REVIEW ARTICLE

Continuous Plexus and Peripheral Nerve Blocks for Postoperative Analgesia

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There is increasing interest in peripheral nerve blocks because of potential benefits and concerns over interactions of anticoagulants and central neuraxial techniques. In a recent survey of members of the American Society of Anesthesiologists and the American Society of Regional Anesthesia and Pain Medicine, nearly half of the respondents anticipated an increased use of peripheral nerve blocks in their practice (1). Continuous plexus and peripheral nerve blocks offer the potential benefits of prolonged analgesia with fewer side effects, greater patient satisfaction, and faster functional recovery after surgery. In this review article, we summarize pertinent anatomy, technical aspects, and current evidence when available in prospective randomized trials for the indications and efficacy of continuous perineural techniques for postoperative analgesia.

Brachial Plexus

Virtually all published clinical trials have used either an interscalene or axillary approach for placement of continuous catheters, and new anatomic investigations have increased interest in the intersternocleidomastoid (ISCM) approach.

Interscalene Approach

Initial prospective, randomized, controlled trials demonstrated that the use of continuous interscalene analgesia reduced opioid requirements compared with placebo (2,3) (Table 1A). Compared with IV patient-controlled analgesia (PCA) for open shoulder surgery, prospective, randomized, controlled trials further demonstrated that the use of continuous interscalene analgesia not only reduced requirements for postoperative opioids (4–7), but also provided better analgesia, reduced opioid-related side effects, and provided better patient satisfaction for at least the first 48 h after surgery (Table 1B). Although a case series of 100 patients suggested enhanced physical rehabilitation after shoulder surgery with continuous interscalene analgesia (8), effects on the success of physical rehabilitation or duration of hospitalization are unknown.

Reported success rates of placing an interscalene brachial plexus catheter range from 75% to 100%. Virtually all of these studies used a peripheral-nerve stimulator technique, needle entry in the interscalene groove, and insertion of catheters 5–10 cm into the brachial plexus sheath (3–5,7,9). An interesting modification of the interscalene approach (9) inserts the stimulating needle midway between the mastoid and clavicle and posterior to the posterior border of the clavicular head of the sternocleidomastoid muscle. The needle is advanced caudad and parallel to the vertebral column. After localization of the brachial plexus by the stimulating needle, a metal-tipped catheter that directly allows electrical stimulation is advanced through the needle to confirm accuracy of the final indwelling catheter position. Potential advantages of this technique are that the needle is directed away from the vertebral artery, epidural and subarachnoid space, and the catheter is inserted in a cephalad-to-caudad direction with potentially increased contact surface with the brachial plexus, and decreased block of the phrenic nerve (9,10). One study using this technique reported 100% success rate in catheter placement and an unusually small incidence of phrenic nerve block (25%) with injection of the initial loading dose through the catheter. Another novel technique of interscalene catheter placement is by direct visualization of the brachial plexus in the interscalene groove with real-time ultrasound guidance. One investigation reported successful catheter placement and postoperative analgesia in all 15 patients (11). Further studies are needed to determine optimal technique.

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Table 1. Studies of Continuous: Brachial Plexus Analgesia

