David C. Warltier, M.D., Ph.D., Editor

Anesthesiology 2006; 104:872–80

Perineural Infusion of Local Anesthetics

*André P. Boezaart, M.B., Ch.B., M.Prax.Med., F.F.A.(C.M.S.A.), M.Med.(Anaesth), Ph.D.**

CONTINUOUS nerve blockade is the only available medium- to long-term modality that blocks evoked pain (*e.g.*, by knee flexion after knee surgery). In addition to the humanitarian and economical aspects of effective pain management, it is not surprising that improved and faster rehabilitation after surgery, such as knee arthroplasty, have been demonstrated.[1] Furthermore, decreased nausea and vomiting and increased patient satisfaction are consequences of continuous peripheral nerve blocks (CPNBs), whereas other interesting concepts, such as improved rehabilitation and decreased incidence of postsurgery chronic pain syndromes, are currently receiving attention. The use of continuous peripheral nerve block for outpatient ambulatory surgery is a growing trend countrywide and worldwide,[2] and the positive economic implications and impact of these promise to be enormous.

Three techniques have been proposed to place perineural catheters: the nonstimulating catheter technique, the stimulating catheter technique, and ultrasound-aided catheter placement. A fourth technique, which is no longer used, is the periarterial placement of axillary catheters under direct vision after cut-down during local anesthesia. This author placed continuous axillary blocks with this technique for patients with war injuries to their arms and hands in 1974–1975 during the Angola Civil War.

The stimulating catheter technique is probably more difficult and time-consuming to perform than the nonstimulating catheter technique. Whereas its primary block success rate probably equals that of the nonstimulating catheter technique, its secondary block success rate can be expected to be around 100%, *versus* approximately 65–85% with nonstimulating catheters.[3] The use of ultrasound for CPNB placement is not yet well established and is currently undergoing extensive preliminary evaluation.

Historical Overview

Early recorded uses of electrical nerve stimulation include assisting in accurate placement of a catheter for neuraxial blockade in 1948,[4] followed shortly thereafter by catheter placement for continuous peripheral nerve blockade in 1950.[5] Anatomical landmarks were still used at that time to place the needle through which the catheter was advanced. Stanley Sarnoff, M.D. (1917–1990) and his wife Lili-Charlotte Sarnoff, R.N., almost accidentally pioneered the use of nerve stimulation for the accurate placement of catheters for continuous peripheral perineural and subarachnoid blockade while working at the Harvard University School of Public Health (Boston, Massachusetts). In the midst of the polio epidemic of the 1950s, they developed the "Electrophrenic Respirator" for artificial ventilation of patients with bulbar polio by percutaneous phrenic nerve stimulation.[6] This device later served as a "nerve stimulator" to place a continuous nerve block catheter on the phrenic nerve for a patient with intractable hiccups.[5] Although later workers were not aware of the previous use of "stimulating catheters" in 1950, years later, in 1999, after the use of nerve stimulators for single-injection blocks of peripheral nerves had been well established, they reinvented the technique of placing catheters for CPNBs by stimulating the nerve *via* both the needle and the catheter.[7]

In the 30 yr after the first descriptions, the main focus in the development of CPNBs was on the upper extremity, and it was mainly to improve blood flow by sympathetic blockade for reimplantations of traumatic upper limb amputations. Most authors used variations of the axillary perivascular technique in the 1970s and 1980s.[8] At the time, the analgesia was almost viewed as an additional bonus, because it was not the primary purpose of the block.

During the 1990s, the emphasis shifted toward the use of CPNBs to manage acute postoperative pain. This was, among other factors, driven by the quest for cost-effective ambulatory surgery after the exponential explosion of medical inflation in the mid to late 1980s. Salter's

* Professor, Director of Regional Anesthesia Study Center of Iowa, and Director of Orthopaedic Anesthesia, Department of Anesthesia, The University of Iowa.

Received from The University of Iowa, Iowa City, Iowa. Submitted for publication January 25, 2005. Accepted for publication September 12, 2005. Support was provided solely from institutional and/or departmental sources. The author is a consultant for Arrow International, Reading, Pennsylvania, and for Stryker Instruments, Kalamazoo, Michigan. He also receives royalty payment for his invention of the Arrow StimuCath stimulating catheter system from Arrow International.

The figures and table in this section have been prepared by Dimitri Karetnikov, 7 Tennyson Drive, Plainsboro, New Jersey 08536.

Address correspondence to Dr. Boezaart: Department of Anesthesia, The University of Iowa, 200 Hawkins Drive, 6-JCP, Iowa City, Iowa 52242-1079. andre-boezaart@uiowa.edu.

discovery of the beneficial use of continuous passive motion for rehabilitation also played an important role in this development.[9] Because of the efficiency and relative safety of continuous neuraxial nerve blocks, the lower extremity received little attention during the early development of continuous nerve blockade; the main focus was on continuous interscalene blocks.[10,11]

Singelyn *et al.*,[1] who worked in Belgium, addressed the question of whether CPNB made any difference to the outcomes of surgery. They demonstrated that continuous femoral nerve blockade for a total knee replacement operation was superior to patient-controlled intravenous morphine in managing postoperative pain for total knee arthroplasty, with earlier and better rehabilitation. They also demonstrated fewer side effects than epidural analgesia, although the analgesia was similar. These results were confirmed in France[12] and the United States.[13]

