Management of Peripheral Nerve Catheters at Home

R. Doris Wang MD, Lori A. Dangler MD, Ellen Radson RN, Bonnie L. Howe RN, Roy A. Greengrass MD

Abstract

Home use of continuous peripheral nerve block has increased rapidly in recent years. Factors to consider when setting up a home infusion program include patient selection, equipment, medications, and management of common problems. Attention to the steps outlined in this paper will help anesthesiologists make a comprehensive patient assessment plan, facilitate patient and caregiver education, and assist patients in completing their course of peripheral nerve catheter infusion therapy at home.

Keywords: ambulatory surgery; patient-controlled anesthesia; peripheral nerve block.

Authors' address: Department of Anesthesiology (R.D.W., B.L.H., R.A.G.), Mayo Clinic, Jacksonville, Florida, and the Department of Anesthesiology (L.A.D., E.R.), University of Florida, Gainesville, Florida.
Correspondence: R. Doris Wang, MD, Department of Anesthesiology, Mayo Clinic, 4500 San Pablo Road, Jacksonville, FL 32224

Introduction

Ambulatory surgery has increased considerably in the past 3 decades. Advances in intravenous and inhalational anesthetic agents have helped make outpatient surgery the standard for many types of procedures. Despite the success of ambulatory surgery, many patients experience moderate to severe postoperative pain at home [1].

The idea of a patient's involvement in his or her own postoperative care at home is not novel. Patients have engaged in self-care at home for many years, performing tasks such as ostomy care and care of peripherally inserted central catheter lines and ports. Long-acting peripheral nerve block has improved pain management after orthopedic procedures and facilitated discharge from ambulatory surgery units [2]. However, the benefits of single-shot nerve blocks are often lost within 24 hours after surgery because of the local anesthetic agent's limited duration [3]. Peripheral nerve block through perineural catheters and continuous local anesthetic infusion by lightweight, portable drug infusion pumps allow ongoing intense analgesia for 24 to 72 hours but minimize opioid-related adverse effects.

The use of continuous peripheral nerve block (CPNB) requires appropriate patient selection, education, and planning to minimize the potential risks and to maximize the benefits of CPNB at home. This review focuses on important factors involved in the management of CPNB at home.

Initiation of CPNB at Home

General Indications

As the practice of ambulatory surgery increases, more invasive and painful procedures are being performed. The challenge to anesthesiologists is not only to provide anesthesia that achieves fast home readiness but also to limit unplanned hospital admission because of pain and opioid-related adverse effects.

CPNB at home is often used now as primary analgesia along with multimodal therapy in the management of pain after ambulatory surgery. Most CPNBs are performed for ambulatory orthopedic procedures because of the pain associated with osteotomy. Fortier has shown that pain was responsible for 12% of unplanned admissions and 60% of these were orthopedic patients [4]. The duration of analgesia after a single-shot peripheral nerve block is less than 24 hours, whereas severe postoperative pain can last up to 7 days [5]. Meta-analysis of CPNB has shown that every type of perineural catheter analgesia is superior to opioid analgesia [6].

In addition to providing analgesia in the ambulatory setting, CPNB has been used to facilitate early inpatient discharge after more complex surgical procedures [7,8] in response to insurance companies' limiting hospital stays. Finally, patients with a history of adhesive capsulitis who require immediate and frequent physical therapy after lysis of adhesion or joint manipulation may benefit from the intense analgesia of CPNB.

Patient Selection

Appropriate patient selection is probably the most important factor in performing successful CPNB at home (Table 1). Despite the superior analgesia that CPNB can provide, some patients may be very conscious of their body image and therefore refuse to have catheters attached to their body. For patients who tend to be noncompliant, who are unwilling to participate in pain management other than taking oral pain medications, who are unlikely to follow directions, or who might tamper with medical devices, CPNB may not be the best choice of treatment.

Patients also need to have a responsible adult caregiver, telephone access, transportation, and a clean and safe recuperative environment. A patient living on the fourth floor of an apartment building without an elevator may not be a good candidate for lower extremity CPNB at home. Patients and their caregivers must be willing and active participants in pain management for CPNBs to work well in the ambulatory environment. Unlike the inpatient setting in which trained medical personnel are responsible for patient assessment, treatment of pain, and management of opioid-related adverse effects, patients using CPNB at home must be able to assess their pain level and perform treatment with the assistance of their caregiver.