Author	Patient no.	Continuous analgesic infusion	Results
A Continuous interscalene analgesia versus placebo after shoulder surgery			
Touminen et al.[2]	20/20[a]	0.25% BU at 0.25 mg · kg^{-1} · h^{-1}	Improved analgesia ($P < 0.01$) and 60% reduction in opioid use ($P < 0.01$). Mean plasma BU levels were 0.7–1.1 μg/mL.
Klein et al.[3]	22/18[b]	0.2% ROP at 10 mL/h	Improved analgesia ($P = 0.0001$) and 50% reduction in opioid use ($P = 0.004$). Mean 24-h plasma ROP levels were 1.04 ± 0.05 μg/mL.
B Continuous interscalene analgesia versus IV PCA after shoulder surgery			
Borgeat et al.[4]	20/20[a]	0.15% BU at 5 mL/h plus 3–4 m bolus q 20 min p.r.n.	Improved analgesia ($P < 0.05$), patient satisfaction ($P < 0.05$), and lower incidence of nausea and vomiting ($P < 0.05$).
Borgeat et al.[5]	30/30[a]	0.2% ROP at 5 mL/h plus 3–4 mL bolus q 20 min p.r.n.	Improved analgesia ($P < 0.05$), patient satisfaction ($P < 0.05$), and lower incidence of nausea and vomiting ($P < 0.05$).
Lehtipalo et al.[6]	10/10[a]	0.25% BU at 0.25 mg · kg^{-1} · h^{-1}	Improved analgesia ($P < 0.001$).
Borgeat et al.[7]	18/15[a]	0.2% ROP at 5 mL/h plus 3–4 mL bolus q 20 min p.r.n	Improved analgesia ($P < 0.05$), patient satisfaction ($P < 0.05$), and lower incidence of nausea and vomiting ($P < 0.05$). Similar decrease in diaphragmatic excursion between two groups.
C Continuous axillary analgesia after upper extremity surgery			
Ang et al.[15]	52[c]	100 mg BU with 1,200,000 EPI q 12–24 h p.r.n manipulation	Perivascular (axillary artery) technique without nerve stimulator. A 98% success rate of catheter insertion; 2% rate of arterial puncture.
Pham-Dang et al.[16]	18[c]	0.25% BU at 3–5 mL/h	Perivascular (axillary vein) technique guided by fluoroscopy. A 100% success rate of catheter insertion.
Mezzatesta et al.[19]	Group C (10)[a]	Group C: 0.25% BU at 0.25 mg · kg^{-1} · h^{-1}	Equivalent analgesia between groups (70%–80% patients reported no pain or minimal pain). Mean plasma BU levels at 24 h higher ($P < 0.05$) in Group C (1.03 ± 0.1 μg/mL) than in Group B (0.73 μg/mL ± 0.08 μg/mL).
	Group B (10)	Group B: 0.25% BU at 0.25 mg · kg^{-1} · h^{-1} as a bolus infusion q 1 h	
Salonen et al.[20]	Group 0.1 (20)[a]	Group 0.1: 0.1% ROP at 0.125 mg · kg^{-1} · h^{-1}	No significant difference in quality of postoperative analgesia (VAS = 5–6/10) among the 3 groups, with >50% in each group requiring supplemental analgesia.
	Group 0.2 (20)	Group 0.2: 0.2% ROP at 0.250 mg · kg^{-1} · h^{-1}	
	Group S (20)	Group S: saline infusion at 6–11 mL	
D Continuous intersternocleidomastoid analgesia after upper extremity surgery			
Pham-Dang et al.[24]	70[c]	0.25% BU with 1,200,00 EPI at 3 mL/h, increased to 10 mL/h for manipulation	A 98% success rate of catheter insertion. VAS scores 0–1/10 at rest and 1–2/10 during rehabilitation.

BU = bupivacaine, ROP = ropivacaine, PCA = patient-controlled analgesia, q = every, p.r.n. = pro re nata, when necessary, EPI = epinephrine, VAS = visual analog scale.
[a] Prospective, randomized study.
[b] Prospective, randomized, double-blinded study.
[c] Descriptive case series.

Nearly every clinical trial administered a large initial loading dose of local anesthetic suitable for intraoperative anesthesia (20–40 mL of 0.4%–0.5% bupivacaine or 0.4%–0.75% ropivacaine) before initiation of analgesic infusions (2–7,9). The administration of such a large initial loading dose will also block the phrenic nerve (85%–100%), recurrent laryngeal (5%–20%), and sympathetic chain (12%–30%) during interscalene anesthesia (7,9,12). It is unclear what initial loading dose of local anesthetic is optimal if only analgesia is desired. There may be a potential reduction in risk of systemic toxicity and a decrease in undesired neural block with the use of a smaller initial loading dose. For example, smaller doses and concentrations of local anesthetic (0.15%–0.25% bupivacaine or ropivacaine) during continuous analgesia reduced the incidence (0%–75%) and severity (0%–20% reduction in forced vital capacity after 24 h compared with preoperative value) of ipsilateral diaphragmatic paresis (7,9,12,13). Of note, the small reduction in resting and forced respiratory function with interscalene analgesia is similar in magnitude to that seen with IV PCA after open shoulder surgery (7).

To evaluate the complications associated with interscalene blocks, 520 patients (234 with placement of a catheter for continuous analgesia and 286 with a single-injection block) undergoing elective shoulder surgeries were prospectively evaluated for 9 mo (14). The study

reported a 0.4% incidence of long-term complications associated with interscalene block without differences between catheter and single-injection techniques.

Axillary Approach

In contrast to documented benefits of continuous interscalene analgesia, definitive benefits from continuous axillary brachial plexus block have not been established. Case series (Table 1C) reported satisfactory analgesia after hand and forearm procedures with continuous axillary brachial plexus infusions (0.2%–0.25% bupivacaine or 0.5% mepivacaine) but have not compared these regimens with IV PCA or other methods of systemic analgesia (15–20). The importance of clinical trials to determine efficacy of this technique is highlighted in a study examining continuous axillary brachial plexus analgesia for elective hand and forearm surgery. Patients received an initial loading dose of 5 mg/kg of 0.75% ropivacaine and were randomized in a double-blinded manner to receive either ropivacaine 0.1% at 0.125 mg · kg^{-1} · h^{-1}, ropivacaine 0.2% at 0.25 mg · kg^{-1} · h^{-1}, or saline at 6–11 mL/h for postoperative analgesia (20). There were no differences in analgesia or need for supplemental systemic analgesics (>50% of patients in each group) between patients receiving ropivacaine or saline (Table 1C).

