REVIEW ARTICLE

Continuous Peripheral Nerve Blocks at Home: A Review

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Postoperative analgesia is generally limited to 12–16 h or less after single-injection regional nerve blocks. Postoperative analgesia may be provided with a local anesthetic infusion via a perineural catheter after initial regional block resolution. This technique may now be used in the outpatient setting with the relatively recent introduction of reliable, portable infusion pumps. In this review article, we summarize the available published data related to this new analgesic technique and highlight important issues related specifically to perineural infusion provided in patients' own homes. Topics include infusion benefits and risks, indications and patient selection criteria, catheter, infusion pump, dosing regimen, and infusate selection, and issues related specifically to home-care.

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In the past decade, there has been an increasing interest in "continuous peripheral nerve blocks," also called "perineural local anesthetic infusions." This technique involves the percutaneous insertion of a catheter directly adjacent to the peripheral nerves supplying an affected surgical site (as opposed to a "wound" catheter placed directly at a surgical site). Local anesthetic is then infused via the catheter providing potent, site-specific analgesia. Combining a perineural catheter with a portable infusion pump, outpatients may theoretically experience the same level of analgesia previously afforded only to those remaining hospitalized. A previous review article (1) of perineural infusion for inpatient analgesia concluded, "whether this technique is effective for ambulatory patients remains to be determined." Subsequently, a plethora of data regarding continuous peripheral nerve blocks in outpatients has been published. In this review, we summarize this new evidence, and highlight important issues related specifically to perineural local anesthetic infusion provided at home.

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Infusion Benefits

Although continuous regional blockade was first described more than 50 yr ago (2), it was not until 1998 that the introduction of lightweight, portable infusion pumps made home infusion possible (3). Subsequently, case reports or series of ambulatory perineural infusion were described via peripheral nerve catheters in various locations including paravertebral (4), interscalene (5–7), intersternocleidomastoid (8), infraclavicular (6), axillary (9), psoas compartment (9,10), femoral (9,11), fascia iliaca (5), sciatic/Labat (9,10), sciatic/popliteal (6,12), and tibial nerve placement (6). Ambulatory continuous peripheral nerve blocks in pediatric patients have also been reported in patients as young as 8 yr of age (13). However, the first prospective evidence of infusion benefits was not reported until a randomized, double-masked, placebo-controlled investigation was published in 2000 (14).

This study by Klein et al. involved 40 subjects undergoing open rotator cuff repair who received an interscalene block and perineural catheter preoperatively and were randomized to receive either perineural ropivacaine 0.2% or normal saline postoperatively (10 mL/h). Patients receiving perineural ropivacaine averaged a score of 1 on a visual analog pain scale of 0–10 compared with a 3 for subjects receiving placebo. Although a pump designed for ambulatory infusion was used, patients remained hospitalized during local anesthetic infusion, and health care providers removed all catheters before home discharge. Because patients remained hospitalized, the investigators "felt compelled to provide more than oral analgesics," and patients had access to IV morphine via patient-controlled analgesia (PCA) (14). Therefore, patients

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receiving placebo theoretically receive a greater degree of analgesia than that available to ambulatory patients who must rely on oral instead of IV opioids. Consequently, although these data suggested perineural infusion might improve postoperative analgesia after hospital discharge, the extent of improvement for patients actually at home remained unknown.

Subsequently, four randomized, double-masked, placebo-controlled studies provided data involving patients discharged home with a catheter *in situ* (15–18). All of these investigations involved patients scheduled for moderately painful procedures who had an infraclavicular (15), interscalene (17), or posterior popliteal (16,18) perineural catheter placed (Table 1). Patients receiving perineural local anesthetic achieved both clinically and statistically significant lower resting and breakthrough pain scores and required dramatically fewer oral analgesics.

Patients who received perineural local anesthetic also experienced additional benefits related to improved analgesia. Zero to 30% of patients receiving perineural ropivacaine reported insomnia as a result of pain, compared with 60%–70% of patients using only oral opioids (15–17). Patients receiving perineural ropivacaine awoke from sleep because of pain an average of 0.0–0.2 times on the first postoperative night, compared with 2.0–2.3 times for patients receiving perineural saline (15–17). Dramatically less opioid consumption in patients receiving perineural local anesthetic resulted in fewer opioid-related side effects, including less nausea, vomiting, pruritus, and sedation (15–18). Furthermore, patients receiving perineural local anesthetic reported satisfaction with their postoperative analgesia (0–10, 10 = highest) of 8.8–9.8 compared with 5.5–7.7 for patients receiving placebo (15–18). Finally, patients with popliteal local anesthetic infusion rated their "quality of recovery" (0–100, 100 = highest) an average of 96 compared with 83 for patients receiving placebo (18). Whether these demonstrated benefits result in an improvement in patients' health-related quality of life remains unexplored (19).

Indications and Selection Criteria

Because there are inherent risks with an outpatient infusion, most published series limit this technique to patients expected to have moderate postoperative pain of a duration more than 24 h that is not easily managed with oral opioids (20,21). However, outpatient infusion may be used after mildly painful procedures—defined here as those usually well managed with oral opioids—to decrease opioid requirements and opioid-related side effects (3,22). Because not all patients desire, or are capable of accepting, the extra responsibility that comes with the catheter and pump system, appropriate patient selection is crucial for safe ambulatory local anesthetic infusion. As some degree of postoperative cognitive dysfunction is common after surgery (23), investigators often require patients to have a caretaker at least through the first postoperative night (15–17,24–27). Whether a caretaker is necessary for one night or for the entire duration of infusion remains unresolved (28). If catheter removal at home is expected, then a caretaker willing to perform this procedure must be available at the infusion conclusion if the patient is unwilling or unable to do this themselves (e.g., psoas compartment catheter).