Short-term postoperative cognitive dysfunction can also be an issue for some patients [9]. Patients with a history of severe dementia or with difficulty communicating are usually not suitable candidates for CPNB. Patients with cultural and language barriers and without the aid of an appropriate caregiver at home may be at risk using home

Table 1 Exclusion Criteria for Continuous Peripheral Nerve Block at Home.

Criteria	Rationale	Examples
Cognitive dysfunction	Difficulty in pain assessment and diagnosis of complication	Multi-infarct dementia, Alzheimer disease, psychiatric disorder
Unreliability	May not or will not follow instructions, unable to follow instructions	Psychiatric disorder, language barrier and no translator available, patient without phone
Lack of home support system	Potential lack of care in case of emergency, perhaps more likely to have complications	Patients living alone, patients caring for a dependent spouse, pediatric patients with unreliable parents
Baseline ambulation difficulty	Increased possibility of trauma from falling	Patient with severe rheumatoid arthritis, history of hemiparesis from stroke, history of weakness from preexisting neuropathies or myopathies
Significant organ dysfunction	Changes in pathophysiology that increased the likelihood of neurologic or cardiac toxicity	History of heart failure with resultant increased perfusion to vital organs, decrease drug or active metabolite clearance during continuous infusion

CPNB because of their lack of ability to communicate with on-call staff in case of emergencies. Risks and benefits of performing CPNB at home must be considered carefully for a patient who has difficulty walking because of an underlying neurologic disorder, has poor balance after previous strokes, or needs to use crutches or a walker.

Surgical procedures that allow a 23-hour postoperative observation period provide another opportunity to assess postoperative cognitive function, educate the patient and responsible caregiver, and help patients understand and prepare for CPNB at home. Although not discussed extensively in the literature, for patients traveling long distances postoperatively, we usually recommend overnight observation in the hospital or at a local hotel. During this additional observation period, many patients are recognized to be suboptimal candidates who must rely on more traditional pain management methods.

In addition to providing pain management for ambulatory surgery patients, CPNB is being used to facilitate early hospital discharge after different types of orthopedic procedures. More data will be available in the future on this particular use of CPNB at home.

Patient and Caregiver Education

In addition to patient selection, appropriate patient and caregiver education ensures patient satisfaction and effective analgesia (Table 2). Important points of education include 1) protection and inspection of the insensate limb; 2) instructions on dressing care, catheter removal, and basic infusion pump function; 3) pain management and use of rescue medications; and 4) management of block and local anesthetic–related adverse effects. Sample forms for both physicians and patients are provided in Appendixes 1 through 4.

Preliminary prospective studies of CPNB at home with proper education of the patient, caregiver, home health nurses, and call staff support the safety of regional anesthesia and discharge with an insensate limb [10-14]. For carefully selected and educated patients, concerns for insensate limbs are often unfounded, probably because most patients' extremities are already immobilized and the block may have minimal effect. Warnings to avoid weight bearing on the blocked limb are also important for lower extremity CPNB, while vigilant observation of the position, color, and temperature of the insensate extremity by patients and their caregivers is required because of the lack of a protective reflex to pain [15].

Patients need to be active participants in managing their postoperative pain and monitoring block or local anesthetic–related adverse effects. Discharge instructions should explain when to administer a local anesthetic bolus through the nerve sheath catheter, when to discontinue drug infusion, and when to take other prescribed medications for multimodal pain therapy. Common indications for discontinuing CPNB infusion are possible signs of local anesthetic toxicity (eg, tinnitus or perioral numbness) and block-related adverse effects (eg, dyspnea unrelieved by sitting up during interscalene catheter infusion or desire to have partial recovery of limb sensation). Patients are encouraged to contact the on-call services if they have questions and concerns. In general, reducing activity and exercising common sense to avoid harming insensate limbs are recommended.

The patient, caretaker, or home health nurse can perform catheter removal at the end of infusion. Complete removal of the catheter should be verified by examining the tip of the catheter and the intactness of the length of the catheter. Some patients prefer to remove the catheter while being supervised by medical staff over the phone [11].