A frustrating problem with perineural catheters was inaccurate catheter placement and secondary block failure, which defeated the object of cost effectiveness. The stimulating catheter originated from this frustration in 1999.[7]

Techniques

The Nonstimulating Catheter Technique

Steele *et al.*[14] described a now commonly used nonstimulating perineural catheter technique. An insulated Tuohy needle (*e.g.*, Contiplex, B. Braun, Bethlehem, PA; Vygon, Les Ulis, France; Alphaplex, Sterimed, Saarbrucen, Germany) is connected to a nerve stimulator. The needle is inserted at the required site and advanced until an appropriate motor stimulus is elicited with a current output of 0.3–0.5 mA, 2 Hz, and 100–300 μs. The needle is attached *via* tubing to a syringe to aspirate for blood or cerebrospinal fluid. The needle is held steady in that position, and saline or local anesthetic agent is injected through it. A 19- or 20-gauge single- or multiple-orifice epidural catheter is advanced 5–10 cm past the tip of the needle; the needle is removed; and the catheter is secured with medical adhesive spray, with transparent occlusive dressing, or by tunneling it.

The Stimulating Catheter Technique

A nerve stimulator, set to 1–1.5 mA, 100- to 300-μs pulse width, and a frequency of 1–2 Hz, is attached to an insulated Tuohy needle (*e.g.*, StimuCath, Arrow International, Reading, PA; Stimulong Plus, Pajunk, Geisingen, Germany), and the nerve or plexus appropriate for the surgery is approached.[7] When the correct motor response is elicited, the needle is advanced until a brisk motor response is elicited with a current output of 0.3–0.5 mA. The needle is then held steady, and without injecting any fluid through the needle, the nerve stimulator is attached to the proximal end of the catheter, and

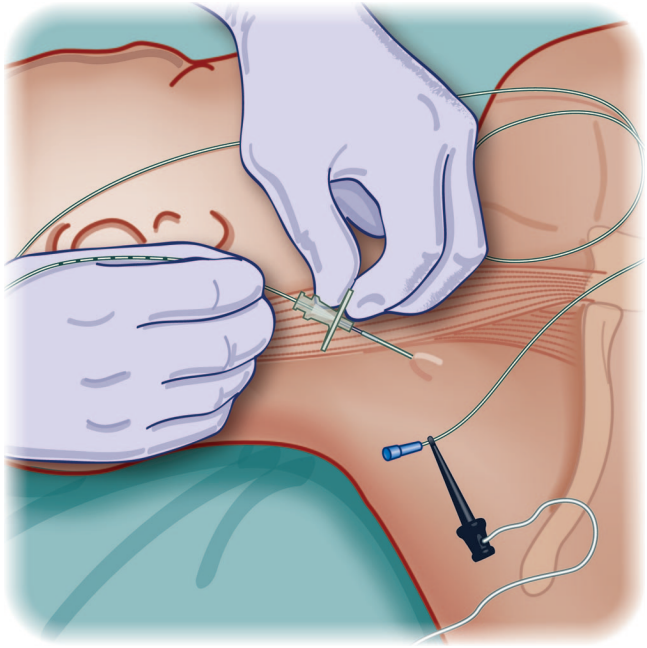

Fig. 1. Longitudinal approach to the continuous interscalene block. A 17- to 18-gauge insulated Tuohy needle is placed on the superior root of the brachial plexus with the aid of a nerve stimulator. Once placed, the nerve stimulator is attached to the proximal end of a 19- to 20-gauge stimulating catheter, which conducts electricity to the tip of the catheter. The catheter is advanced 3–5 cm beyond the needle tip, while maintaining an unchanged motor response.

the catheter is advanced through the needle (fig. 1). The elicited motor response should now be similar to that elicited by stimulating *via* the needle. The catheter is advanced beyond the needle tip with the motor response remaining unchanged. If the motor response changes, the catheter is carefully withdrawn to inside the shaft of the needle, and the needle's position is changed slightly by rotating clockwise or counterclockwise, moving it a few millimeters deeper or more superficial, or slightly changing the angle of the needle (fig. 2). The catheter is then advanced again. This process is repeated by making small, systematic changes to the needle after careful catheter withdrawal until the desired motor response is elicited when the catheter is advanced. The catheter is then advanced 3–5 cm beyond the needle tip.

It is currently unclear what the acceptable stimulating current should be for confirming proper placement of the catheter. This probably varies from one type of block to the other.

Ultrasound-guided Blocks

Sutherland[15] proposed the use of ultrasound for the accurate placement of continuous sciatic nerve blocks. Although the idea is promising, substantial development still must take place before ultrasound can be accepted as an alternative or additional method to place continuous nerve blocks. A problem with ultrasound is that,