Reported success rates from clinical trials and case series for placing a continuous brachial plexus catheter via the axillary approach guided by a nerve stimulator are >90% (15–20). Periarterial (15), perivenous guided by fluoroscopy (16,21), ultrasound-guided (22), and peripheral-nerve stimulator (19,20) techniques have been described for continuous axillary brachial plexus block, but none have been formally compared with each other for continuous analgesia. Thus, the optimal technique remains to be determined. Axillary catheters are typically inserted 3–10 cm into the brachial plexus sheath, but optimal insertion depth is unknown. Determination of optimal insertion depth is of interest because of the anatomy of the axillary brachial plexus. Ultrasound examination of the axillary brachial plexus in 69 healthy volunteers revealed that the median, ulnar, and radial nerves are most compactly arranged at the most proximal aspect of the axilla (lateral edge of pectoralis minor) and steadily diverge away from the axillary artery and each other as one examines more distally (23). This finding suggests that optimal efficacy may be achieved by deeply inserting the catheter to lie as proximally as possible within the axillary brachial plexus sheath, yet the course of catheter travel with greater insertion depth is unknown.

ISCM Approach

There are no published trials comparing the ISCM approach with conventional systemic analgesic techniques or to continuous interscalene analgesia (24).

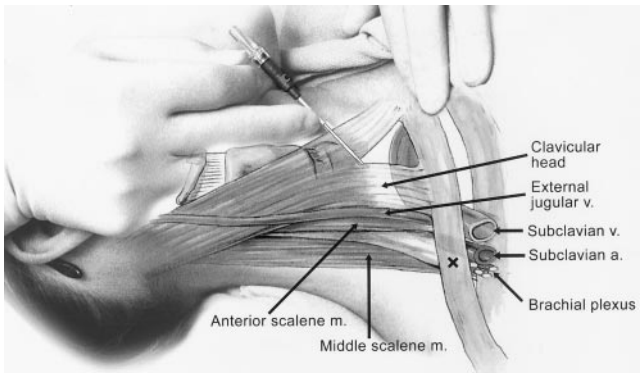

Figure 1. Photograph and schematic drawing of the intersternocleidomastoid approach to the brachial plexus. The patient is supine with the head turned away and the sternocleidomastoid (SCM) triangle is identified. The needle insertion point is located 3 cm above the sternal notch along the inner border of the SCM clavicular head. The stimulating needle is directed caudally, dorsally, and laterally toward the midpoint of the clavicle, passing behind the SCM clavicular head, forming a 40°–50° angle with the plane of the operating table. The needle is advanced until the desired motor response is elicited. Note that the trajectory of the needle facilitates catheter placement along the long axis of the brachial plexus sheath. v = vein, a = artery, m = muscle.

The proposed advantages to this approach are readily identifiable landmarks for needle insertion, facilitation of catheter placement (Fig. 1), and minimal risk of pneumothorax. A prospective case series of 70 patients undergoing upper extremity surgery (Table 1D) used a continuous infusion of 0.25% bupivacaine with 1:200,000 epinephrine at an average rate of 4 mL/h for 48 h and reported excellent rest (visual analog scale [VAS] 0–1/10) and dynamic (VAS 2/10) analgesia (24). Using a peripheral nerve stimulator, the reported success rate of placing a catheter via the ISCM approach was 90%. There was one case of subclavian artery hematoma, a 60% incidence of ipsilateral phrenic nerve block, and no cases of pneumothorax (24).

Lumbar Plexus

Femoral Nerve Sheath Approach

Prospective clinical trials support the use of continuous femoral analgesia after total knee replacement (25–27). Continuous femoral analgesia provides comparable or better analgesia with fewer side effects than IV PCA and epidural analgesia for at least the first 48 h after surgery (Table 2A). The improved analgesia provided by continuous femoral nerve blocks consistently resulted in faster short-term functional recovery of knee flexion during rehabilitation than IV PCA, but without significant differences between the two groups after 6–12 wk. Although these trials used different discharge criteria, accelerated physical rehabilitation resulted in a 20%

Table 2. Studies of Continuous Lower Extremity (Lumbar Plexus and Sciatic Nerve) Analgesia