Patients With a History of Opioid Tolerance and Dependence

Acute postoperative pain management in patients who are recovering from substance addiction or who are currently dependent on opioids presents special challenges. Standard medication dosages and strategies are often ineffective in providing pain relief for these patients [16,17]. Appropriate treatment of acute postoperative pain and prevention of relapse are particularly important for the recovering patient. Management of increased opioid requirements, hyperalgesia secondary to reduced opioid dosage, and anxiety related to the fear of inadequate pain management are common issues in patients with increased opioid requirements [18,19].

The benefits of CPNB for opioid-dependent or -tolerant patients, although not well studied compared with the benefits for opioid-naïve patients, can nevertheless be inferred from these data [10,20]. For opioid-dependent and -tolerant patients, the continuation of maintenance opioid medication and other existing medications (such as antidepressants, anticonvulsants [eg, gabapentin], nonsteroidal anti-inflammatory drugs or cyclooxygenase 2 inhibitors, and benzodiazepines) is important to prevent opioid withdrawal and anxiety in the perioperative period.

Patients With Renal or Hepatic Dysfunction

Patients with hepatic or renal dysfunction are not the best candidates in general for regional anesthesia because of underlying hemostasis problems. Although desirable in reducing stress responses in these critically ill patients, continuous local anesthetic infusion poses considerable risk even with ropivacaine, a safer alternative than bupivacaine [21]. In patients with chronic end-stage

Table 2 Patient Instruction and Education.

Concerns	Examples
Catheter-related issues	
Type of catheter	Interscalene, femoral, axillary, or popliteal catheter
Management of catheter leak or dislodgment	Reinforcement of dressing
Catheter removal plan	By self, caregiver, home health nurse, or under supervision by medical staff over the phone
Block-related adverse effects and management	
Dyspnea, hoarseness, or difficulty swallowing from interscalene block	Decrease or hold infusion for 1 h, suggest resting in chair or recliner to improve pulmonary mechanics
Weakness and lack of control of the blocked limb	Practice limb protection, can decrease infusion rate or hold infusion for 1 h
Limb protection	
Protection of insensate limb	Upper extremity splint, lower extremity braces, or protective shoe wear; use of crutches, walker
Check circulation	Check temperature and skin color to make sure dressing is not too tight
Medications	
Name of the local anesthetic infusion	Ropivacaine, bupivacaine, or levobupivacaine
Signs of local anesthetic toxicity	Mouth or tongue numbess, ringing in ears
Rescue pain medications	Oral opioids, NSAIDs, acetaminophen
Multimodal pain management	Including possible cryotherapy
Pump function	
How to turn on and off	
Protect reservoir from sunlight, heat, and water	
Check for signs of infusion	
Contact phone numbers	
On-call staff must have patient's phone number	
Patient or caregiver must have contact number of the on-call service or home health care nurse	
NSAID, nonsteroidal anti-inflammatory drug.	

liver disease, clearance of ropivacaine is 60% lower than it is in healthy subjects. Therefore, more than 2-fold higher steady-state plasma concentrations are expected during continuous infusion. In addition, during continuous ropivacaine infusion, patients with chronic end-stage liver disease are expected to have a steady-state plasma ropivacaine concentration more than double, at a given infusion rate, that of healthy subjects. Also, the 4-fold-longer ropivacaine half-life (about 11 hours) in patients with chronic end-stage liver disease should be taken into consideration if repeated ropivacaine doses are used in these patients. For patients with end-stage renal disease, the concern with continued local anesthetic infusion is higher plasma concentrations of free ropivacaine than the plasma concentrations in nonuremic patients. Another concern in these patients is the accumulation of cardiotoxic metabolites.

Pediatric Patients

Recently, continuous regional analgesia has been used in pediatric patients to treat or to minimize disabling behavioral and psychological pain associated with complex regional pain syndrome I or postoperative pain [22,23]. CPNB is usually initiated under general anesthesia with minimal complications [24]. Indications for CPNB in children are similar to those for adults with intense postoperative pain, painful physical therapy, or complex regional pain syndrome [22,25]. Techniques for performing pediatric CPNB were summarized in a recent review [22,24].

