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Review

Peripheral nerve blocks in the management of postoperative pain: challenges and opportunities

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Abstract Peripheral nerve blocks (PNBs) are increasingly used as a component of multimodal analgesia and may be administered as a single injection (sPNB) or continuous infusion via a perineural catheter (cPNB). We undertook a qualitative review focusing on sPNB and cPNB with regard to benefits, risks, and opportunities for optimizing patient care. Meta-analyses of randomized controlled trials have shown superior pain control and reductions in opioid consumption in patients receiving PNB compared with those receiving intravenous opioids in a variety of upper and lower extremity surgical procedures. cPNB has also been associated with a reduction in time to discharge readiness compared with sPNB. Risks of PNB, regardless of technique or block location, include vascular puncture and bleeding, nerve damage, and local anesthetic systemic toxicity. Site-specific complications include quadriceps weakness in patients receiving femoral nerve block, and pleural puncture or neuraxial blockade in patients receiving interscalene block. The major limitation of sPNB is the short (12-24 hours) duration of action. cPNB may be complicated by catheter obstruction, migration, and leakage of local anesthetic as well as accidental removal of catheters. Potential infectious complications of catheters, although rare, include local inflammation and infection. Other considerations for ambulatory cPNB include appropriate patient selection, education, and need for 24/7 availability of a health care provider to address any complications. The ideal PNB technique would have a duration of action that is sufficiently long to address the most intense period of postsurgical pain; should be associated

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with minimal risk of infection, neurologic complications, bleeding, and local anesthetic systemic toxicity; and should be easy to perform, convenient for patients, and easy to manage in the postoperative period.

1. Introduction

Multimodal analgesia refers to the use of combinations of analgesics acting via different mechanisms and thus taking advantage of additive or synergistic activity while minimizing adverse events with larger doses of a single analgesic [1]. Evidence-based multimodal techniques are procedure specific and may include combinations of systemic analgesics (eg, opioids, acetaminophen, nonsteroidal anti-inflammatory drugs), neuraxial analgesia (spinal, epidural, and combination spinal/epidural), local infiltration, and peripheral nerve blocks (PNBs).

The benefits of PNBs are numerous and include improvement in clinical, economic, and humanistic outcomes (Table 1). PNBs have been associated with improvement in postoperative pain control and reduction in the use of opioids in a variety of surgical procedures [2-7]. Avoidance of opioids not only minimizes the risk of adverse events but also has important public health implications given that opioids prescribed at hospital discharge, which are often in excess of the amount required to manage postoperative pain, may serve as a source for diversion [8,9]. Other benefits of PNBs include reduction in hospital resource utilization [10,11], improved postoperative recovery [10,12,13], and improvement in patient satisfaction [2].

Given the many benefits of PNBs in practice, it is not surprising that their use has expanded over the last several decades. PNBs are now a common component of analgesia for both upper extremity (eg, brachial plexus block using interscalene, supra- or infraclavicular, and axillary nerve approaches) [14] and lower extremity (eg, lumbar plexus, femoral, sciatic, and popliteal sciatic blocks, among others) procedures [15]. Technical advances include the use of ultrasound-guided needle placement and the movement from the use of single injections of local anesthetic (single-shot PNB [sPNB]) to a continuous infusion administered using a perineural catheter (continuous PNB [cPNB]). One recent study showed that the use of femoral nerve block (FNB, both cPNB and sPNB) after total knee arthroplasty (TKA) among Medicare patients increased dramatically between 2008 and 2009 [16]. As this use has expanded both within the hospital and in ambulatory settings, a greater understanding of the potential risks of these procedures and unmet needs has been achieved.

The objective of this article is to review the recent literature on sPNB and cPNB as a component of multimodal postoperative analgesia, highlighting benefits, risks, and opportunities for optimizing patient care. A search of the literature was performed using PubMed, including citations published up to March 2015. Search terms included *nerve block* [MeSH term], combined with *efficacy or effectiveness*, *safety or complication or adverse event*, and *cost or economic*. From the search results and the references cited in articles identified in the search, we selected articles most relevant to our objective. The assessment of efficacy focused on systematic reviews and meta-analyses comparing sPNB and cPNB to opioid-based analgesia and to each other. Additional information on risks and complications was gathered primarily from PNB registries and retrospective database analyses, which represent the use of PNB in current clinical practice.