Author	Patient no.	Continuous analgesic infusion	Results
A CFA versus CEA or IV PCA after total knee replacement			
Capdevilla et al.[25]	20/17/19[a]	1% LIDO, morphine 30 μg/mL, clonidine 2 μg/mL at 0.1 ml · kg^{-1} · h^{-1}	CFA versus IV PCA: improved analgesia ($P < 0.01$), improved knee ROM ($P < 0.05$), and decreased nausea/vomiting ($P < 0.05$). CFA versus CEA: comparable analgesia and knee ROM.
Singelyn et al.[26]	15/15/15[a]	0.125% BU, sufentanil 0.1 μg/mL, clonidine 1 μg/mL at 10 mL/h	CFA versus IV PCA: improved analgesia ($P = 0.04$). A 50% decrease in time to reach functional recovery goals ($P < 0.001$) and 20% in hospital stay ($P < 0.001$). CFA versus CEA: comparable analgesia and knee ROM.
Chelly et al.[27]	29/30/33[b]	0.2% ROP at 12 mL/h	CFA versus IV PCA: improved analgesia ($P < 0.05$), earlier mobilization ($P < 0.05$), and 20% decrease in hospital stay ($P < 0.05$). Decreased nausea, dizziness, and urinary retention ($P < 0.05$). CFA versus CEA: comparable analgesia and functional recovery (ROM).
B CFA versus CEA or IV PCA after THR			
Singelyn and Gouverneur[28]	1142/64/132[b]	0.125% BU, sufentanil 0.1 μg/mL, clonidine 1 μg/mL at 10 mL/h	Comparable analgesia between three analgesic regimens. CFA with lower incidence of nausea, vomiting, pruritis, and sedation versus IV PCA ($P < 0.05$), and lower incidence of urinary retention and hypotension versus CEA ($P < 0.05$).
C Fascia iliaca compartment analgesia after total knee replacement			
Ganapathy et al.[35]	Group S (20)[a]	Group S: saline at 10 mL/h	Comparable analgesia between the three analgesic regimens. BU 0.2% associated with decreased morphine consumption versus placebo ($P < 0.05$). Mean plasma BU levels were 1.19–1.76 ± 0.8 μg/mL over 72-h period.
	Group 0.1B (20)	Group 0.1: 0.1% BU at 10 mL/h	
	Group 0.2B (22)	Group 0.2: 0.2% BU at 10 mL/h	
D Continuous psoas compartment analgesia after THR40 and after surgical repair of hip fractures41			
Capdevilla et al.[40]	18[c]	0.125% BU at 6–10 mL/h plus 4 mL q 45 min p.r.n.	All patients had excellent postoperative analgesia (VAS 1–2/10) without the need for systemic opioid supplementation. No significant side effects reported.
Chudinov et al.[41]	Group A (20)[a]	Group A: 0.25% BU with 1:200,000 EPI at 1–2 mg/kg BU q 8 h p.r.n. VAS > 3/10	Improved analgesia and patient satisfaction in continuous psoas compartment analgesia group versus IV PCA ($P < 0.05$).
	Group B (20)	Group B: IV PCA	
E Continuous popliteal sciatic nerve analgesia versus IV PCA after foot surgery			
Singelyn et al.[44]	60/45[d]	0.125% BU, sufentanil 0.1 μg/mL, clonidine 1 μg/mL at 7 mL/h	Superior analgesia, decreased incidence of nausea/vomiting, urinary retention, and sedation in continuous sciatic analgesia group versus IV PCA ($P < 0.005$).

CFA = continuous femoral analgesia, CEA = continuous epidural analgesia, PCA = patient-controlled analgesia, LIDO = lidocaine, ROM = range of motion, BU = bupivacaine, ROP = ropivacaine, THR = total hip replacement, q = every, p.r.n. = pro re nata, when necessary, VAS = visual analog scale, EPI = epinephrine.

[a] Prospective, randomized study.
[b] Prospective nonrandomized study.
[c] Descriptive case series.
[d] Prospective nonrandomized study with retrospective control group.

reduction in both hospital stay (26,27) and total length of rehabilitation (25,26) with the use of femoral nerve and epidural analgesia versus IV PCA.

Preliminary evidence suggests that continuous femoral analgesia may be beneficial after total hip replacement (THR) (28,29). A prospective survey of 1338 patients evaluated the effectiveness of IV PCA, continuous femoral analgesia, or continuous epidural analgesia after THR (Table 2B). Postoperative analgesia during the 48-h trial period was effective in all three groups, but both continuous femoral analgesia and continuous epidural analgesia had significant morphine-sparing effects, with only 8% of these patients requiring any opioid. Continuous femoral analgesia was associated with a significantly less frequent incidence of nausea, vomiting, pruritus, and sedation versus IV PCA, and with a significantly less frequent incidence of urinary retention and arterial hypotension versus continuous epidural analgesia. There was a 0.4% incidence of complications with the use of continuous femoral analgesia.

Reported success rates of placing a catheter via the femoral nerve sheath range from 80% to 100% with most studies using a peripheral-nerve stimulator (25–30). Despite documented benefits of femoral sheath analgesia, the extent that the lumbar plexus is blocked via this approach remains uncertain. In most clinical trials, the catheter was typically inserted 10–15 cm into the femoral sheath to maximize cephalad proximity to the lumbar plexus (25–29), but only 40%–90% of patients reported complete lumbar plexus block after 24–48 h of continuous analgesia (29,31). Thus, it is unclear where femoral catheters travel with increased insertion depth, and the optimal depth is unknown. Finally, the required extent of blockade of the lumbar plexus for effective analgesia is unknown. Magnetic resonance imaging of successful single-injection "3-in-1" block showed primarily lateral, medial, and caudal spread of 30 mL of solution without evidence of cephalad spread to the lumbar plexus, yet provided satisfactory analgesia (32).