Contraindications to CPNB in children are similar to those in adults. Parental and/or patient consent must be obtained before starting CPNB. In adult patients, the infusion rate is mainly limited by the type of infusion pump; a rate of 0.2 mg/kg per hour is recommended for children [25]. Patient- or parent-controlled local anesthetic bolus, although possible, has not yet been studied in pediatric patients.

Selecting the Appropriate Type of Catheter and Infusion Technique for Home Infusion

Upper Extremity Procedures

Single-catheter techniques often provide complete analgesia for upper extremity procedures. The choice of catheter depends on the site of the surgery. Interscalene catheters are indicated for shoulder-related

Table 3 Examples of Published Infusion Regimens.

Author	Catheter	Procedure	Initialbolus	Infusion	Rate
Sandefeo 2005 (41)	Posterior approach, interscalene, 20- to 22-gauge catheter, 3-4 cm into the sheath	Shoulder surgery	20-30 mL of ropivacaine 0.75%	Ropivacaine 0.1%	C, 5-10 mL/h B, 5 mL LO, 20 min
Ekatodramis et al 2003 (40)	Interscalene, 2-3 cm into the sheath, catheter tunneled 4-5 cm from insertion site	Shoulder surgery	30 mL of ropivacaine 0.75%	Ropivacaine 0.2%	C, 2, 6, or 9 mL/h
Ilfeld et al 2002 (52)	Infraclavicular, 3 cm into the sheath	Procedures distal to the elbow	50 mL of mepivacaine 1.5% with clonidine, epinephrine, and sodium bicarbonate	Ropivacaine 0.2%	C, 8 mL/h B, 2 mL LO, 20 min
Nielsen et al 2003 (68)	Interscalene, 5 cm into nerve sheath	Shoulder surgery	30-40 mL of ropivacaine	Ropivacaine 0.2%	C, 10 mL/h
Ilfeld et al 2003 (69)	Interscalene, 5 cm into nerve sheath	Shoulder surgery	40 mL of mepivacaine 1.5% with epinephrine and sodium bicarbonate, 100 μg of clonidine	Ropivacaine 0.2%	C, 8 mL/h B, 2 mL/h LO, 15 min
Kline et al 2000 (70)	Interscalene, 10 cm into nerve sheath or as far as possible	Open rotator cuff, biceps tenodesis	30 mL of ropivacaine 0.5% with epinephrine	Ropivacaine 0.2%	C, 10 mL/h
Casati et al 2003 (71)	Interscalene, 4-5 cm into nerve sheath	Open shoulder surgeries	30 mL of ropivacaine 0.5% or levobupivacaine 0.5%	Ropivacaine 0.2% or levobupivacaine 0.125%	C, 6 mL/h B, 2 mL LO, 15 min, up to 3 doses per hour

procedures such as shoulder arthroscopy, arthroscopic rotator cuff repair, open rotator cuff repair, or proximal humeral procedures. However, interscalene catheter insertion and maintenance remain technically challenging [26-28]. New approaches and tunneling of perineural catheters help prevent catheter dislodgement [29].

For patients undergoing elbow-related procedures and for those with a history of decreased lung function, axillary or infraclavicular catheters are better choices than interscalene catheters because of the lack of phrenic nerve paralysis. Procedures of the forearm, wrist, and hand can be managed with axillary or infraclavicular catheters. Although infraclavicular and axillary blocks are equally effective, infraclavicular block seems to cause less discomfort and is associated with a lower incidence of accidental vessel puncture than axillary block in the single-shot approach. In addition, the infraclavicular site may be easier to care for during catheter inspection by the patient and home health nurses [30].

Supraclavicular block is associated with considerable risk of pneumothorax, and patients may remain asymptomatic until hours after discharge from the hospital or ambulatory surgery center. Thus, supraclavicular block is not commonly performed for outpatient surgery [31,32]. This approach to the brachial plexus, although ideal for procedures involving the entire upper extremity below the shoulder joint, should be performed after careful consideration and in the absence of safer alternatives [31]. Preliminary data on

ultrasound-assisted supraclavicular block are promising, but it is not clear at present whether ultrasound techniques facilitate catheter placement [33,34].