Table 1 Benefits of PNB as a component of multimodal postoperative analgesia regimen

- Improvement in postoperative pain control and reduction in the use of opioids [2-7]
- Reduction in hospital length of stay [10,11]
- Prevention of hospital readmissions [16]
- Reduction in postoperative nausea and vomiting [2]
- Faster movement to phase 2 recovery and/or postanesthesia care unit bypass [13]
- Earlier participation in physical therapy [10]
- Improved patient satisfaction [2]

2. Clinical efficacy of PNB

2.1. PNB vs opioids

The efficacy of sPNB in improving short-term pain control has been shown in a number of upper and lower extremity surgical procedures. In a Cochrane review of randomized trials in patients undergoing major knee surgery, PNB used in combination with systemic analgesics (primarily opioids) was associated with significantly lower pain scores at rest from 0 to 72 hours after surgery, but no difference in pain on movement until 48 to 72 hours postoperatively, compared with systemic analgesics alone [6]. This review included a broad range of surgical procedures (TKA, anterior cruciate ligament [ACL] repair, and meniscectomy), block techniques (sPNB and cPNB), and locations (femoral, femoral/sciatic, adductor canal), many of which have been investigated in more focused systematic reviews. A meta-analysis of randomized trials comparing single-shot FNB to intravenous patient-controlled analgesia opioids showed a significant reduction in pain at rest and on movement for up to 24 and 48 hours, respectively, with significantly less opioid consumption for up to 48 hours [2]. When continuous FNB was compared with intravenous patient-controlled analgesia, pain at rest and pain on movement were significantly reduced for 48 and 72 hours, respectively [2]. In a meta-analysis comparing single and continuous psoas compartment block to oral opiates in patients undergoing total hip arthroplasty, visual analogue scale pain scores was significantly reduced in patients receiving either type of psoas compartment block at up to 24 hours postoperatively [3]. Pain outcomes were not reported for any subsequent time points. One retrospective study found a significantly lower 30-day all-cause readmission rates in Medicare patients undergoing TKA with cPNB (hazard ratio = 0.43, $P < .001$) or sPNB (hazard ratio = 0.49, $P < .001$) compared with no PNB; 90-day and 365-day readmission rates were also significantly reduced [16].

The impact of PNB on pain intensity in patients undergoing ACL repair is not as clear. In a Cochrane review comparing PNB in combination with systemic analgesia to systemic analgesia alone (n = 3 randomized controlled trials), pain intensities at rest and on movement were not significantly improved in patients undergoing ACL repair receiving PNB [6]. In a systematic review of 13 randomized trials comparing FNB to sham or placebo blocks in patients undergoing ACL surgery, Mall and Wright [17] found that pain relief was greater with FNB in only 5 trials and that opioid-related nausea and sedation occurred less frequently in the FNB group in only 1 trial.

Differences in study designs and outcomes have largely prevented studies of upper extremity surgical procedures to be combined using meta-analysis [4]; however, several systematic reviews have provided qualitative summaries of the existing evidence. In a review of trials comparing single-shot and continuous interscalene block (ISB) to saline injection or opioids for shoulder surgery, pain control was superior with single-shot ISB for up to 24 hours in 4 of 4 trials and with continuous ISB for up to 48 hours in 2 of 2 trials [18]. A more recent review focusing on arthroscopic shoulder surgery reported that all of the 10 studies included found significant reductions in pain for up to 24 hours after surgery, with significant reductions in opioid use seen in 8 of 9 studies reporting this outcome [7].

2.2. cPNB vs sPNB

Administration of local anesthetics via continuous infusion allows for a duration of analgesia significantly longer than that of a single injection. In a pooled analysis of 21 studies comparing cPNB to sPNB for postoperative analgesia, worst visual analogue scale pain scores and pain at rest were significantly lower in patients receiving cPNB on postoperative days 0, 1, and 2 but not day 3 [19]. Opioid consumption was also significantly reduced in the cPNB group on days 1 and 2.

The availability of cPNB has allowed for appropriate patients to be discharged home with an ambulatory infusion pump rather than stay in the hospital or receive alternative analgesics (eg, oral opioids) at home. In 3 similarly designed trials in patients undergoing TKA, total hip arthroplasty, or total shoulder arthroplasty, Ilfeld and colleagues [20-22] found that readiness for hospital discharge, as measured by adequate analgesia, not requiring IV opioids, and ability to walk at least 30 m, was achieved significantly faster among patients receiving cPNB until postoperative day 4 compared with those receiving cPNB until the morning after surgery.