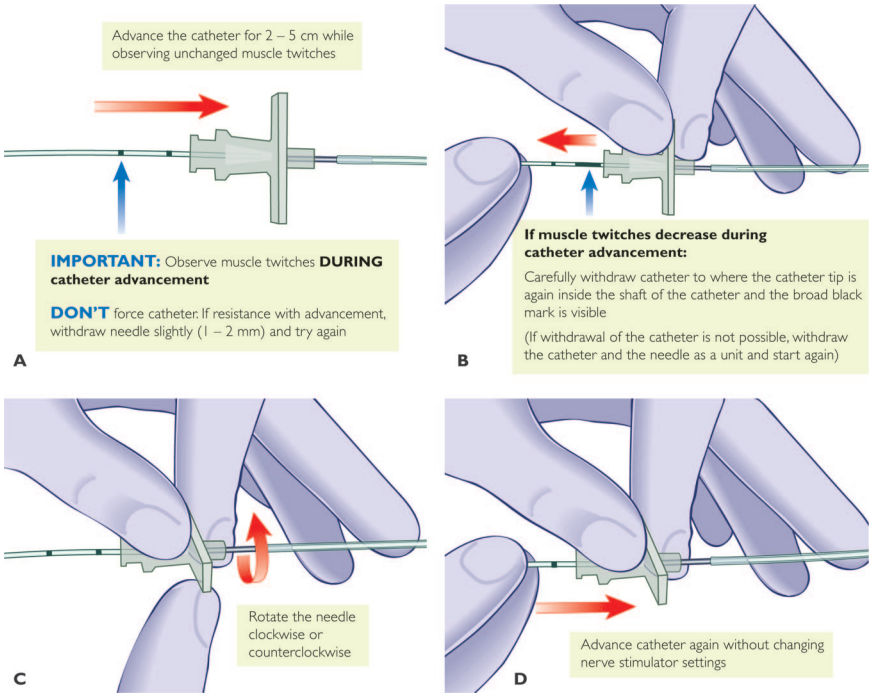

Fig. 2. The motor response should remain brisk and unchanged during catheter advancement.

although it works well for superficial nerves (when it is not really needed), the depth of penetration of most readily available and affordable ultrasound probes is not sufficient to identify deeper nerves, especially in very obese patients (where it is most needed). This problem will no doubt be addressed as more advanced technology becomes available. Like ultrasound does not replace x-rays in orthopaedics, it is ultimately not likely to replace nerve stimulation for continuous nerve block. It is most likely to be a valuable addition to nerve stimulation.

Catheter Fixation

Most authors tunnel the catheter subcutaneously.[7,16] This has virtually eliminated the problem of catheter dislodgement. Various methods of tunneling a catheter have been described, but most of them are variations of tunneling with or without a "skin bridge."[7,16]

Special Considerations for Perineural Catheters

- Because an indwelling catheter is left *in situ* for some time, sterile procedures are necessary for insertion. The catheter should be covered with a transparent dressing to allow daily inspection of the catheter exit site and skin bridge area for early signs of infection.
- Catheters should only be removed after full sensation has returned to the limb after discontinuation of the infusion. If severe surgical pain is persistent after the infusion has been stopped, a bolus of the local anesthetic agent may be initiated and the infusion may be restarted for a further 24 h. If the pain is manageable with oral or other analgesic, the catheter can be removed.
- Radiating pain experienced by the patient during catheter removal should be approached with caution.
- Because the whole limb is likely to be insensitive for the duration of a continuous block, vulnerable nerves, such as the ulnar nerve at the level of the elbow, the radial nerve at the midhumeral level, and the common peroneal nerves at the fibular head, should be specifically protected from injury or pressure for the duration of the block (fig. 3). Similarly, cold or warm pad application to the insensitive limb must be done with caution to avoid thermal skin injury.
- Patients with continuous blocks should use a properly fitted arm sling to prevent traction injury to the brachial plexus or pressure injury to the radial nerve (fig. 3).
- If a stimulating catheter is used, the catheter should not be cut at any time. These catheters have an inner wire that electrically connects the proximal and distal ends of the catheter. Cutting this may separate parts of the catheter that may be left behind after removal, or may make catheter removal difficult.
- The needle should not be manipulated while the catheter still protrudes beyond its tip. This may cause shearing of the catheter.
- Discharging a patient from the surgical facility with a perineural infusion in place is only feasible if the position and functionality of the catheter have been proven. This is done by using a stimulating catheter or by injecting the main bolus dose through the catheter and not the needle when a nonstimulating catheter has been used.