Lower Extremity Procedures

Unlike the brachial plexus, the anatomy of the lower extremity peripheral nerves precludes complete analgesia with single-catheter techniques. Depending on the site of operation, 1 peripheral catheter, either femoral or sciatic, is usually selected for home infusion therapy. Analgesia for a wound that is not covered by a single CPNB is achieved with conventional oral medications.

Different approaches to the lumbar plexus such as femoral or psoas catheters can be used to provide analgesia after arthroscopic ligament reconstruction [35,36]. Psoas catheters are theoretically less likely to dislodge, are located in a "cleaner" insertion site compared with femoral catheters, and provide for better coverage at the obturator nerve distribution. However, they may result in serious complications such as epidural or spinal spread of local anesthetic [37]. Psoas catheters are commonly used for the management of pain after hip-related procedures [38].

Table 4 Published Infusion Strategies for Sciatic Catheters.

Author	Study	Surgery	Initial bolus	Infusion	Rate
Singelyn et al 1997 (72)	Popliteal sciatic	Foot	30 mL of mepivacaine 1% with 1:200,000 epinephrine	Bupivacaine 0.125%, 0.1 µg/mL of sufentanil, 0.1 µg/mL of clonidine	C: 7 mL/hr
Ilfeld et al 2002 (52)	Popliteal sciatic	Distal to knee	50 mL of mepivacaine 1.5% with 125 mg of epinephrine, 100 µg of clonidine, 5 mEq of bicarbonate	Ropivacaine 0.2%	C, 8 mL/h B, 2 mL LO, 20 min
di Benedetto et al 2002 (73)	Subgluteal sciatic	Foot	20 mL of ropivacaine 0.75%	Ropivacaine 0.2%	C, 5 mL/h B, 10 mL LO, 60 min
di Benedetto et al 2002 (73)	Popliteal sciatic	Foot	20 mL of ropivacaine 0.75%	Ropivacaine 0.2%	C, 20 mL/h or 5 mL/h B, 5 mL LO, 60 min
Rodriguez et al 2006 (39)	Popliteal sciatic	Hallux valgus repair	20 mL of mepivacaine 1.5%	Levobupivacaine 0.125% or 0.0625%	C, 3 mL/h B, 3 mL LO, 60 min

There are different approaches to the sciatic nerve as well. Sciatic nerve block at the mid thigh such as popliteal block can provide excellent analgesia after foot and ankle procedures with minimal motor block to the semimembranous muscles above the knees compared with the Labat and parasacral approaches [13,39].

We believe that an approach for lower extremity CPNB at home that causes the least amount of muscle weakness prevents injury to the insensate part of the limb. However, this opinion needs to be balanced with other factors such as the anesthesiologists' comfort level in performing the nerve block, the patient's ability to assume the proper position during placement of the catheter, and the anesthetic plan relative to the use of nerve block as primary anesthesia for the surgery. The major concern with lower extremity block is fall secondary to lower limb weakness from CPNB.

Equipment

Selecting a Needle System and Catheter for CPNB at Home

The ideal needle system is easy to use and has a low failure rate. Two popular needle systems are the insulated 18G Tuohy needle with continuous catheter insertion system and the cannula-over-insulated needle technique [40,41]. No comparison data are available. Depending on the clinician's level of experience, both systems can be reliable in facilitating the placement of perineural catheters. Placement of perineural catheters has traditionally been performed after injection of a large volume of local anesthetic via the block needle. Alternatively, nerve block can be achieved by injecting the local anesthetic through the perineural catheter.

Despite the success of initial nerve block via the block needle or catheter, the lower volume of dilute local anesthetic used for secondary analgesia may not provide adequate analgesia if the catheter tip is too far from the nerve. Some studies have reported a 10% to 15% secondary failure rate [42], which introduces a major concern about using CPNB at home. Secondary block failure is recognized as the lack of analgesia during infusion of dilute local anesthetic via the peripheral nerve catheter [43,44]. Large case series have demonstrated the failure of secondary block in up to 10% of patients [26]. Lack of satisfactory anesthesia after injection of local anesthetic indicates an improperly positioned catheter before initiation of CPNB.