3. Risks and limitations of PNB

Potential risks of PNB, regardless of technique or block location, include vascular puncture and bleeding, nerve damage, and local anesthetic systemic toxicity (LAST). PNB placement using ultrasound guidance has been shown to reduce the incidence of vascular puncture [23]. Neurologic complications are of particular concern because the duration of symptoms can extend for weeks or months after surgery [24,25]. These events are typically described by patients as tingling, pain on pressure, or pins and needles, and are associated with both sPNB and cPNB [24]. The incidence has been reported to be as high as 8.2% [26], with mixed evidence regarding the relative risk with sPNB vs cPNB. One study showed a higher incidence with sPNB vs cPNB in patients receiving femoral blocks [24], one showed no difference in risk among a population receiving PNB at various locations [26], and one showed higher rates of neurological complications lasting at least 6 months with cPNB, although this difference did not reach statistical significance ($P = .08$) [27]. Rates of long-term neurologic symptoms have been shown to be higher in patients receiving ISBs (3.5% vs 0.5% with other blocks, $P = .002$) [27].

Signs and symptoms of LAST are dose dependent and range from metallic taste, tinnitus, and perioral numbness to seizure, cardiac arrest, and death [28]. Registry-based studies that included either exclusively or primarily sPNB have reported seizure incidence of 0.08 to 0.28 case per 1000 blocks [27,29,30], whereas studies evaluating exclusively cPNB have found no cases of seizure [25,31]. Because of significant overlap in the range of incidence, it is difficult to determine whether seizure risk is reduced with cPNB. LAST without seizure is reported at rates of 0.25%-0.9% in patients receiving cPNB [25,31].

Site-specific limitations of PNBs include quadriceps weakness in patients receiving FNB, which may increase risk of falls, although this is controversial. Retrospective studies have found no increased risk of falls in patients undergoing TKA with PNB [16,32,33]. However, in a pooled analysis of 3 randomized, placebo-controlled trials, patients with lower extremity cPNB with ropivacaine had significantly more falls than patients receiving perineural saline (7% vs 0%; $P = .013$) [34]. In a meta-analysis of 5 studies comparing fall risk among patients receiving lumbar plexus (either femoral or psoas) cPNB to sPNB or no PNB, cPNB was associated with a nearly 4-fold increase in the risk of falls [35]. However, the authors note that avoiding the use of cPNB is unlikely to eliminate the risk of falls and may have a negative impact on pain management and recovery. A retrospective analysis of falls in 2197 patients undergoing primary TKA found an overall fall rate of 2.7%; independent risk factors for falls included continuous FNB (4.4; 95% confidence interval [CI], 1.04-18.2), increased age (odds ratio, 1.04; 95% CI, 1.0-1.07), and body mass index >30 kg/m^2 (2.4; 95% CI, 1.3-4.5) [36]. Single-shot FNB was not associated with an increased risk of fall. Adductor canal blocks are associated with less quadriceps weakness [37-39], greater ability to ambulate [40,41], and similar pain control compared with FNB in patients undergoing TKA [38-41]; however, it is not yet clear whether these differences directly impact fall risk.

Upper extremity PNBs may be complicated by pleural puncture and central neuraxial needle placement [18]. Pneumothorax has been recently reported in 0.2% of patients receiving continuous ISB [42]. In a systematic review of 13 prospective and retrospective studies in patients receiving ISBs, Moore and colleagues [43] reported that adverse effects including dyspnea, hoarseness, Horner syndrome, and failed block occurred in 8.14% of patients. However, a retrospective analysis of 17 157 patients undergoing total shoulder arthroplasty found no increase in the risk of pulmonary complications or need for mechanical ventilation among patients receiving ISB in combination with general anesthesia compared with general anesthesia alone [44].

3.1. Single-shot PNB

The major limitation of sPNB is the short duration of action of most local anesthetics. As such, sPNB is best suited for surgical procedures in which postoperative pain is not expected to exceed 12-24 hours in duration; otherwise, patients are at risk for significant rebound pain after discharge [45]. Administration of larger volumes or higher concentrations of local anesthetics may increase the duration of block but also increase the risk of motor block and LAST [45]. Thus, alternative methods of overcoming these limitations for surgical procedures with pain persisting past the first postoperative day are required.

3.2. Continuous PNB

The incidence of cPNB complications is highly dependent on the insertion technique and block location, and thus, it is difficult to make generalizations across studies. Minor complications include catheter dislodgement, obstruction, and fluid leakage at the catheter site [46]. Rates of catheter dislodgment in studies of volunteers engaging in activities of daily living were as high as 25% [47]. One study found that 2 of the 9 patients with dislodged interscalene catheters were readmitted to the hospital, with the remaining 7 patients experiencing no significant pain [42].

Although rates of catheter bacterial colonization appear high, clinically relevant infection is rare (Table 2) [46]. Risk factors for colonization among patients receiving ultrasound-guided catheter insertion include catheter duration >48 hours, diabetes, and antibiotic administration during the month prior to surgery [48]. In contrast, single-injection PNB conducted under ultrasound guidance has not been associated with infection [49].