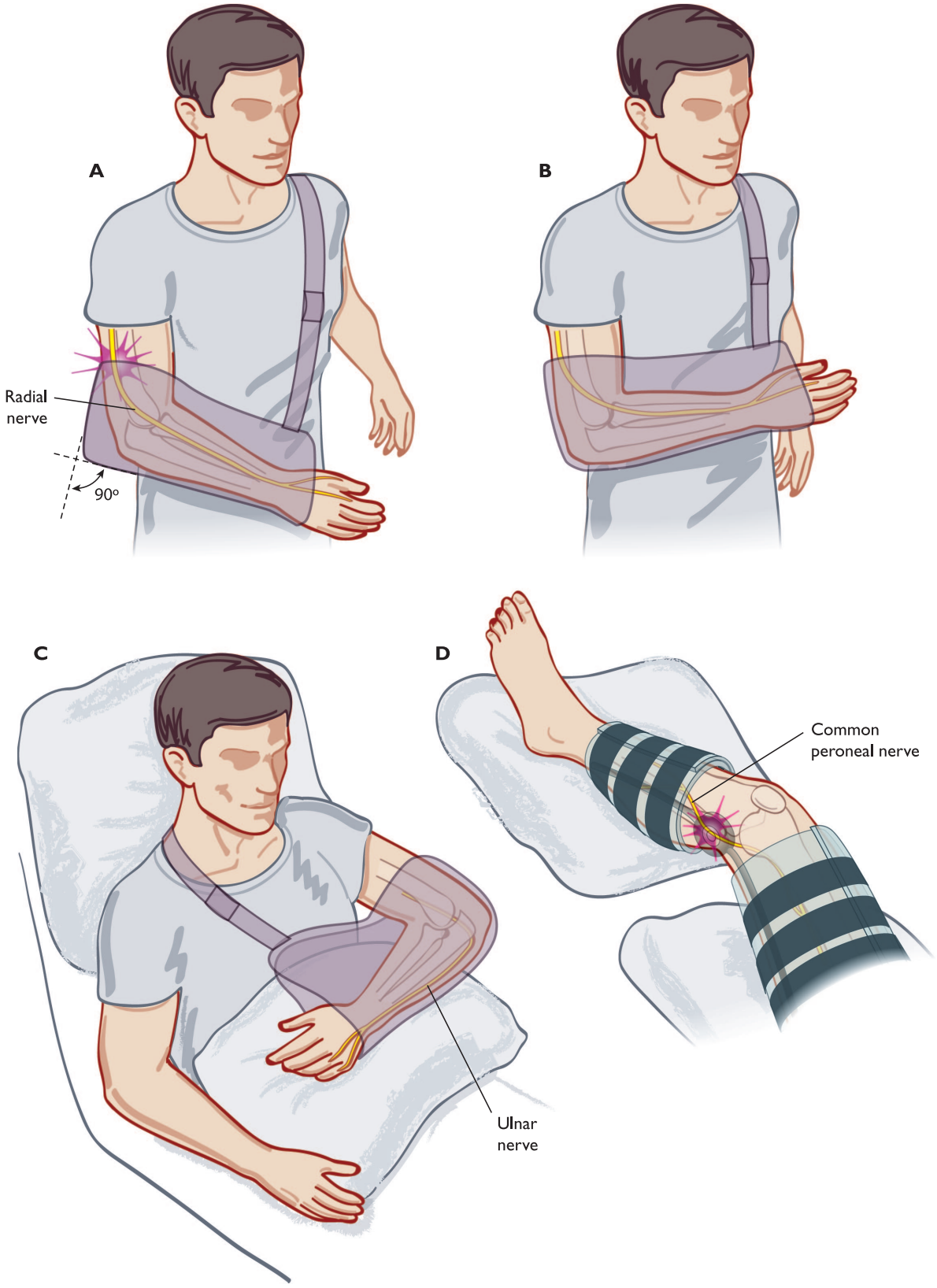

Fig. 3. (*A*) A poorly fitted arm sling may cause compression of the radial nerve where it curves around the humerus. (*B*) A properly fitted sling allows for an angle of at least 90° at the elbow. (*C*) The ulnar nerve is very vulnerable at its position behind the elbow and should be protected from pressure or other injury throughout the duration of the continuous nerve block of the upper extremity. (*D*) The common peroneal nerve is very vulnerable where it curves around the fibular head and should be protected from pressure or other injury throughout the duration of the continuous nerve block of the lower extremity. Corrected valgus deformities of the knee place this nerve under particular threat of traction injury.

Table 1. Proposed Continuous Blocks and Infusion Strategies for Common Surgical Procedures

Surgical Procedure	Suggested Continuous Block	Suggested Infusion Strategy* (Note: adjust individually to suit patient requirements)
Total shoulder arthroplasty (Hemi-shoulder arthroplasty) Rotator cuff repair Anterior Bankart repair SLAP repair Shoulder arthrodesis Laterjet stabilization procedure Subscapularis repair	CCPVB* CISB	POB - 0.5% bupivacaine or 0.5 – 0.75% ropivacaine, 20 – 40 ml CI – 0.2% ropivacaine at 5 ml/h PCRA – 0.2% ropivacaine 10 ml with 60 min lockout time
Scapula fractures and surgery Humerus fractures and surgery Radius fractures and surgery Ulna fractures and surgery	CCPVB* CISB (Low CCPVB and high CTPVB needed for scapula)	
Total elbow arthroplasty Total wrist arthroplasty	CCPVB* CICB CAxB	
Elbow arthrodesis Wrist arthrodesis	CCPVB* CICB CAxB	
Upper limb reimplantation surgery	CCPVB* CICB CAxB	
Major upper limb trauma (Significant risk of compartment syndrome. Beware fractures around elbow)	CCPVB* CICB CAxB	
Arthroscopic capsulotomy for frozen shoulder	CCPVB	POB - 0.5% bupivacaine or 0.5 – 0.75% ropivacaine, 20 ml CI – 0.1% ropivacaine at 0 - 5 ml/h (preserve motor function) PCRA – 0.1% ropivacaine 10 ml with 60 min lockout time (Bolus higher concentration before physical therapy if necessary)
Latissimus dorsi transfer	CCPVB Plus CLPVB	POB - 0.5% bupivacaine or 0.5 – 0.75% ropivacaine, 20 – 40 ml CI – 0.2% ropivacaine at 5 ml/h PCRA – 0.2% ropivacaine 10 ml with 60 min lockout time
Unilateral thoracotomy	CTPVB* Thoracic Epidural	
Major unilateral breast surger	CTPVB (Add lateral pectoral nerve block) Thoracic Epidural	
Revision total hip arthroplasty (Continuous peripheral nerve block probably not indicated for primary hip arthroplasty. Consider CSE) Pelvic osteotomy	CLPVB CSE* Epidural	
Hip fracture	CFNB (Combine with unilateral spinal for surgery)	
Femur fracture (Significant risk of compartment syndrome.)	CFNB (Combine with unilateral spinal for surgery)	
Tibia fracture (Significant risk of compartment syndrome.)	CSSNB* CPSB CPopB (CFNB additionally required for saphenous nerve)	