Complications that could be managed routinely within the hospital may take longer to identify or be more difficult to manage in medically unsupervised patients at home. Investigators often exclude patients with known hepatic or renal insufficiency in an effort to avoid local anesthetic toxicity (29). For infusions that may affect the phrenic nerve and ipsilateral diaphragm function (e.g., interscalene or cervical paravertebral catheters), patients with heart or lung disease are often excluded because continuous interscalene local anesthetic infusions have been shown to cause frequent ipsilateral diaphragm paralysis (30). Although the effect on overall pulmonary function may be minimal for relatively healthy patients (31), conservative application of this technique is warranted until additional investigation of hospitalized and medically supervised patients documents its safety (32,33).

Catheter Placement

Inaccurate catheter placement occurs in a substantial number of cases (17,34,35); it is reported to be as frequent as 40% in some reports (36). Although this is a significant issue for all patients, it is of vital importance for ambulatory patients because catheter replacement is not an option once the patient has left the medical facility. There are multiple techniques and equipment types available for catheter insertion. One common technique involves giving a bolus of local anesthetic via an insulated needle to provide a surgical block, followed by the introduction of a catheter (14). However, using this technique, it is possible to provide a successful surgical block with inaccurate catheter placement (17). Reported catheter failure rates are as much as 40% (36). For outpatients, the inadequate perineural infusion often will not be detected until after surgical block resolution after home discharge (17). Some investigators first insert the catheter and then administer a bolus of local anesthetic via the catheter in an effort to avoid this problem, with a reported failure rate of 1%–8% (37,38). Alternatively, catheters that deliver current to their tips have been developed in an attempt to improve initial placement success rates (39). These catheters provide feedback on

Table 1. Randomized, Controlled Studies of Continuous Peripheral Nerve Blocks Involving Patients Discharged Home with a Catheter *In Situ*

Author	Catheter location	Total subjects	Infusate	Basal (mL/h)	Bolus (mL)	Lockout (min)	Primary outcome	Secondary outcomes
Local anesthetic versus placebo								
White et al. (18)	Popliteal (posterior, traditional approach)	24	Bupivacaine 0.25%	5	NA	NA	Improved analgesia	Decreased IV opioid requirements in the hospital, improved patient satisfaction, improved quality of recovery as evaluated by the patients themselves
Ilfeld et al. (16)	Popliteal (posterior, intertendinous technique)	30	Ropivacaine 0.2%	8	2	20	Improved analgesia at rest	Decreased break-through pain, oral opioid requirements, opioid-related side effects, and sleep disturbances; improved patient satisfaction
Ilfeld et al. (15)	Infraclavicular (coracoid technique)	30	Ropivacaine 0.2%	8	2	20	Improved analgesia with limb movement	Improved analgesia at rest and patient satisfaction; decreased oral opioid requirements, opioid-related side effects, and sleep disturbances
Ilfeld et al. (17)	Interscalene (lateral approach)	20	Ropivacaine 0.2%	8	2	20	Improved analgesia at rest	Decreased break-through pain, oral opioid requirements, opioid-related side effects, and sleep disturbances; improved patient satisfaction
Ropivacaine versus bupivacaine								
Rawal et al. (22)	Axillary (paresthesia or nerve stimulator)	60	Ropivacaine 0.125% versus Bupivacaine 0.125%	0	10 mL	None, but instructed not to bolus >1/h	No difference in analgesia	For both treatment groups, analgesia improved after local anesthetic bolus; on the day of surgery, satisfaction was better in the ropivacaine group the day of surgery
Dosing regimens (e.g. bolus-only versus basal-only)								
Ilfeld et al. (24)	Interscalene (lateral approach)	20	Ropivacaine 0.2%	Group A: 8 Group B: 4	Group A: 2 Group B: 6	60	Group A: Decreased break-through pain	Group A: improved analgesia at rest on postoperative day 2 and overall patient satisfaction; decreased oral opioid requirements, sleep disturbances, and infusion duration
Ilfeld et al. (25)	Infraclavicular (coracoid technique)	30	Ropivacaine 0.2%	Group A: 12 Group B: 8 Group C: 0	Group A: 0 Group B: 4 Group C: 10	60	Group A: Increased oral opioid use Group C: Decreased analgesia	Group A: Shorter infusion duration followed by increased break-through pain; Group C: increased break-through pain and sleep disturbances; Groups A and C: decreased patient satisfaction
Ilfeld et al. (27)	Popliteal (posterior, intertendinous approach)	30	Ropivacaine 0.2%	Group A: 12 Group B: 8 Group C: 0	Group A: 0 Group B: 4 Group C: 10	60	Group C: Decreased analgesia	Group C: Increased break-through pain, oral opioid requirements, and sleep disturbances; Group A: shorter infusion duration followed by above outcomes
Local anesthetic with clonidine versus local anesthetic without clonidine								
Ilfeld et al. (26)	Infraclavicular (coracoid technique)	34	Ropivacaine 0.2%, with or without clonidine 1 μg/mL	8	2	20	No difference in break-through pain	No clinically relevant differences in resting pain scores, bolus doses, oral analgesics, sleep quality or patient satisfaction
Ilfeld et al. (59)	Interscalene (lateral approach)	20	Ropivacaine 0.2%, with or without clonidine 2 μg/mL	5	5	60	No difference in break-through pain	No clinically relevant difference in resting pain scores, bolus doses, oral analgesics, sleep quality or patient satisfaction
Three infusion pump models (Group A: elastomeric device with bolus administered with syringe (74); Groups B & C: electronic pumps with bolus control)								
Capdevila et al. (73)	Interscalene, femoral, and tibial (at ankle level)	76	Ropivacaine 0.2%	5	5	Group A: unspecified; Groups B & C: 20–30	No difference in analgesia; lower patient satisfaction in Group C	Increased number of technical problems in Group C

