPS

Ambulatory perineural infusions are provided by portable pumps with various power sources, including electronic, vacuum, spring or elastomeric [64–68,69▪▪]. Pump characteristics determine which type of pump is optimal for a given clinical scenario [70,71]. Electronic pumps are the most accurate and customizable for setting basal, bolus and lockout parameters. They often have alarms signaling occlusion, making pump failure more apparent, and are capable of being reusable or have exchangeable reservoirs. Alternatively, elastomeric pumps are simple, lightweight, quiet and often less expensive (per unit) [64–68,69▪▪]. Electronic pumps deliver a consistent basal rate, ± 5%, throughout the infusion. In contrast, the basal rate of elastomeric models is more variable. Historically, they tended to infuse 10–30% over the expected rate in the first 3–8 h and again within the last few hours before reservoir exhaustion. Although a recent investigation by Weisman *et al.* [69▪▪] suggests some improvement in the accuracy of some elastomeric pumps, these devices still tend to infuse up to 30% over the expected rate at the beginning and end and are subject to relatively small inaccuracies that are dependent upon ambient temperature and height changes relative to the catheter tip.

One novel feature recently described and very promising for ambulatory infusion is the capacity for remote control. In a pilot study of 59 patients undergoing nonambulatory cPNB, Macaire *et al.* [72▪▪] examined the feasibility of using remote-controlled portable pumps (Rhythmic PCEA Pump, Micrel, Athens, Greece). Patients received either an interscalene, femoral or sciatic popliteal cPNB for 72 h duration. The infusions were managed remotely via a General Packet Radio Service module (IP-Connect) through the Internet with a proprietary application layer protocol. This allowed patients to respond to questions prompted by the pump, to alert anesthesiologists via text message if a potential need for infusion management had arisen and then allowed anesthesiologists to enact changes to the pump through the website MicrelCare. The primary outcome was response time of new settings to patient's needs, whereas secondary outcomes addressed the quality of analgesia, motor blockade, patient satisfaction and functional outcomes. All necessary modifications were made remotely within 17 min of request with a mean of 15 min. Moreover, patients were satisfied. The regimen was without safety issue and reported to be easy for the anesthesiologists involved with the study to conduct.

COMPLICATIONS

Serious and permanent complications related to cPNB are rare, whereas minor complications occur with a frequency similar to single-injection peripheral nerve blockade [73]. The most common minor problems may be failure to provide adequate analgesia, infusion failure or disconnection/dislocation of catheter; however, the heterogeneity of indication, technique, location and equipment renders generalizations less meaningful [34,74,75].

Serious adverse events may be categorized relative to cause: infection, bleeding, nerve injury,

Table 1. Suggested indications and dosing for common continuous peripheral nerve blocks in adults