(Continued)

Table 1. Continued

Surgical Procedure	Suggested Continuous Block	Suggested Infusion Strategy* (Note: adjust individually to suit patient requirements)
Fibula fracture	CSSNB* CPSB CPopB (CFNB not additionally required)	
Anterior cruciate ligament reconstruction	CFNB (If hamstring muscle is harvested for graft SI sciatic nerve bock required)	
Posterior cruciate ligament reconstruction	CSSNB* CPSB (CFNB additionally required)	POB - 0.5% bupivacaine or 0.5 – 0.75% ropivacaine, 20 – 40 ml CI – 0.2% ropivacaine at 5 ml/h PCRA – 0.2% ropivacaine 10 ml with 60 min lockout time (Split POB between blocks and use 5ml/hr for each block)
Total knee arthroplasty	CFNB (Area behind knee sometimes require SI sciatic nerve bock)	POB - 0.5% bupivacaine or 0.5 – 0.75% ropivacaine, 20 – 40 ml CI – 0.1% ropivacaine at 5 ml/h (preserve motor function) PCRA – 0.1% ropivacaine 10 ml with 60 min lockout time
Ankle fusion (arthrodesis)	CSSNB* CPSB CPopB (CFNB additionally required for saphenous nerve)	POB - 0.5% bupivacaine or 0.5 – 0.75% ropivacaine, 20 – 40 ml CI – 0.2% ropivacaine at 5 ml/h PCRA – 0.2% ropivacaine 10 ml with 60 min lockout time (Split POB between blocks and use 5ml/hr for each block)
Subtalar fusion (arthrodesis)	CSSNB* CPSB CPopB (CFNB not additionally required)	POB - 0.5% bupivacaine or 0.5 – 0.75% ropivacaine, 20 – 40 ml CI – 0.2% ropivacaine at 5 ml/h PCRA – 0.2% ropivacaine 10 ml with 60 min lockout time
Total ankle arthroplasty	CSSNB* CPSB CPopB (CFNB additionally required for saphenous nerve)	POB - 0.5% bupivacaine or 0.5 – 0.75% ropivacaine, 20 – 40 ml CI – 0.2% ropivacaine at 5 ml/h PCRA – 0.2% ropivacaine 10 ml with 60 min lockout time (Split POB between blocks and use 5ml/hr for each block)

* Preference of this author

CAxB = continuous axillary block; CCPVB = continuous cervical paravertebral block; CFNB = continuous femoral nerve block; CI = continuous infusion; CICB = continuous infraclavicular block; CISB = continuous interscalene block; CLPVB = continuous lumbar paravertebral block; CPSB = continuous parasacral block; CPopB = continuous popliteal sciatic nerve block; CSE = combined spinal epidural; CSSNB = continuous subgluteal sciatic nerve block; CTPVB = continuous thoracic paravertebral block; PCRA = patient controlled regional anesthesia; POB = pre-operative bolus; SI = single injection; SLAP = superior labrum anterior and posterior.

- The American Society of Regional Anesthesiologists recommended in a consensus statement† that CPNB catheters be regarded as similar to neuraxial catheters in the presence of anticoagulation therapy. Clinicians should, however, be less rigid and perform a careful risk-to-benefit ratio calculation in such cases. Logically, the more peripheral the site of the catheter is (*i.e.*, the more reachable the site is to compression in case of bleeding, *e.g.*, popliteal and femoral catheters), the less of a problem this poses, and *vice versa*.

† Available at: http://www.asra.com. Accessed September 30, 2005.

Infusion Strategies

There are three basic regimens to provide continuous peripheral nerve block analgesia: fixed basal rate, fixed basal rate plus bolus doses, or boluses only. The latter two regimens can be defined as patient-controlled regional analgesia (PCRA) systems. Not unlike patient-controlled intravenous analgesia, this is a drug delivery system aimed at controlling acute pain by using negative feedback in a closed-loop system in which the patient plays an active role. It overcomes the inadequacies of traditional analgesic protocols, which are caused by the marked differences in pharmacokinetics of analgesic re-

quirements between patients. Patients can control the analgesic dose to balance pain relief with the side effects they are willing to tolerate and required motor function. Patients usually choose less than the available total dose of analgesic.

The choice of infusion strategy depends on the preference of the practitioner, which should be based on the needs of the patients. There are limited guidelines based on research data available, but it seems feasible to use a baseline infusion plus patient-controlled bolus doses for very painful conditions and bolus dosing alone for less painful conditions. Ultimately, the infusion strategy should vary from one patient population or type of surgery to the next. Preliminary evidence indicates that a basal background infusion with PCRA provides equivalent or superior analgesia and improved patient satisfaction when compared with continuous infusion only or bolus dosing alone.[17,18] The use of bolus doses allows the patient to rapidly reinforce the block before physical therapy. If only PCRA boluses are used, patients experience more difficulty in sleeping[19] but might use less local anesthetic.[20]