NA = not applicable (an elastomeric pump without bolus capability was used).
One additional randomized, controlled investigation was published but not included above since it was aborted prior to completion (28).

the positional relationship of the catheter tip to the target nerve before local anesthetic dosing (24,25). Although there is evidence that passing current via the catheter may improve the accuracy of catheter placement (40), there are no investigations directly comparing stimulating and nonstimulating catheters (36). Further study is required to identify the optimal placement techniques and equipment for ambulatory perineural infusion (41). Regardless of the equipment/technique used, a test dose of local anesthetic with epinephrine should be administered via the catheter in an effort to identify intrathecal (42), epidural (43), or intravascular (44) placement before infusion.

One major difference between inpatient and ambulatory infusion is that an experienced medical professional will not observe the catheter site daily and reinforce the dressing with ambulatory infusion. Therefore, every effort to optimally secure the catheter must be made for outpatients. These have included the use of sterile liquid adhesive (e.g., benzoin), sterile tape (e.g., Steri-Strips), securing of the catheter-hub connection with either tape or specifically designed devices (e.g., Statlock), subcutaneous tunneling of the catheter (39,45), and the use of 2-octyl cyanoacrylate glue (46). Using a combination of these maneuvers (24,25,27), investigators have reported a catheter retention rate of 95%–100% for more than 60 h in ambulatory patients (Fig. 1).

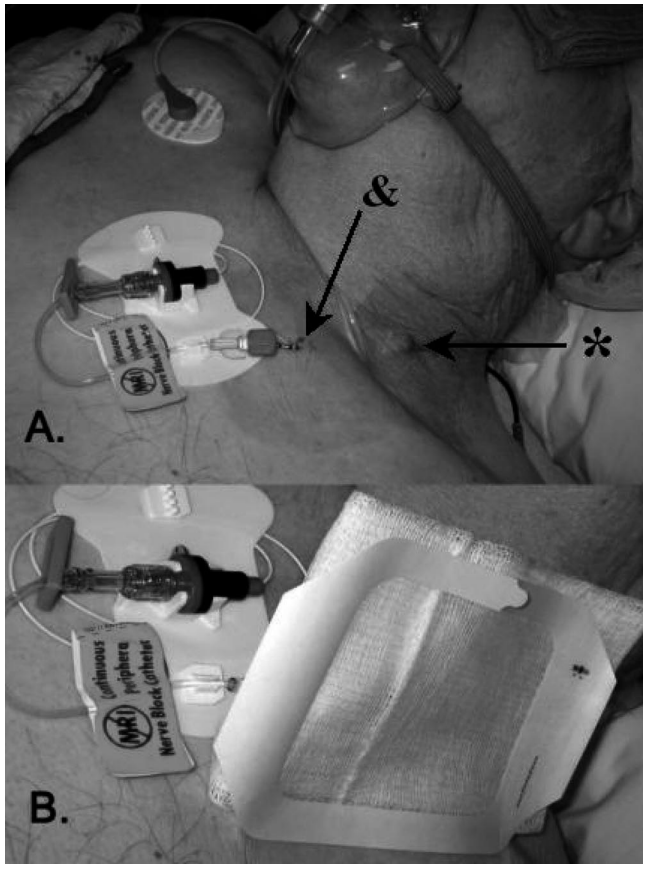

Figure 1. An example of a secured interscalene perineural catheter (Arrow Stimucath, Arrow International, Reading, PA). (A) Several techniques are used in an effort to optimally secure the catheter for ambulatory infusion. These include 1) tunneling the catheter from "*" to "&", 2) using a sterile liquid adhesive that extends beyond all of the borders of the occlusive dressings, 3) ensuring no air remains beneath the occlusive dressings and their borders remain unfrayed, 4) using two small occlusive dressings instead of one large dressing in this area without a flat surface, and 5) using a specifically designed anchoring device (Statlock, Venetec International, San Diego, CA). Note that the "skin bridge" is <1 cm (denoted by "*"), the catheter exits the tunnel below the clavicle (denoted by "&"), and the excess catheter is secured between the anchoring device and skin to minimize the chance of dislodgement. (B) Surgeons often place a sterile drape across the occlusive dressing to maximize the surgical field. If this occurs, at the completion of the procedure the occlusive dressing will be accidentally removed with the surgical drape, leading to catheter dislodgement or contamination. To avoid this complication, a large occlusive dressing affixed to gauze is draped over the catheter dressing. The surgical drape may be placed over this protecting dressing/gauze, removing it after the procedure, and leaving the underlying catheter dressing intact.