Fascia Iliaca Approach

The fascia iliaca compartment (FIC) block is a modification of the femoral nerve block approach and may share similar indications to femoral analgesia (34). A prospective, randomized trial compared continuous FIC analgesia with 0.2% bupivacaine at 10 mL/h to placebo after total knee replacement (Table 2C), and was associated with significantly less morphine consumption and improved range of motion of the knee during the immediate postoperative (24 h) period (35). Case series and prospective trials reported a 95%–100% success in placement of FIC catheters (35–37). The anatomy and technique are described in Figure 2. A prospective randomized study observed 73% of patients with complete block of the lumbar plexus, and computed tomography evaluation revealed that only 40% of catheters were "ideally located" (superior to the upper third of the sacroiliac joint in the psoas sheath). These incidences of incomplete lumbar plexus block are similar to the femoral nerve approach and suggest no obvious superiority for the FIC approach compared with the femoral nerve approach (35).

Complications from either the femoral nerve or FIC technique are few. A prospective observational study followed 208 patients for incidence of infectious, vascular, and neurologic complications after placement of a continuous femoral nerve catheter via either the femoral nerve sheath approach or the FIC approach (33). The catheters were removed after 48 h and cultured. Although there was a frequent incidence of catheter colonization (57%), only 3 patients presented with fever and bacteremia and they did not require antibiotic therapy. There was only one case of persistent femoral nerve dysesthesia that persisted for 1 yr, and there were no vascular complications noted during the study. There was no difference in the rate of complications between the two approaches.

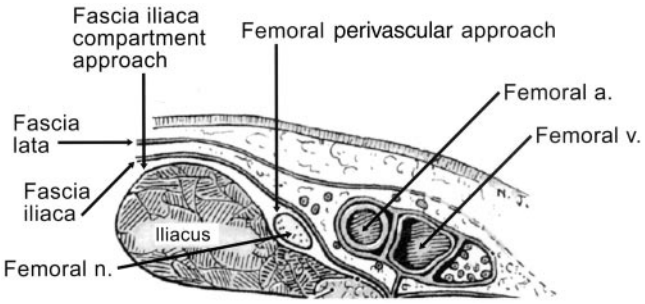

Figure 2. Inguinal structures depicting the anatomic relationships for the fascia iliaca compartment approach compared with the perivascular femoral nerve approach. The patient is placed supine and a cutaneous projection of the inguinal ligament is drawn from the pubic tubercle to the anterior superior iliac spine and trisected. The needle insertion point for the fascia iliaca compartment approach is 1 cm below the junction of the lateral third and middle third of the cutaneous line, approximately 2–3 cm lateral to the femoral artery. The needle is advanced at a 40°–70° angle to the skin until a "loss of resistance" is encountered twice (first through the fascia lata and then the fascia iliaca), indicating entrance into the fascia iliaca compartment. A nerve stimulator technique may also be used. The angle to the skin is then decreased to 30°, and 20 mL of analgesic solution is injected incrementally to expand the compartment. A catheter is advanced 15–20 cm cephalad and then an additional 10 mL of analgesic solution is injected incrementally via the catheter. a = artery, v = vein, n = nerve. [Modified with permission from Agur (72).]

Psoas Compartment Approach

The lumbar plexus may also be blocked by the psoas compartment approach, which provides a more consistent block of the obturator nerve than either the femoral or FIC approach (38). For continuous analgesia, the posterior approach may allow less chance for catheter displacement compared with the anterior approach because the paravertebral muscles securely fix the catheter away from an active joint area (39). However, there is a paucity of large case series or prospective clinical trials investigating the efficacy of continuous psoas compartment analgesia, and there are no data comparing it with the femoral approach (Table 2D). A recent prospective series evaluating the efficacy of continuous psoas compartment analgesia (0.2% ropivacaine at 0.15 mL/kg/h) after THR reported a 97% success rate for catheter placement, with 94% of the patients reporting excellent postoperative analgesia (median VAS 10/100 at rest and 15–25/100 with mobilization) without the need for systemic opioid supplementation (40). One prospective randomized trial compared it with IV PCA with meperidine after repair of hip fractures (Table 2D) and reported better analgesia (approximately 20%–30% lower pain scores over 3 days) and a 45% more frequent incidence of

patient satisfaction ($P < 0.05$) with continuous psoas compartment analgesia (41).