The ease or difficulty of catheter advancement past the block needle tip alone is not an adequate indicator for optimal catheter positioning, as demonstrated by a contrast study [45]. At present, the definitive method of confirming catheter placement near the target nerve is to establish primary block though the catheter. If the primary nerve block is established through the block needles first, the effectiveness of the catheters is not known for sure until resolution of the primary block. For inpatients with established intravenous access, parenteral opioids can be given to assist in pain management and to limit adverse effects of the opiates, although undesirable effects can be monitored and treated. Delayed diagnosis of secondary block failure after ambulatory surgery can lead to severe pain and delay in achieving pain control with oral medications, as the initial nerve block begins to resolve. The use of stimulating catheters has been advocated by some investigators in the hope of decreasing secondary block failure rates [39, 46, 47]. Preliminary comparisons of the success of stimulating versus nonstimulating catheters for primary and secondary nerve block have shown no significant difference between them [48, 49]. Nevertheless, some advantages of using stimulating catheters include shorter block onset time and increased quality of the nerve block compared with nonstimulating catheters [46, 50]. As with other new devices, differences in application techniques may lead to disparate results. The use of real-time stimulation as the catheter exits the tip of the block needle is being advocated to further improve catheter placement using the stimulating catheter technique. Further study is needed to decide whether the use of stimulating catheters decreases the secondary block failure rate for every type of peripheral nerve block. For practitioners using nonstimulating catheters and attempting to establish nerve blocks through perineural catheters, the injection of dextrose 5% in water instead of local

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considered are the pump's bolus and basal capabilities, programmability, reservoir volume, disposability, unit cost, temperature sensitivity, and log-interrogation functions [52-54]. Currently available pumps are of either the elastomeric or the mechanical, battery-powered type.

An elastomeric pump consists of a disposable container with an inner elastic bladder that can be filled with the local anesthetic agent. They are also described as balloon or spring vacuum pumps. The flow rate of the elastomeric pump is set by the diameter of the flow regulator. These are simple in design, relatively inexpensive, and easily explained to the patient. In vitro evaluation of elastomeric pump flow rates showed a significant increase in the infusion rate when the temperature at the flow regulators was increased [54]. In addition, an increase or decrease in pump height can increase or decrease the infusion rate when elastomeric pumps are used [54]. Ilfeld et al [54] usually recommend that their patients wear the elastomeric infusion pumps around the shoulder using the carrying devices made for the pumps to eliminate variations in pump height. To control the temperature factor, during the summer months in Florida, we routinely advise patients to stay indoors during CPNB at home because the high ambient temperature can increase pump flow rates unintentionally.

According to manufacturers' recommendations, elastomeric pumps are nonrefillable. A new generation of elastomeric pumps has a large reservoir volume (about 500 mL) for 3-day infusions as well as the capability to deliver a patient-controlled local anesthetic bolus. Several clinical studies found elastomeric pumps to be easy for patients to use and effective in providing CPNB at home, despite the inaccuracy of the flow rate [10,12,55-57].

A major factor affecting the flow rate of mechanical pumps is battery life [54]. Overall, mechanical pumps allow greater flexibility in programming infusion therapy. However, despite this advantage, many patients do not feel comfortable changing the pump setting can produce concentration-dependent reductions in nerve blood flow by 20% to 35% in laboratory studies [87]. Continuous infusion of clonidine at 1 μg/mL did not decrease breakthrough pain intensity [12].

No current data support the addition of an opioid to the CPNB infusion. Peripheral opioid receptors are located primarily on the terminals of primary afferent neurons, and their expression is enhanced in the presence of inflammation, which may be exacerbated by CPNB catheters located proximally to these axons [88,89]. Overall, dilute local anesthetic alone works well.

Securing the Perineural Catheter

After catheter placement, sterile liquid adhesives and sterile tape are used to secure the catheter to skin. Small to moderate amounts of local anesthetic leakage around the catheter insertion site are common. Sterile gauze pads can be placed above the sterile tape and under the sterile occlusive dressing to absorb some of the local anesthetic. Tunneling of the perineural catheters using a shielded catheter or the 18G insulated Tuohy needle has been used for interscalene catheters that are difficult to secure because of shallow depth from skin to the brachial plexus at the neck area.