Infusate Selection

Most publications regarding perineural infusion have involved bupivacaine or ropivacaine, although levobupivacaine (47) and shorter acting drugs have been reported (48–50). As these local anesthetics have varying durations of action (51), investigations involving one may not be applied to another. One trial involving inpatient interscalene infusion found that ropivacaine 0.2% and bupivacaine 0.15% provide similar analgesia but that ropivacaine was associated with better preservation of strength in the hand and less paresthesia in the fingers (51). However, another study of interscalene infusion found ropivacaine 0.2% and levobupivacaine 0.125% equivalent after shoulder surgery, with patients receiving levobupivacaine consuming a smaller volume of anesthetic (47). Similarly, a third investigation found no difference between 0.125% bupivacaine and ropivacaine provided as self-administered bolus doses via an axillary catheter after mildly painful surgery of the upper extremity (22). Unfortunately, the precise equipotent local anesthetic concentrations within the peripheral nervous system remain undetermined, making the evaluation of comparisons problematic. Currently, there is insufficient information to determine if there is an optimal local anesthetic for ambulatory infusions. When deciding on an infusate, providers should consider the risk of local anesthetic toxicity as the concentration of local anesthetic increases (50).

Investigators have added clonidine to long-acting local anesthetic (1–2 μg/mL) for continuous perineural femoral (52), anterior lumbar plexus (53–55), interscalene (56), and popliteal (57) infusions for inpatients.

Unfortunately, although clonidine increases the duration of single-injection nerve blocks (58), the only controlled investigations of adding clonidine to a continuous ropivacaine infusion (1 or 2 μg/mL) failed to reveal any clinically relevant benefits in outpatients (26,59). Additionally, opioids and epinephrine have been added to local anesthetic infusions, but there are currently insufficient published data to draw any conclusions regarding these adjuvants.

Dosing Regimen

Investigations of inpatient interscalene (56), axillary (60), fascia iliaca (61), extended femoral (53,55), and subgluteal (62) catheters suggest that the optimal local anesthetic dosing regimen varies with anatomic location. Therefore, data from studies involving one catheter location cannot necessarily be applied to another anatomic location. Three publications specifically investigated the optimal dosing regimen for ambulatory perineural infusions (24,25,27). All involved moderately painful surgical procedures, ropivacaine local anesthetic, stimulating catheters, electronic infusion pumps, and a randomized, double-masked study design. The first two, involving infraclavicular and popliteal infusions, demonstrated that providing PCA bolus doses without a basal infusion results in a longer duration until local anesthetic exhaustion but less potent analgesia, increased sleep disturbances, and less satisfaction compared with a regimen including both a basal infusion and bolus capability (25,27). For both types of infusions, adding PCA bolus doses allowed for a slower continuous basal rate and decreased local anesthetic consumption compared with a basal-only regimen, thereby increasing the duration of infusion benefits when in an ambulatory environment with a limited local anesthetic reservoir. Furthermore, for infraclavicular catheters, providing only continuous basal infusion results in larger oral analgesic consumption (25) and increased opiate-related side effects (15).

For interscalene catheters after shoulder surgery, decreasing the basal rate from 8 to 4 mL/h lengthens infusion duration and provides similar baseline analgesia when patients supplement their block with large bolus doses (24). However, patients experience an increase in breakthrough pain incidence and intensity and sleep disturbances and a decrease in satisfaction with their analgesia. Therefore, if ambulatory patients do not return for additional local anesthetic, practitioners are left with the dilemma of superior analgesia for a shorter duration versus a lesser degree of analgesia for a longer period of time. It should be noted that with a reprogrammable infusion pump, the basal infusion rate may be decreased as surgical pain resolves, thus lengthening the infusion duration and theoretically maximizing postoperative analgesia (7).

There are limited data available on which to base recommendations on the optimal basal rate, bolus volume, and lockout period. Although additional investigations of dosing regimen optimization involving hospitalized patients are available (53,55,56,60–62), data derived from inpatient infusion cannot necessarily be applied to outpatients. Furthermore, in all probability, other confounding variables may affect the optimal regimen, including the surgical procedure, catheter location, physical therapy regimen, and specific local anesthetic infused. Available published data related to dosing regimen optimization for outpatients involved surgical procedures producing moderate postoperative pain. It is possible—even probable—that adequate analgesia for procedures inducing mild postoperative pain would be adequately treated with a bolus-only dosing regimen (22). Additionally, there is a theoretical possibility that stimulating catheters may be placed, on average, closer to the target nerve/plexus compared with nonstimulating devices (40). If this proves to be true, then potentially different dosing regimens, basal rates, and bolus doses would be optimal for different types of catheters. However, currently published data are insufficient to draw any conclusions.

Available inpatient and outpatient data suggest that after procedures producing moderate-to-severe pain, providing patients with the ability to self-administer local anesthetic doses increases perioperative benefits or decreases local anesthetic consumption (24,25,27). Unfortunately, other than for interscalene infusions (24), no information is available to base recommendations on the optimal basal rate, bolus volume, or lockout period. In all probability, these factors will also be influenced by the variables noted above. Until recommendations based on prospectively collected data are published, practitioners should be aware that investigators have reported successful analgesia using the following with long-acting local anesthetics: basal rate of 5–10 mL/h, bolus volume of 2–5 mL, and lockout duration of 20–60 min. Additionally, the maximum safe doses for the long-acting local anesthetics remain unknown. However, multiple investigations involving patients free of renal or hepatic disease have reported blood concentrations within acceptable limits after up to 5 days of perineural infusion with similar dosing schedules (29,63–65).