Limited case series and clinical trials reported an 85%–100% success rate of placing catheters by this approach at the L4-5 level; the anatomy is presented in Figure 3 (30,42). With the patient in the lateral decubitus position and operative side up, the needle insertion site is 3 cm caudad and 5 cm lateral to the L4 spinous process. As the needle is advanced, contractions of the paravertebral muscles will be observed, and within 6–8 cm, these contractions disappear and contraction of the quadriceps muscles with a current output of <0.5 mA indicates close proximity of the needle tip to the lumbar plexus. The catheter is then advanced 3–5 cm past the needle orifice (39).

A prospective randomized clinical trial demonstrating superior analgesia with continuous psoas compartment analgesia versus IV PCA reported variable success in block of the lumbar plexus during continuous analgesia with 0.25% bupivacaine (L1 50%, L2 100%, L3 100%, L4 80%, L5 70%, S1 40%). This variability in block of the lumbar plexus with continuous analgesia is consistent with recent cadaveric and computerized axial tomography scan data indicating that the lumbar nerves often lie within the psoas muscle at the L4-5 vertebral level and question the concept of a true psoas compartment (43).

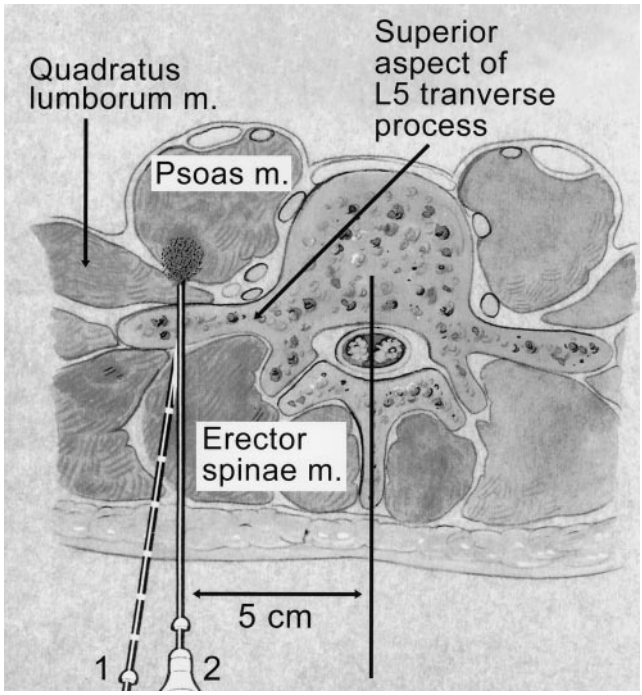

Figure 3. Illustrated cross-section depicting the psoas compartment approach. The patient is placed in the lateral decubitus position with the operative extremity up. The needle insertion point is 3 cm caudal and 5 cm lateral to the L4 spinous process. A 15-cm stimulating needle is advanced perpendicular to the skin and directed slightly midline until the L5 transverse process is encountered. The needle is then redirected slightly cephalad, sliding past the superior aspect of the L5 transverse process and advanced until stimulation of the quadriceps muscle is elicited. A catheter is then advanced through the needle, 3–5 cm past the needle tip into the psoas compartment. m = muscle. [Modified with permission from Brown (71).]

Sciatic Nerve

In a prospective nonrandomized series of 60 patients undergoing various foot surgeries, continuous popliteal sciatic nerve block was compared with data obtained from a retrospective review of 45 patients receiving IV PCA (44). Compared with IV PCA, continuous popliteal block was associated with superior analgesia (approximately 50% lower pain scores). Morphine consumption over 48 h in the IV PCA group averaged 57 mg compared with 1 mg in the popliteal block (with only 8% of these patients requiring any opioids). There was also a significantly less frequent incidence of nausea/vomiting (5% versus 49%), urinary retention (0% versus 18%), and sedation (0% versus 11%) in the continuous popliteal block group. There were no immediate or long-term complications noted in the study group (Table 2E).

The posterior popliteal approach is performed with the patient in the prone position. The skin crease behind the knee serves as the base of the popliteal triangle, and the medial (semimembranosus muscle) and lateral (biceps femoris tendon) margins are identified to complete the popliteal triangle. Anatomic studies revealed that the sciatic nerve divides into the tibial nerve and common peroneal nerve at a mean distance of 61 mm (±27 mm) above the popliteal fossa crease (45). This study indicated that needle insertion 100 mm above the popliteal fossa crease ensures placement of the needle in the vicinity of, or proximal to, the division of the sciatic nerve in 100% of cadaver dissections. A peripheral nerve-stimulating needle is introduced at an angle of 45°–60° to the skin to facilitate catheter insertion approximately 3–5 cm past the needle tip. The posterior placement of the catheter at an active joint seems potentially troublesome for catheter durability and function, and one study reported a 25% incidence of either broken or kinked catheters (44).