One should be flexible in choosing the infusion strategy for any particular patient or surgical setting. The chosen strategy should be individualized and designed to suit the individual needs of every patient. Every infusion strategy referred to above[7,16–20] is likely to be successful, and the patient is likely to be satisfied, if the catheter is accurately and painlessly placed and the infusion rate, concentration of the drug, and volume and lockout time of boluses are constantly adjusted to suit the changing requirements of individual patients. This ability to constantly tailor the infusion emphasizes the major advantage of CPNB over long-acting local anesthetic agents, which cannot be adjusted and, after unwanted side effects or complications occur, cannot be reversed. A good strategy is to start the CPNB with a bolus of approximately 0.3 ml/kg (with a maximum of 40 ml) of a high-concentration drug, *e.g.*, 0.5–0.75% ropivacaine, for intraoperative and directly postoperative analgesia. This is followed by an infusion of a low concentration of ropivacaine (0.1–0.2%) at an infusion rate of 5 ml/h and PCRA boluses of 10 ml at a lockout time of 2–4 h. If more motor function is required (*e.g.*, after total knee arthroplasty), adding normal saline to the reservoir will reduce the concentration of the drug (table 1).

There are numerous commercial infusion pumps available, and the final choice of these should be made on the ability to deliver the required infusions and boluses at the required lockout intervals. With initiating the bolus dose, effort should not be required from the patient to empty the reservoir holding the drug. The ideal infusion pump should also be refillable and reprogrammable.

Rawal *et al.*[21] offered plausible arguments for the use of bolus doses only, although their indications for CPNB, *e.g.*, carpal tunnel decompression and other minor procedures, may be questionable. Because the analgesic needs of individual patients differ greatly and the duration of a single-dose local anesthetic varies considerably, PCRA by bolus doses on demand may be preferable to continuous infusion. Analgesia by bolus injection only satisfies individual needs, and it permits patients to maintain adequate analgesia regardless of changes in pain intensity. A possible disadvantage of the bolus-only PCRA technique may be either too dense a motor block after the bolus or too weak a sensory block for some time before the next bolus. Another important factor that needs to be considered is sleep disturbances that may occur when a basal infusion is not given.

After 1 or 2 days of continuous infusion, as the postoperative pain decreases and the need for motor function increases, the concentration of local anesthetics can be decreased by adding saline to the reservoir. If a motor block is also required at this stage, the drug concentration can be kept constant, while reducing the infusion rate.

Table 1 summarizes the surgical procedures for which CPNBs have been used.

Complications and Problems

Complications of perineural catheters for continuous nerve blockade are rare and probably less than those for single-injection nerve blocks,[22] although large comparative studies have not yet been reported. The most common problems associated with continuous nerve blockade are technical problems, including failed blocks or incomplete analgesia, which does seem to become less as the use of stimulating catheters increase[7,16]; catheter dislodgement, which seems to be largely solved with catheter tunneling[7,16]; and leakage around the catheter entry site. The latter is more frequent if a skin bridge is used during tunneling.

Nerve Injury

Complications due to nerve injury are usually secondary to the insensitive limb. The nerves most commonly injured by this are the ulnar, radial, and common peroneal nerves, because of compression by ill-fitting slings and braces or compression of the ulnar nerve on the bed in supine patients (fig. 3). Nerve injury due to traction, diathermy, and direct injury during surgery are often unfairly attributed to nerve blocks. Severe permanent nerve injury caused by continuous nerve blockade has not yet been reported, although surgical damage to nerves, especially the musculocutaneous nerve during shoulder surgery, has recently been shown to be more common than originally thought.[23]

Transient neurologic damage has also mainly been reported for continuous interscalene blocks[22] and in 0.5% of continuous axillary blocks.[24] Because the interscalene approach has been abandoned as first choice

from the personal practice of this author and the continuous cervical paravertebral block is used as routine first choice for shoulder surgery, the complication of burning pain down the arm, especially in patients after arthroscopic capsulotomy for "frozen shoulder," has not yet been encountered in well over 2,000 cases.

Furthermore, this author does not offer any preoperative nerve blocks to patients scheduled to undergo shoulder surgery if these patients experience pain, paresthesia, or dysesthesia distal to the elbow. *Bona fide* shoulder pathology does not cause pain or dysesthesia distal to the elbow. This pain is most likely caused by existing brachial plexopathy, and it may be prudent to err on the side of safety in such patients by offering them a postoperative nerve block after the shoulder pathology is clear. This is especially relevant if the patient was scheduled to undergo subacromial decompression, in which case a continuous or single-injection cervical paravertebral[16] or interscalene block can be performed postoperatively if shoulder pathology was found and treated and if deemed necessary by the patient. Motor responses due to nerve stimulation are usually painful after surgery, and proper use of potent analgesics, such as remifentanil, loss-of-resistance to air technique without nerve stimulation (cervical paravertebral block), or ultrasound (interscalene block) should be considered.

Infection

Capdevila *et al.*[25] reported their experience with 1,416 CPNBs, and although technical problems (17%), failure of pain relief (3.2%), persistent motor block (2.2%), and transient paresthesia and dysesthesia (1.4%) represented the most common complications, colonization of catheters by bacteria was reported in 28% of cases if prophylactic antibiotics were not used. Infection, defined as redness, swelling, or pus around the catheter entry site, can be expected to be present in 3%[25] to 5%[16] of cases, whereas deep abscess formation has not been reported yet. Bacterial species found include *Staphylococcus epidermidis* (61%, mostly found in interscalene catheters), gram-negative bacilli (22%, mainly associated with femoral nerve blocks), and *Staphylococcus aureus* (17%).[25] The incidence is not known if prophylactic antibiotics are used, as is often the case with orthopaedic surgery, but it can be expected to be lower. Risk factors for local inflammation are patients in intensive care units, males, catheter duration longer than 48 h, absence of prophylactic antibiotics, diabetes, and femoral nerve blockade.[25] Catheters should be removed and appropriate antibiotics should be prescribed when signs of infection are present.