Infusion Pump Selection

Many factors must be considered to determine the optimal device for a given clinical application (66). Such factors include—but are not limited to—the acceptable infusion rate accuracy, PCA bolus capability, and total local anesthetic volume requirement. The infusion devices reviewed in this article include those

Table 2. Infusion Pump Attributes

Pump model (References)	Wt. (g)	Reservoir volume (max mL)	Basal infusion (mL/h)	Bolus dose (mL)	Bolus lockout (min–h)	Retail price (US $)	Power source
Programmable, reusable models							
6060 MT (70)	525	IV bag*	0.1–50.0	0–50	0–60	3995	Electronic
ambIT PCA (70)	133	IV bag*	0–20	0–20	5–24	500–800†	Electronic
AutoMed 3400 (69)	325	IV bag*	0–50	0–50	0–60	675	Electronic
BlockIt (WalkMed) (68)	323	IV bag*	0–30	0–30	0–24	1750–2300	Electronic
CADD-Legacy PCA (68)	372	IV bag*	0–50	0–9.9	5–24	3595	Electronic
CADD-Prism PCS (68)	547	IV bag*	0–30	0–9.9	5–24	4125	Electronic
Ipump PMS (70)	415	IV bag*	0–19.9‡	0–9.9	1–6	4295	Electronic
Microject PCA (67,68)§	198	IV bag*	0–9.9	0–2	6–1	N/A§	Electronic
Microject PCEA (69)§	198	IV bag*	0–29	0–10	10–120	N/A§	Electronic
Programmable, Disposable Models							
ambIT LPM (70)	133	IV bag*	0–20	0–20	5–24	250–350†	Electronic
AutoMed 3200 (70)	350	250	0–10	0–5	2–60	255	Electronic
Pain Pump II (69)	408	400	0.5–15	0–15	10–2	250†	Electronic
Nonprogrammable, disposable, basal- and bolus-capable models							
Accufuser Plus XL (68–70)	109	550	5, 8, or 10‖	2‖	15, 60 min‖	260	Elastomeric
Pain Care 3200 (69)	290	200	5.7 –2.9‖¶	4–6‖¶	40–1.3‖¶	175	Spring
On-Q C-Bloc with OnDemand (70)	135	400**	5‖	5‖	60 min‖	250–500	Elastomeric
Nonprogrammable, disposable, basal- or bolus-only models							
Accufuser (67)	95	275	2, 4, 5, 8, 10‖	N/A	N/A	150–225	Elastomeric
C-Bloc (67)	65	400	5 or 10‖	N/A	N/A	395†	Elastomeric
Infusor LV5 (69)	65	275	2, 5, 7, 10‖	N/A	N/A	55	Elastomeric
Pain Pump I (67)	104	120	0.8, 2.1, 4.2‖	N/A	N/A	150†	Vacuum
Sgarlato (67)	225	200	0.5, 1, 2, 4‖	N/A	N/A	225†	Spring

N/A = not applicable.

Weight includes batteries and disposable cassette in electronic pumps and excludes infusate for all pumps.

* Local anesthetic reservoir is an external syringe or IV-style bag of any size; † approximate price for Florida (USA): other regions may vary; ‡ if a bolus dose is not provided, the maximum basal rate is 90 mL/h; § the Microject pumps may be reused as disposable cassettes are used with the mechanical pump, but the pumps themselves are less expensive than some disposable pumps, and may thus be considered disposable, if desired. No longer available in the US; ‖ fixed during manufacture.

¶ Basal infusion rate described as "4 mL/h continuous flow" on product packaging and marketing materials. However, product information contained within the instruction manual specifies that the rate is 5.7 mL/h at the beginning of the infusion, and steadily declines to 2.9 mL/h by reservoir exhaustion. Bolus dose is variable and lockout increases as infusion progresses (69).

** On-Q C-Block with OnDemand may be overfilled to 500 mL, decreasing the basal rate for a portion of the infusion, but allowing for a longer infusion duration (70).

for which performance data are available from independent sources (Table 2 and Appendix).

Accuracy, Consistency, Reliability

For the purposes of this review, accuracy is defined as infusing at the set or expected rate and consistency is infusing at the same rate for most of the infusion (Fig. 2). In general, electronic infusion pumps provide highly accurate (90%–100% expected) and consistent (±5% baseline) basal rates over the entire infusion duration (67–70). Elastomeric devices provide a more rapid than expected basal rate initially (110%–150% expected), return to their expected rate within 2–12 h, and again increase to a higher rate before reservoir exhaustion (67–71). Similarly, spring-powered pumps initially provide a more rapid than expected basal rate (115%–135% expected) which steadily decreases to a less rapid than expected rate (70%–75% expected) by reservoir exhaustion (67,69,71). There are insufficient published data to determine the clinical situations in which the typical basal rate variation of nonelectronic pumps would be clinically relevant. Although investigators have used elastomeric pumps for multiple catheter locations and surgical procedures (6,14,17), it