Follow-up Care

Well-thought-out follow-up care after discharge is critical to maintaining CPNBs at home. Follow-up care can be performed by telephone calls by designated anesthesia personnel or by visits from home health care staff who are familiar with the common adverse effects and management of CPNBs. The goal during follow-up assessment is to answer specific questions encountered after discharge, to reassure the patient and caregiver, and to ascertain any change in the patient's condition that may warrant discontinuation of CPNB at home. The spouses of elderly patients may not be able to take on the additional responsibility of CPNB at home, and for these patients, home healthcare is appropriate. For younger patients, options are a designated caregiver and home health care provider.

Education of Regional Catheter Service Staff

The regional analgesia follow-up team in the teaching hospital setting often consists of an anesthesiology resident and a specially trained nurse caring for patients with peripheral nerve catheters. The regional analgesia team callback numbers should be available to patients on their discharge orders. A member of the regional catheter team should call the patient daily and document phone assessment. For phone follow-up, nurses working in a pain clinic or on the hospital pain service should be familiar with block techniques, complications, and medications. Some patients do well without further instruction, and others are more comfortable with a follow-up phone call the night after surgery [11]. It is not clear whether follow-up phone calls reduce the need for contact with the on-call physician or home health care nurses [11].

Education of Home Health Care Nurses

Nurses from home health care agencies may need additional education on the rationale for use of CPNB, anatomy of the block, sites and duration of expected sensory and motor changes, pump operation, infusion strategies, symptoms of local anesthetic toxicity, problems and complications, catheter site evaluation, catheter removal technique, appropriate oral analgesic dosing and adverse effect management, and updating the patient's record. Preprinted peripheral nerve catheter orders should be available for home health care nurses. Agencies need to be contacted in advance and orders must be faxed before the patient's discharge. Nursing assessment of motor sensory function, catheter site, and pain control must be performed by a registered nurse. The daily duties of the home health care nurse include assessment of the catheter, tenderness at the catheter insertion site, the portable infusion pump, the patient's verbal pain score (range, 0–10), and any adverse effects. Documentation should include peripheral nerve catheter site, infusion system, adverse effects, and pain scores.

An on-call anesthesiologist usually serves as a backup resource for the home health care nurse. The home health care nurse can perform catheter removal.

Potential Complications Related to CPNB

Although needle- or catheter-induced trauma and local anesthetic toxicity have been identified as anesthetic-related risk factors [90] in peripheral nerve blocks, the presence of preexisting neurologic deficits, perioperative positioning, tourniquet ischemia, and surgical traction may also contribute to nerve injuries. Theoretically, the risk of neurologic complications may increase because of catheter-induced mechanical trauma compared with that of a single-shot nerve block. However, a retrospective review by Bergman et al [58] showed that the risk of neurologic complications associated with continuous axillary blocks is similar to that of single-dose techniques. Symptoms such as hypoesthesia or paresthesia can occur but with complete resolution between 36 hours and 10 weeks after the procedure [91].

Localized Tenderness and Infection at the Catheter Insertion Site

Localized discomfort in the area of the nerve sheath catheter insertion site has been reported after CPNB [11]. Bacterial colonization of the peripheral nerve catheter is common, but the risk of abscess formation is low [91,92]. Localized infection is usually self-limiting and resolves after catheter removal [91,92].

Local anesthetic myotoxicity, if not attributable to localized infection or surgery-related issues, is a clinically rare complication associated with peripheral nerve blockade. The discomfort around the catheter insertion site can be readily attributed to the operation itself or, alternatively, may be caused by local anesthetic myotoxicity, but concealed by surgical pain. Although experimental effects in animals are clearly intense and reproducible, clinically there are few reports of myotoxicity in patients after local anesthetic administration via peripheral nerve block [93]. Most reported cases were related to dental injections and ophthalmic blocks for cataract surgery [94-96]. Histologic studies in animal models showed that hypercontracted myofibrils become evident within minutes after injection, followed by lytic degeneration of striated muscle sarcoplasmic reticulum, myocyte edema, and myonecrosis over the next few hours. These effects are considered to be reversible because myoblasts are not affected by the local anesthetic agents and can therefore regenerate within 2 to 4 weeks [96]. In experimental models, local anesthetic myotoxicity has been described after administration of all local anesthetic agents with a drug-specific and dose-dependent rate of toxicity [96]. Histologically, bupivacaine appears to cause the most local anesthetic myotoxicity, and the least myotoxicity occurs with ester-type local anesthetic agents such as tetracaine and procaine [93]. A study of local anesthetic myotoxicity in animals with CPNB with equipotent dilute bupivacaine and ropivacaine infusions without initial bolus of a large dose of local anesthetic by Zink et al [94] showed destruction of myocytes with obvious signs of fiber regeneration. The animals in the ropivacaine group had a much lower rate of acute myotoxicity compared with those in the bupivacaine group.