Associated Unwanted Nerve Blockade

A comparison was made between the Winnie paresthesia interscalene blocks (group I), stimulating needle single-injection interscalene blocks (group II), and continuous interscalene blocks using a stimulating catheter (group III).[7] The authors reported 85% complete phrenic nerve blocks in the first group compared with 35% in the second group and 20% in the continuous interscalene block group. Other common nerves that are incidentally blocked are the recurrent laryngeal nerve and the superficial cervical plexus, but these do not usually pose any problems.

Total spinal anesthesia has been associated with continuous lumbar paravertebral blockade,[26] but not with any other continuous perineural catheter. Recurrent brachial plexus neuropathy in a diabetic patient after shoulder surgery and a continuous interscalene block has been reported.[27] Epidural spread with contralateral block, although not causing any problems, has been reported during continuous cervical paravertebral block.[16]

Complications due to Drug Effects

Toxic drug effects during continuous infusion have not yet been reported, but reports of toxic effects can be expected as continuous peripheral nerve blocks become more widely used. Acute myotoxic effects of local anesthetic agents have been described after continuous peripheral nerve blockade with bupivacaine and ropivacaine in a porcine model.[28] Compared with bupivacaine, which caused both muscle fiber necrosis and apoptosis, the tissue damage caused by ropivacaine was significantly less severe than that caused by bupivacaine in experimental animals.

Pain during Catheter Placement

All catheters (and all nerve blocks for that matter) are placed during some form of anesthesia: some during general anesthesia, some during regional anesthesia, and others during local anesthesia. (In dentistry and ophthalmology, for example, nerve blocks are even placed during topical anesthesia). In this respect, the practitioner should not be rigid but instead should choose the technique appropriate for each individual patient. Placing catheters for CPNBs should never be painful or uncomfortable. The most common cause for pain with CPNB placement is anxiety, which can be adequately dealt with by administering adequate dosages of anxiolytic agents, such as 0.015– 0.15 mg/kg midazolam. Propofol is commonly used, but practitioners should be cautioned because this drug may cause the patient to become unruly at low doses and unconscious, causing airway obstruction, at higher doses.[29]

Furthermore, when appropriate (*e.g.*, in the case of children, in cases of very painful conditions or very anxious patients), the catheter can be placed during general anesthesia. There is no guidance from the literature as to whether this may increase the incidence of complications or side effects of CPNBs, but the current

author contends that placing blocks during general anesthesia in certain circumstances may even be less hazardous, because the patient will not move during needle and catheter placement, and nothing about potential nerve injury can be learned from a crying child or a distressed adult.

The area where the CPNB is placed should be anesthetized thoroughly before the catheter is placed. For example, a regional block of the superficial cervical plexus, slowly injected with a fine needle, can be performed before a continuous interscalene block is attempted.[7] Similarly, a field block down to the pars intervertebralis (or articular column) of the sixth cervical vertebra should be done before a continuous cervical paravertebral block is performed.[16] It should go without saying that the area of intended catheter tunneling should be appropriately anesthetized before tunneling.

Other rare and minor complications of perineural catheters have been reported, although none seem to be due to long-term continuous exposure of the nerves to local anesthetic agents or the presence of the catheter on or near the nerves.

Conclusion

Perineural catheters for CPNBs have developed from pure motor blockade for intractable hiccups, through upper limb sympathetic blocks to enhance blood flow after reimplantation surgery, to sensory blocks for the ambulatory management of acute pain. Over the years, the techniques and equipment have improved, and it is now possible to place catheters for CPNBs accurately and thus virtually eliminate secondary block failure. Although complications of CPNBs are not yet sufficiently investigated, it seems that they are rare and, if present, they are mild and occur after the initial, relatively large dose of local anesthetic agent, while the patient is usually still under the care of the anesthesiologist. It is never necessary to hurt patients during catheter placement, and infusion strategies can and should be tailored to the individual requirements of each patient.

It is important that patients' well-being and pain relief continuously improve each day after surgery. It is therefore inappropriate to remove catheters prematurely before pain is manageable with oral or parenteral analgesics.

The author thanks Peter van de Putte, M.D., and Martial van der Vorst, M.D. (both from the Department of Anesthesia, Ziekenhuis O.L.V. Middelares, Deune, Belgium), Chris Theron, M.D. (Oranjezicht, Cape Town, South Africa), and Paul Casella (Program Associate, University of Iowa, Iowa City, Iowa) for their valuable assistance with the preparation of this manuscript.