Table 2 Infection-related complications of continuous PNB [46,48]

Complication	Incidence from observational studies	Notes
Colonization	6%-69%	Most common organisms are coagulase-negative *Staphylococcus*; others include gram-negative bacilli, including *Escherichia coli* and *Enterococcus*, and *S aureus*.
Inflammation	3%-9.6%	
Infection	0%-3%	

The costs associated with cPNB are an important consideration for providers and hospitals implementing this technique. These costs include infusion pumps, catheters, and other supplies; local anesthetic medications; and provider time required for patient education and follow-up. Sites using cPNB may realize cost savings with the use of reusable vs disposable pumps and using fixed-rate, basal-only pumps compared with variable-rate, bolus-capable pumps [50]. Ultrasound-guided sciatic cPNB has been shown to be more cost-effective than nerve stimulation guidance for catheter placement, with an increase in equipment costs being offset by a reduction in postoperative nursing time [51].

Whether cPNB is used in an inpatient or ambulatory setting, the resources required to provide this therapy safely and effectively are substantial. Facilities implementing cPNB programs must first invest in developing the appropriate infrastructure (policies and protocols, communication channels) and then commit resources to patient and provider education and follow-up to ensure the best possible outcomes for patients. Practical considerations for home use of cPNB include appropriate patient selection, follow-up, and education on pump management and removal. Patients for whom ambulatory cPNB may be inappropriate include those with known renal and hepatic insufficiency [52], heart and/or lung disease (among patients with ISBs) [52], altered mental status or psychosocial issues [53], inability to be contacted after discharge or to access a medical facility in case of emergency [45], and unwillingness to accept responsibility for pump management [52]. Prior to discharge, patients must be educated on the appropriate care of the catheter site and dressing, when to stop the pump for signs of toxicity, how to troubleshoot any catheter or pump issues, when to call the physician or nurse for signs of infection or problems with the infusion system, and instructions for catheter removal [53,54]. Ambulatory cPNB protocols differ in the frequency and mode of contact with patients after discharge, ranging from written instructions only to home nursing visits [55], and the appropriate strategy should be determined on a case-by-case basis with consideration for the type of surgery and patient characteristics. Regardless of planned follow-up, however, a health care provider is required to be available 24 hours per day, 7 days per week to address patient concerns and questions. Catheter removal can usually be performed by the patient or a caregiver [45].

4. Opportunities

The ideal PNB technique would have a duration of action sufficient to provide pain relief for the most intense period of postoperative pain but not result in a dense motor block that could be unpleasant to the patient or lead to safety issues such as falls. Moreover, the risk of infection, neurologic complications, bleeding, and LAST should be minimized to the extent possible. The technique should be easy to perform and thus independent of the technical skill of the anesthesiologist and with minimal chance of failed procedures. Finally, the ideal PNB technique should be convenient for patients and easy to manage in the postoperative period.

Currently available PNB techniques fall short of this ideal in a number of ways. sPNB is simple to perform, avoids the concerns associated with indwelling cPNB catheters, and does not require the patient to be responsible for medication administration at home, but the duration of block is often insufficient to manage pain beyond the first postoperative day. cPNB has the advantages of a prolonged duration of analgesia while administering more dilute local anesthetic solutions (and thus minimizing risk of LAST). However, catheter dislodgement rates may be unacceptable, not all patients are willing to accept the responsibility of home cPNB, and extensive education and follow-up are required for successful use.

5. Discussion

Peripheral nerve block techniques are now commonly incorporated into multimodal postoperative analgesic strategies. The consequences of expanded use of PNB include improvement in pain relief and postoperative opioid requirements, in addition to improved postoperative recovery and fewer opioid-related adverse events. As an extension of these benefits, patients are able to be discharged from the hospital earlier, and surgical procedures are able to be performed in outpatient settings.

Despite these advances, there is room for improvement in the provision of postoperative pain management. Although cPNB addressed the primary limitation of sPNB, it has introduced a new set of technical difficulties, patient education needs, and complications. For carefully selected patients and well-trained anesthesiologists, cPNB can be a safe and effective postoperative pain management strategy. Unfortunately, the increased complexity associated with an indwelling catheter and pump assembly increases the likelihood of technique failure (ie, catheter dislodgement, kinking, or leaking), and there are many patients for whom cPNB is not appropriate either because of comorbid conditions, logistical issues, or unwillingness to participate in management. Additional PNB modalities are needed to reach this population, in addition to minimizing risks of complications and costs among patients who are cPNB candidates.

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