The lateral approach to the popliteal block may offer an advantage for placement of a continuous catheter. With the patient supine and the operative leg extended at the knee joint, a stimulating needle is inserted in a horizontal plane 7 cm cephalad to the most prominent point of the lateral femoral condyle in the groove between the biceps femoris and vastus lateralis muscle (46). Potential advantages are supine patient position and more secure placement of the catheter between the vastus lateralis and biceps femoris away from the mobile knee joint. Although this approach

may be promising, there have been no clinical trials to determine whether the lateral approach is optimal for continuous sciatic analgesia. More proximal approaches for continuous sciatic analgesia have also been described. Case series using continuous sciatic perineural infusions via a parasacral approach (47,48), the classic posterior approach of Labat (30), and a novel posterior subgluteal (Fig. 4) approach (49) reported effective postoperative analgesia in patients undergoing surgical procedures of the lower leg and foot. Further clinical trials are needed to compare the efficacy and superiority (ease of initial insertion and technical problems of maintaining the catheter) of these different approaches for continuous sciatic perineural analgesia.

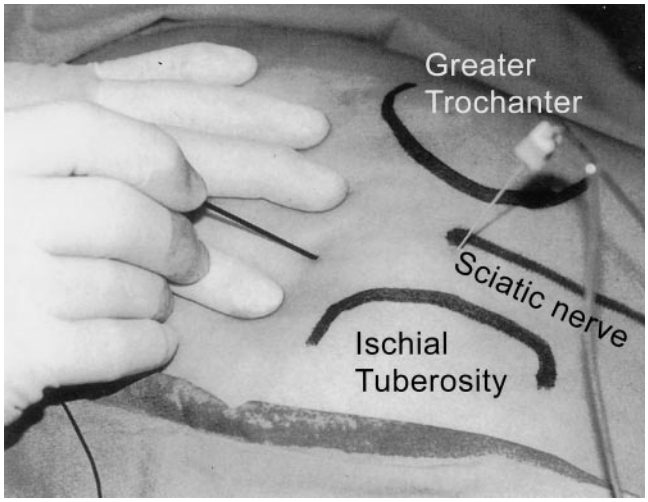

Figure 4. Modified subgluteal approach to continuous sciatic perineural analgesia (48). The patient is placed in the lateral decubitus position with the operative extremity up and the upper thigh flexed approximately 45°. The greater trochanter and ischial tuberosity are marked and a cutaneous projection of the sciatic nerve ("sciatic line") is drawn from the apex of the popliteal fossa to midway between the two bony landmarks. A stimulating needle is inserted vertically to the skin just medial to the upper end of the sciatic line and advanced until the desired sciatic motor response is elicited. A second insulated Touhy needle is inserted through the skin approximately 5 cm proximal to the first stimulating needle and angled to aim at its distal tip. The electrical connection is transferred to the second needle and advanced until the desired sciatic motor response is elicited. A specially modified stimulating catheter is then advanced 5–10 cm past the needle tip with electrical stimulation via the catheter to confirm proper catheter placement along the sciatic nerve. Note that the trajectory of the needle placement facilitates catheter placement along the long axis of the sciatic nerve.

Drugs for Continuous Perineural Analgesia

Local Anesthetics

There are insufficient data to determine an optimal analgesic solution for the various types of continuous plexus analgesia. Lidocaine, bupivacaine, and ropivacaine have all been used as the primary local anesthetic for continuous plexus analgesia, with bupivacaine and ropivacaine being the most commonly used drugs. The use of bupivacaine (0.1%–0.25%) typically does not result in toxic blood levels when used for postoperative analgesia for 24–72 h in current regimens (Tables 1 and 2). Typical venous total bupivacaine levels during continuous brachial plexus analgesia are 0.5–1.0 μg/mL (2) and during continuous lumbar plexus analgesia are 0.5–1.8 μg/mL (35,50), whereas levels >2 μg/mL are considered toxic.

The use of ropivacaine may provide several advantages over bupivacaine and levobupivacaine for providing continuous plexus analgesia. Studies suggest that ropivacaine produces less motor block compared with bupivacaine, which may result in improved participation in postoperative rehabilitation (51). A comparison of continuous interscalene analgesia with ropivacaine 0.2% versus bupivacaine 0.15% observed equivalent analgesia in both groups, but significantly less motor block with ropivacaine (51). The potential for systemic toxicity from a large initial loading dose may be a clinical area in which the decreased cardiotoxicity of ropivacaine may provide an advantage over both bupivacaine and levobupivacaine. Animal studies comparing ropivacaine, levobupivacaine, and bupivacaine suggest cardiac toxicity ratios of approximately 1:1.7:3.0 (52,53). Perhaps more importantly, the ability to administer a smaller initial loading dose of any local anesthetic for only postoperative analgesia may lessen potential toxicities, but has not been formally investigated.