Location	Surgical site	Surgical procedure or indication	Dosing	Suggested starting dose
Interscalene brachial plexus	Shoulder and proximal humerus	Shoulder arthroplasty, shoulder arthroscopy, primary rotator cuff repair, subacromial decompression, biceps tenodesis, Bankart repair, capsular plication, SLAP repair, shoulder debridement, acromioclavicular joint reconstruction; complex regional pain syndrome upper arm	Bupivacaine 0.0625–0.125%, 4–10 ml/h; ropivacaine 0.1–0.4%, 2–12 ml/h	Ropivacaine 0.2% 8 ml/h + 4 ml bolus 30 min lockout
Supraclavicular and infraclavicular brachial plexus	Elbow, forearm and hand	ORIF distal humerus, ORIF radius, ORIF ulna; total elbow arthroplasty; elbow arthroscopy; wrist fusion; wrist carpectomy or capsulodesis; metacarpal arthorplasty; thumb fusion; other major wrist and hand surgery; complex regional pain syndrome arm or hand	Bupivacaine 0.0625–0.125%, 4–10 ml/h,; ropivacaine 0.1–0.2%, 4–12 ml/h	Ropivacaine 0.2% 8 ml/h + 4 ml bolus 30 min lockout
Paravertebral	Thorax and breast	Mastectomy with or without sentinel node biopsy or axillary dissection, thoracotomy, video assistedthorascopic surgery	Bupivacaine 0.125–0.2%, 6–10 ml/h; ropivacaine 0.2–0.4%, 4–10 ml/h	Ropivacaine 0.2% 8 ml/h + 4 ml bolus 30 min lockout
Transversus abdominus plane	Abdomen and inguinal region	Open abdominal and pelvic surgery with midline or low transverse incision (bilateral), open hernia repair	Bupivacaine 0.125%, 8 ml/h; ropivacaine 0.2%, 10 ml/h	Ropivacaine 0.2% 8 ml/h + 4 ml bolus 30 min lockout
Lumbar plexus	Hip, anterior thigh and lateral thigh	Total hip arthroplasty, above knee amputation, thigh tumor resection	Bupivacaine 0.0625–0.125%, 4–10 ml/h; ropivacaine 0.1–0.4%, 2–10 ml/h	Ropivacaine 0.2% 8 ml/h + 4 ml bolus 30 min lockout
Femoral	Knee and thigh	Knee arthroplasty, quadriceps extensor mechanism reconstruction, above or below knee amputation; femur osteotomy; proximal tibial and fibula osteotomy, proximal tibia and fibula ORIF	Bupivacaine 0.0625–0.125%, 4–10 ml/h; ropivacaine 0.1–0.2%, 4–10 ml/h	Ropivacaine 0.2% 6 ml/h + 4 ml bolus 30 min lockout
Adductor canal	Knee and medial leg	Knee arthroplasty, major medial ankle surgery (arthrodesis and prosthesis); ACL reconstruction	Bupivacaine 0.0625–0.125%, 4–10 ml/h; ropivacaine 0.2%, 6–10 ml/h	Ropivacaine 0.2% 8 ml/h + 4 ml bolus 30 min lockout
Subgluteal sciatic	Leg, ankle and foot	Below or above knee amputation; all procedures listed for popliteal sciatic	Bupivacaine 0.0625–0.125% 4–10 ml/h; ropivacaine 0.1–0.4%, 2–10 ml/h	Ropivacaine 0.2% 6 ml/h + 4 ml bolus 30 min lockout
Popliteal sciatic	Leg, ankle and foot	Major ankle surgery: arthrodesis, prosthesis, ORIF, arthroplasty; achilles tendon repair; major foot surgery: calcaneal ORIF, midfoot ORIF; distal tibial and fibula osteotomy; complex regional pain syndrome foot or ankle	Bupivacaine 0.0625–0.125% 4–10 ml/h; ropivacaine 0.1–0.4%, 2–10 ml/h	Ropivacaine 0.2% 6 ml/h + 4 ml bolus 30 min lockout

local anesthetic toxicity, neural blockade sequelae and inaccurate or inappropriate catheter placement. Catheter site inflammation may occur in up to 4% of patients; while infection is rare but possible [76,77,78▪]. Risk factors for infection of ambulatory cPNB include duration greater than 48 h, location (axillary and femoral have higher risk), absence of antibiotic prophylaxis and diabetes [79▪]. Despite a rate of vascular puncture as high as 6% prior to the advent of ultrasound-guided techniques, pericatheter hematoma and hematoma-related complication are rare events [80,81]. cPNB-related nerve injury lasting more than 9 months is possible but rare. Data suggest the risk to be 4–7 per 10 000 blocks [13,82]. Transient acute neuropraxia, transient subtle clinical or subclinical deficit may occur in up to 3% of cPNB depending upon location [75,83]. Research in this subject matter is limited by a lack of standardization of what constitutes a neural deficit across studies. Moreover, it is unclear whether the risk of nerve injury with cPNB is different from single injection nerve block or different from when no nerve block is performed at all. Local anesthetic toxicity is also rare and may manifest as myonecrosis or as systemic toxicity [84,85,86▪,87–89]. One potential cPNB-related risk is the increased risk for fall with femoral nerve and lumbar plexus cPNB [90–92]. Given the potential for quadriceps weakness and fall, one may consider only performing continuous femoral nerve blockade in patients whose postoperative plan includes a straight leg brace for duration greater than that of cPNB. Last, complication may occur when the catheter tip is placed or migrates into an inappropriate anatomic location: epidural [93–95], intrathecal [96,97], intravascular [98], intraneural [99] and intrapleural [100].

CONCLUSION

cPNB is now a well-accepted and research-supported technique for the safe and efficacious treatment of moderate-to-severe pain related to surgery in the ambulatory setting. Recent advancements in equipment facilitate their use and optimize their efficacy. New research further supports well-accepted indications and supports previously less investigated ones, while refining techniques, improving knowledge of infusions and providing guidance for patient selection and management.

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Conflicts of interest

A.T.M.'s previous institution received funding for his previous clinical research from Summit Medical (Sandy, Utah) and Teleflex Medical (Research Triangle Park, North Carolina), and Pacira Pharmaceuticals (Parsippany, New Jersey). B.M.I.'s institution has received funding for his previous clinical research from Summit Medical (Sandy, Utah), Smiths Medical (St. Paul, Minnesota), Baxter International (Deerfield, Illinois), Teleflex Medical (Research Triangle Park, North Carolina) and Pacira Pharmaceuticals (Parsippany, New Jersey). In addition, B.M.I. has received honoraria from Pacira Pharmaceuticals for presentations and workshops.

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