References

1. Singelyn FJ, Deyaert M, Joris D, Pendeville E, Gouverneur JM: Effects of intravenous patient-controlled analgesia with morphine, continuous epidural analgesia, and continuous three-in-one on postoperative pain and knee rehabilitation after unilateral total knee arthroplasty. Anesth Analg 1998; 87:88–92

2. Ilfeld BM, Enneking FK: Continuous peripheral nerve block at home: A review. Anesth Analg 2005; 100:1822–33

3. Salinas FV, Neal JM, Sueda LA, Kopacz DJ, Liu SS: Prospective comparison of continuous femoral nerve block with nonstimulating catheter placement *versus* stimulating catheter-guided perineural placement in volunteers. Reg Anesth Pain Med 2004; 29:212–20

4. Sarnoff SJ: Functional localization of intraspinal catheters. ANESTHESIOLOGY 1950; 11:360–6

5. Sarnoff ST, Sarnoff LC: Prolonged peripheral nerve block by means of indwelling plastic catheter: Treatment of hiccup. ANESTHESIOLOGY 1951; 12:270–7

6. Sarnoff SJ, Hardenbergh E, Whittenberger JL: Electrophrenic respiration. Science 1948; 108:482

7. Boezaart AP, de Beer JF, Du Toit C, van Rooyen K: A new technique of continuous interscalene nerve block. Can J Anaesth 1999; 46:275–81

8. Selander D: Catheter technique in axillary plexus block. Acta Anaesthesiol Scand 1977; 21:324–9

9. Salter RB: Continuous passive motion: From origination to research to clinical application. J Rheumatol 2004; 151:1076–80

10. Haasio J, Tuominen M, Rosenberg PH: Continuous interscalene brachial plexus block during and after shoulder surgery. Ann Chir Gynaecol 1990; 79: 103–7

11. Rosenberg PH, Pere P, Hekali R, Tuominen M: Plasma concentrations of bupivacaine and two of its metabolites during continuous interscalene brachial plexus block. Br J Anaesth 1991; 66:25–30

12. Capdevila X, Barthelet Y, Biboulet P, Ryckwaert Y, Rubenovitch J, d'Athis F: Effects of perioperative analgesic technique on the surgical outcome and duration of rehabilitation after major knee surgery. ANESTHESIOLOGY 1999; 19:8–15

13. Chelly JE, Greger J, Gebhard R, Coupe K, Clyburn TA, Buckle R, Criswell A: Continuous femoral blocks improve recovery and outcome of patients undergoing total knee arthroplasty. J Arthroplasty 2001; 16:436–45

14. Steele SM, Klein SM, D'Frcole FJ, Greengrass RA, Gleason D: A new continuous catheter delivery system (letter). Anesth Analg 1998; 87:28

15. Sutherland ID: Continuous sciatic nerve infusion: Expanded case report describing a new approach. Reg Anesth Pain Med 1998; 23:496–501

16. Boezaart AP, De Beer JF, Nell ML: Early experience with continuous cervical paravertebral block using a stimulating catheter. Reg Anesth Pain Med 2003; 28:406–13

17. Mezzatesta JP, Scott DA, Schweitzer SA, Selander DE: Continuous axillary brachial plexus block for postoperative pain relief: Intermittent bolus *versus* continuous infusion. Reg Anesth 1997; 22:357–62

18. Singelyn FJ, Seguy S, Gouverneur JM: Interscalene brachial plexus analgesia after open shoulder surgery: Continuous *versus* patient-controlled infusion. Anesth Analg 1999; 89:1216–20

19. Ilfeld BM, Morey TE, Enneking FK: Infraclavicular perineural local anesthetic infusion: A comparison of three dosing regimens for postoperative analgesia. ANESTHESIOLOGY 2004; 100:395–402

20. Turkoglu K: Comparison of patient controlled analgesia and continuous infusion with 0.2% ropivacaine in brachial plexus analgesia after hand surgery. Reg Anesth Pain Med 2003; 28 (suppl):52

21. Rawal N, Allvin R, Axelsson K, Hallen J, Ekback G, Ohlsson T, Amilon A: Patient-controlled regional analgesia (PCRA) at home. ANESTHESIOLOGY 2002; 96: 1290–6

22. Borgeat A, Ekatodramis G, Kalberer F, Benz C: Acute and non-acute complications associated with interscalene block and shoulder surgery: A prospective study. ANESTHESIOLOGY 2001; 95:875–80

23. Boardman ND III, Cofield RH: Neurologic complications of shoulder surgery. Clin Orthop 1999; 368:44–53

24. Bergman B, Hebl J, Kent J, Horlocker T: Neurologic complications of 405 consecutive continuous axillary catheters. Anesth Analg 2003; 96:247–52

25. Capdevila X, Pirat P, Bringuier S, Gaertner E, Singelyn F, Bernard N, Choquet O, Bouaziz H, Bonnet F: Continuous peripheral nerve blocks on hospital wards after orthopedic surgery: A multicenter prospective analysis of their efficacy and incidences and characteristics of adverse events in 1,416 patients. ANESTHESIOLOGY 2005; 103:1035–45

26. Lekhak B, Barley C, Conacher ID, Nouraei SM: Total spinal anaesthesia in association with insertion of a paravertebral catheter. Br J Anaesth 2001; 86: 280–2

27. Horlocker TT, O'Driscoll SW, Dinapoli RP: Recurring brachial plexus neuropathy in a diabetic patient after shoulder surgery and continuous interscalene block. Anesth Analg 2000; 91:688–90

28. Zink W, Seif C, Bohl JRE, Hacke N, Braun P, Sinner B, Martin E, Fink RHA, Graf BM: The acute myotoxic effects of bupivacaine and ropivacaine after continuous peripheral nerve blockades. Anesth Analg 2003; 97:1173–9

29. Boezaart AP, Berry RA, Nell ML, van Dyk AL: A comparison of propofol and remifentanil for sedation and limitation of movement during periretrobulbar block. J Clin Anesth 2001; 6:422–6