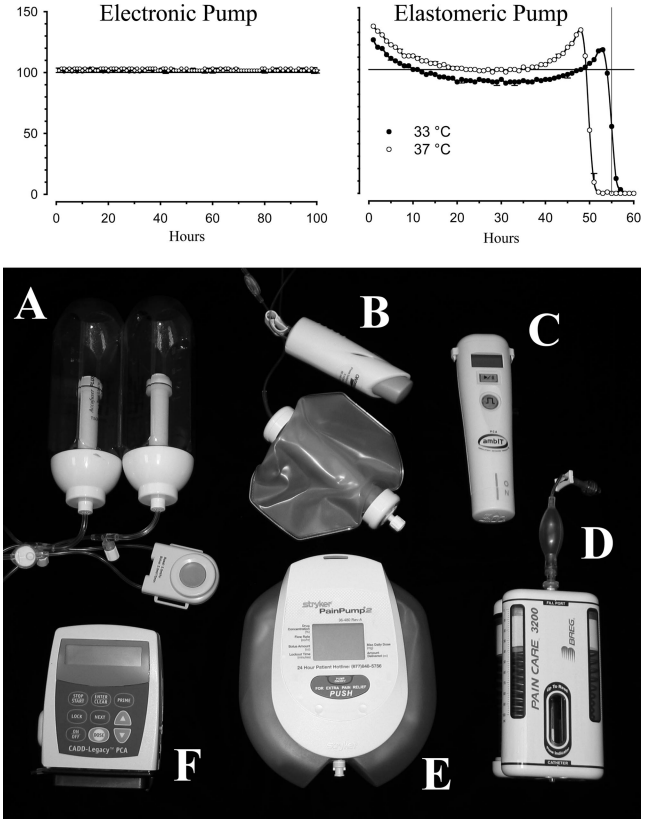

Figure 2. Examples of portable basal-capable and bolus-capable infusion pumps. (Top panel) Performance over time for typical portable infusion pumps. The actual infusion rate is shown as a fraction of the set infusion rate. The constant horizontal line represents the expected pump rate at 100% of set flow rate. The constant vertical line for the elastomeric pump represents the expected infusion duration as calculated from the set rate and reservoir volume. Axes' labels apply to both panels. (Lower Panel) A, Accufuser Plus XL; B, On-Q C-Bloc with OnDemand; C, ambIT PCA; D, Pain Care 3200; E, Pain Pump II; F, CADD-Legacy PCA.

is not known whether providing a less variable basal rate would have affected outcomes. Additionally, there are few published data regarding the failure rates—or reliability—of the various pump models (72). Of note, the Microject patient-controlled epidural analgesia (PCEA) pump has been noted to have a frequent rate of false alarm activation (73). However, redesigned models are replacing both the Microject PCA and PCEA. There are electronic pumps that have been noted to infuse without an erroneous alarm for more than 10,000 cumulative hours of clinical use (24,25,27). Although the nonelectronic pumps cannot trigger alarms which are an irritant to both patients and health care providers (73), there is also no warning if a catheter occlusion or pump malfunction occurs (16).

Bolus-Dose Capability

Various pumps allow for both patient-controlled local anesthetic boluses and a basal infusion (Table 2), whereas others allow for only one of these (67–70,74). Without the option for a bolus dose (74), larger doses of oral opiates are often required for breakthrough pain (25). Patient-controlled local anesthetic administration, also called patient-controlled regional analgesia (PCRA), provides equivalent or superior analgesia with less local anesthetic consumption compared with continuous infusions alone with a variety of perineural techniques (25,53,55,56). PCRA is often important for ambulatory patients because the infusion may be tailored to provide a minimum basal rate allowing maximum infusion duration and minimal motor block (7) yet allow bolus dosing for breakthrough pain (25) and before physical therapy (24,27,75). Finally, for patients with difficulty applying force to a bolus button (e.g., patients with arthritis), electronic pumps offer easily depressed buttons compared with the manual bolus injection systems of nonelectronic units (Fig. 2).

Some investigators have used elastomeric pumps that provide bolus-only dosing when the patient releases a clamp on the tubing connecting the pump and catheter (3,5,22). The patient is instructed to reclamp the tubing after a specified period of time (3,22). If a patient forgets to reclamp the tubing it is possible for the entire contents of the local anesthetic reservoir to be administered in less than an hour. This potentially devastating scenario has been reported, although no apparent morbidity has yet occurred (5). Although the safety of this method may be demonstrated in the future, practitioners should consider the relative risks and benefits now that multiple pumps are available providing controlled bolus dosing (Table 2).

Programmability

If various rates of infusion, bolus volumes, and lockout times are desired, an electronic pump will be required. However, most of the nonelectronic pumps may be ordered at various infusion rates, although this aspect is usually fixed during manufacturing and cannot be adjusted; Baxter Healthcare International manufactures an elastomeric pump with an adjustable basal rate that is currently unavailable in the United States (personal communication, Mary Kingsbury, 2004). Just as with epidural infusions, the optimal basal infusion rate for perineural catheters is highly variable among patients (15,26). Allowing patients to vary their basal rate (with instructions from a health care provider via the telephone) has allowed analgesia optimization (7,26).

Disposability and Unit Price

It may be cost-effective for practitioners who use these devices repeatedly to use a more-expensive, reusable, electronic pump that uses relatively inexpensive disposable cassettes for each new patient (Table 2). This scenario requires the patient to either be provided

with a padded envelope for infusion pump return (41) or revisit the surgical center (76).