Overall, the clinical impact of local anesthetic myotoxicity is controversial. Many anesthesiologists do not consider local anesthetic myotoxicity a genuine clinical problem because skeletal muscle injuries after the application of these drugs remain clinically unapparent in most cases and are typically reversible within several weeks. It is not clear at this time if continuous local anesthetic infusion postoperatively, whether patients are hospitalized or not, contributes to additional myotoxicity after the initial block with higher doses of local anesthetics. Nevertheless, local anesthetic myotoxicity remains a rare complication after peripheral nerve block and CPNB.

Difficult Catheter Removal

Difficulty during catheter advancement has been reported with knotted femoral and infraclavicular catheters that required surgical removal with subcutaneous incision [11,97]. There has also been 1 reported case of nerve entrapment by the wire from the stimulating catheter that also required surgical removal of the catheter [14].

Financial Considerations

Any discussion of the management of CPNB at home would be incomplete without providing some information on the financial aspect of the practice. The main factors to be considered are the expense of the home infusion pump and the local anesthetic agent for continuous infusion at home. Our hospital cost for 3-day infusion of ropivacaine is approximately US $58 (US $19.33 per 200-mL bottle of 0.2% ropivacaine), and the cost to the institution for a portable infusion pump ranges from US $325 to $400. Thus, at our institutions, the total cost for providing a 3-day infusion of CPNB is approximately US $383 to $458. Infusion pump costs vary, depending on the type of pump (electronic vs elastomeric), the pump manufacturer, and the number of pumps purchased by the institution. The infusion pump and ropivacaine are not separately reimbursable items for Medicare patients, although they may be covered by other third-party insurers. The amount of reimbursement for non-Medicare patients depends on contract negotiations or patients' insurance policies.

Discharging patients with CPNBs has financial advantages for the institution. A conservative estimate of overall hospital costs for a teaching hospital is $1,000 to $1,200 per day for surgical inpatients when the hospital is not at full occupancy. When occupancy is high and beds are in demand, delayed discharge of patients is an obvious lost opportunity. For Medicare patients, the expense to hospitals of providing the pump and local anesthetics are easily offset by the cost savings realized by discharging patients early and minimizing unplanned readmission due to poor pain control.

Finally, unrelated to hospital costs for CPNB at home is the cost for home health care visits. Home health care is sometimes needed for elderly or patients with special needs. For homebound elderly patients who have satisfied the criteria for home health care, Medicare covers home health nursing visits. The amount of home health care reimbursement depends on the level of care the patient requires, as determined by the home health care nurse's assessment during the initial visit. For non-Medicare patients, home healthcare–related reimbursement depends on each patient's insurance carrier and the type of health care coverage.

Conclusions

In summary, CPNB at home as part of multimodal analgesia after surgery provides analgesia that is superior to conventional treatments. The efficacy and advantages of CPNB over traditional therapy such as opioid medications has been demonstrated by multiple randomized, prospective studies in the past 5 years and a recent meta-analysis of 19 randomized controlled trials [6]. The keys to successful completion of CPNB at home are comprehensive patient assessment initially, followed by patient and caregiver education, and postoperative follow-up care. Initial clinical studies of CPNB at home focused on safety, feasibility, and efficacy, and more recent studies have evaluated complications and improved equipment such as stimulating catheters and ultrasound-assisted techniques to decrease the rate of secondary block failure and perhaps improve the quality of block by reducing local anesthetic infusion doses. Additional studies are under way on the potential of CPNB to improve rehabilitation and to decrease the incidence of postoperative chronic pain syndrome. The use of CPNB at home is a growing trend in the United States and worldwide, in both teaching institutions and private practice, and the positive effect on patient satisfaction and health care costs suggests this trend will continue.

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