Miscellaneous Factors

Most elastomeric pumps regulate their infusion rate using a temperature-dependent device (67–70). Although older pump models demonstrated a basal rate increase up to 35% with a 4°C increase in ambient temperature (67), current units are more resistant to temperature variations (68–70). Under hypobaric conditions, such as those occurring at high altitude, elastomeric pump infusion rates are reduced (77). Finally, the required local anesthetic reservoir volume is determined by the infusion rate, PCA bolus doses, and anticipated infusion duration (Table 2). Spring and electronic pumps are refillable, but elastomeric pumps may not function properly if simply refilled (unpublished data).

Discharge and Home Care

Patient Education

Because most patients have some degree of postoperative cognitive dysfunction, most investigators educate both patient and caretaker at the same time before discharge. Although currently uninvestigated, there is consensus among practitioners that both verbal and written instructions should be provided, along with contact numbers for health care providers who are available throughout the infusion duration (6,15,22,78). Along with standard postoperative outpatient instructions, topics reviewed usually include infusion pump instructions, expectations regarding surgical block resolution, breakthrough pain treatment, specific instruction to not drive or operate machinery, catheter site care (sponge bath instead of shower), limb protection, what to do if local anesthetic leaks from under the protective dressing, signs and symptoms of possible catheter-related and local anesthetic-related complications, and catheter removal plan.

Patients being discharged home must be able to ambulate. Therefore, discharge with a lower extremity peripheral nerve block remains controversial (79). Although there is evidence that discharge with an insensate extremity after a single-injection nerve block can result in minimal complications (80), whether patients should weight-bear with a continuous peripheral nerve block remains unexamined. Therefore, conservative management may be optimal; some investigators have recommended that patients avoid using their surgical limb for weight bearing (8,16,27). This is usually accomplished with the use of crutches, and the patient's ability to use these aids without syncope or difficulty must be confirmed before discharge. The importance of protecting the surgical extremity must be emphasized as well. Any removable brace or splint should remain in place except during physical therapy sessions.

If the initial surgical block has not resolved before home discharge, postoperative analgesic requirements cannot be assessed. Although perineural infusions of local anesthetic usually decrease postoperative pain dramatically, many patients still require oral analgesics. The percentage of patients who will use supplemental oral opioids is dependent on a multitude of factors, including the type of surgery, other analgesic adjuvants such as cryotherapy, the local anesthetic used for infusion, and the infusion dosing regimen provided. Furthermore, the possibility of catheter misplacement during initial insertion or subsequent dislodgement will usually require the use of oral analgesics. However, it is currently impossible to accurately predict which patients will require oral opioids. Therefore, a prescription for oral analgesics should be provided to all patients, and the importance of filling the prescription immediately after leaving the surgical center should be emphasized. A period of inadequate analgesia may result if patients wait to fill the prescription until after they have determined if oral analgesics are required.

Patient Contact and Catheter Removal

Although not systematically investigated, practitioners may want to consider documenting each patient contact, as is standard of care for inpatients (Fig. 3). The optimal frequency of contact with ambulatory patients is currently unknown and is probably dependent on multiple factors, such as patient comorbidities and surgical procedure. Multiple investigators have suggested that patients be contacted daily by telephone (15–17,22,81); others have provided twice-daily home nursing visits in addition to telephone calls (6,73). Issues deserving attention consist of signs and symptoms of potential complications including, but not limited to, site infection (82), nerve injury (83), pulmonary compromise (32,33), and local anesthetic toxicity (44). There are case reports of initially misplaced catheters (42–44,84,85), but migration after a documented correct placement has not been described (but remains a theoretical risk). Possible complications of an unidentified initially misplaced catheter or of a catheter migration include intravascular or interpleural placement/migration resulting in local anesthetic toxicity, IM placement/migration resulting in myonecrosis, and epidural/intrathecal placement/migration when using interscalene, intersternocleidomastoid, paravertebral, or psoas compartment catheters.

Investigators have reported catheter removal by various techniques: some discharge patients with written instructions (12), others have insisted on a health care provider performing this procedure (76),

Florida Surgical Center
AT SHANDS HOSPITAL AT THE UNIVERSITY OF FLORIDA

PATIENT
LABEL

Progress Note for Ambulatory Perineural Local Anesthetic Infusion

Surgery Date_____/_____/200__ Surgeon:_____ Home phone: (_____) _____ - _____

Procedure: _____ Other phone: (_____) _____ - _____

Post-op in PACU

- ☐ Catheter w/ neg. aspiration & ____ cc of _____ w/ _____ mcg epi/cc to catheter w/ neg aspiration q2 cc
- ☐ No heart rate or sensory changes within 5 minutes
- ☐ Instructions and local anesthetic toxicity symptoms explained to pt & all questions answered, MD phone #s provided
- ☐ Pump tubing secured to catheter, pump programmed & infusion begun

Notes:

_____
Physician Signature

POD #0 ____: ____

- ☐ Patient or patient's caretaker contacted by phone
- ☐ Symptoms of local anesthetic toxicity, catheter migration and infection denied
- ☐ Appropriate sensory/motor function of affected extremity acknowledged
- ☐ Surgical pain under control
- ☐ Patient would like to have catheter remain in situ at this time
- ☐ All questions answered

Notes:

_____
Physician Signature

POD #1 ____: ____

- ☐ Patient or patient's caretaker contacted by phone
- ☐ Symptoms of local anesthetic toxicity, catheter migration and infection denied
- ☐ Appropriate sensory/motor function of affected extremity acknowledged
- ☐ Surgical pain under control
- ☐ Patient would like to have catheter remain in situ at this time
- ☐ All questions answered

Notes:

_____
Physician Signature

POD #2 ____: ____

- ☐ Patient or patient's caretaker contacted by phone
- ☐ Symptoms of local anesthetic toxicity, catheter migration and infection denied
- ☐ Appropriate sensory/motor function of affected extremity acknowledged
- ☐ Surgical pain under control
- ☐ Patient would like to have catheter remain in situ at this time
- ☐ Catheter removed by patient's caretaker with MD on phone, tip reported to be blue/silver
- ☐ All questions answered

Notes:

_____
Physician Signature

POD #3 ____: ____

- ☐ Patient or patient's caretaker contacted by phone
- ☐ Symptoms of local anesthetic toxicity, catheter migration and infection denied
- ☐ Appropriate sensory/motor function of affected extremity acknowledged
- ☐ Surgical pain under control
- ☐ Patient would like to have catheter remain in situ at this time
- ☐ Catheter removed by patient's caretaker with MD on phone, tip reported to be blue/silver
- ☐ All questions answered

Notes:

_____
Physician Signature

POD #4 ____: ____

- ☐ Patient or patient's caretaker contacted by phone
- ☐ Symptoms of local anesthetic toxicity, catheter migration and infection denied
- ☐ Appropriate sensory/motor function of affected extremity acknowledged
- ☐ Surgical pain under control
- ☐ Patient would like to have catheter remain in situ at this time
- ☐ Catheter removed by patient's caretaker with MD on phone, tip reported to be blue/silver
- ☐ All questions answered

Notes:

_____
Physician Signature

Figure 3. An example of a progress note that may be used to record telephone contacts with ambulatory patients.

although others have patients' caretakers (or occasionally the patients themselves) remove the catheters with instructions given by a provider over the telephone (15–17,24,25,27). Although there are no data documenting the superiority of any one technique, one survey revealed that with instructions given by phone, 98% of patients felt comfortable removing their catheter at home (86). Of note, only 4% would have preferred to return for a health care provider to remove the catheter, and 43% responded that they would have felt comfortable with exclusively written instructions (86). Practitioners may consider providing nonsterile gloves for patients having their catheters removed at home (15–17). The presence of a blue/silver catheter tip identified by the person removing the catheter confirms complete removal (depending on catheter design) and should be documented in the medical record.

Conclusions

In keeping with evidence-based medical practice, we believe the optimal techniques, equipment and patient oversight should be determined by prospective, controlled trials and not merely by institutional preference. We have noted the available relevant data and information. There is strong evidence suggesting that continuous peripheral nerve blocks provided at home improve postoperative analgesia, sleep quality, and patient satisfaction while decreasing supplemental opioid requirements and opioid-related side effects. In addition, a basal infusion after moderately painful surgery maximizes infusion benefits, whereas adding PCA bolus doses allows for a decreased basal rate and increased infusion duration. However, because of the relatively recent evolution of outpatient perineural infusion, illuminating data on many aspects of this analgesic technique are unavailable. Future investigation should include determining which patients and procedures benefit most from perineural infusion, the optimal local anesthetic, concentration, and adjutants, the most advantageous delivery regimen and dosing structure, the optimal catheters (e.g., stimulating versus nonstimulating catheters), placement techniques, and infusion pumps, the safest frequency of patient contact and method of catheter removal, and, finally, whether additional outcomes are affected with ambulatory perineural local anesthetic infusion (e.g., health-related quality of life).

Appendix: Infusion Pump Distributors

Pump (reference)	Distributor	City	State
6060 MT (70)	Baxter Healthcare	Deerfield	IL
Accufuser (67)	McKinley Medical	Wheat Ridge	CO
Accufuser Plus XL (68–70)	McKinley Medical	Wheat Ridge	CO
ambIT LPM (70)	Sorenson Medical	West Jordan	UT
ambIT PCA (70)	Sorenson Medical	West Jordan	UT
AutoMed 3200 (70)	Algos, LC	Salt Lake City	UT
AutoMed 3400 (69)	Algos, LC	Salt Lake City	UT
BlockIt (WalkMed) (68)	McKinley Medical	Wheat Ridge	CO
CADD-Legacy PCA (68)	Smiths Medical	St. Paul	MN
CADD-Prism PCS (68)	Smiths Medical	St. Paul	MN
C-Bloc (67)	I-Flow Corporation	Lake Forest	CA
Infusor LV5 (69)	Baxter Healthcare	Deerfield	IL
Ipump (70)	Baxter Healthcare	Deerfield	IL
Microject PCA (67,68)	Sorenson Medical	West Jordan	UT
Microject PCEA (69)	Sorenson Medical	West Jordan	UT
On-Q C-Bloc with OnDemand (70)	I-Flow Corporation	Lake Forest	CA
Pain Care 3200 (69)	Breg, Inc.	Vista	CA
Pain Pump I (67)	Stryker Instruments	Kalamazoo	MI
Pain Pump II (69)	Stryker Instruments	Kalamazoo	MI
Sgarlato (67)	Sgarlato Labs	Los Gatos	CA

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