Adjuvants

The addition of analgesic adjuncts to local anesthetic solutions potentially offers the ability to spare local anesthetic, reduce motor and sensory blocks, and improve the quality of analgesia. The adjuncts most frequently used include epinephrine, clonidine, and opioids in various combinations (Tables 1 and 2). There are no studies that have systematically examined the optimal analgesic combinations for continuous analgesia, and we will briefly review data from single-injection peripheral nerve blocks.

Epinephrine. The addition of epinephrine increases the duration of single-injection peripheral nerve blocks by 100%–200% and also decreases blood levels by 20%–30% via vasoconstriction (54) with the exception of ropivacaine (55). Epinephrine has the potential for direct and ischemic neurotoxicity, because clinically relevant concentrations of epinephrine (2.5–10 μg/mL) produce concentration-dependent reductions in nerve flow by 20%–35% in laboratory studies (56).

Clonidine. Clonidine acts peripherally by blocking conduction through A-α fibers, C fibers, and by potentiating conduction block of local anesthetics (57). The analgesic effects of clonidine are dose-dependent

with the smallest effective dose of 0.1 μg/kg added to local anesthetic providing a 50%–100% increase in the duration of analgesia after single-injection peripheral nerve block (58). The addition of small doses of clonidine (1 μg/mL added to 0.125% bupivacaine) for continuous infusions (Table 2) is not neurotoxic and does not increase sedation or hypotension (25,26).

Opioids. Peripheral opioid receptors are located primarily on end terminals of primary afferent neurons (59) and their expression is enhanced in the presence of inflammation (60). Because neither peripheral opioid receptors nor inflammation is typically located at the sites for continuous plexus analgesia, this would seem to be an unlikely mechanism for adjunctive analgesia. In a systematic review, it was concluded that the benefit from the addition of opioid to single-injection peripheral nerve blocks was unsubstantiated (61). However, in the majority of these studies, large doses of large-concentration local anesthetic were used for intraoperative anesthesia (e.g., 0.5% bupivacaine). In a recent study, it was observed that the addition of 100 μg of fentanyl to 40 mL 0.25% bupivacaine for axillary block provided a 45% increase in the duration of postoperative analgesia (62). Perhaps the use of smaller doses and lesser concentrations of local anesthetic suitable for postoperative analgesia may unmask augmentative effects of opioids.

Delivery of Continuous Plexus Analgesia

Continuous plexus analgesia may be provided with boluses, continuous infusion, PCA, or a combination of background infusion and PCA boluses. There is a paucity of clinical trials to definitively determine optimal means of delivery for each application. Preliminary evidence indicates that patient-controlled infusions (either background infusion plus patient-controlled boluses or patient-controlled boluses only) may be advantageous for delivery of continuous plexus analgesia. The use of these methods allows comparable analgesia and improved patient satisfaction, but with decreased consumption of local anesthetics (~30%) compared with continuous infusions without patient-controlled techniques during interscalene analgesia (63) and femoral analgesia (29,31).

Contraindications

Common contraindications include infection at the block site and allergy to analgesics. Peripheral nerve blocks have generally been considered safe to perform in the anticoagulated patient. However, one should be aware of the potential for perineural hematomas in these patients with development of compressive neuropathy. One case report described psoas hematoma with lumbar plexopathy after psoas compartment block in a patient receiving enoxaparin (64). Placement of peripheral nerve catheters can be uncomfortable for the patient, and the clinician may be tempted to place the continuous catheter during a central neuraxial or general anesthesia to improve patient comfort (9). The use of a nerve stimulator does not guarantee avoidance of neurologic injury (65), and a recent clinical study indicated that a noninsulated needle position causing sensory paresthesia in axillary block produced a motor response at 0.5 mA in <77% of cases, pointing to the inconsistency of elicited motor responses (66). This interesting finding suggests that one could traumatize a more proximally blocked nerve without evidence of motor stimulation (67).

Summary and Future Directions

There is evidence for superior analgesia and a less frequent incidence of opioid-related side effects of continuous perineural infusions compared with IV PCA for open shoulder procedures and total knee replacement, but there are insufficient data to provide firm recommendations for virtually all aspects of continuous plexus analgesia. Future work will need to determine which surgical procedures gain benefit from continuous perineural analgesia, what are optimal analgesic solutions for each application, and optimal means of delivery for each application. Given the increased effort associated with continuous perineural techniques (specialized equipment for placement of catheters and delivery of infusions, drug costs, and billing for postoperative pain management), further trials may need to show advantages beyond improved analgesia and decreased side effects (such as decreased hospital length of stay or total length of rehabilitation) to justify their continued use.

A particular area of future importance will be the suitability of continuous plexus analgesia for outpatients (68). In a recent series, 228 patients undergoing upper and lower extremity outpatient procedures were treated with continuous peripheral nerve block catheters for 24 h within an ambulatory surgery center (30). In this group, 90% of catheters were functional after 24 h, and no patients reported complications at 1 and 7 days follow-up. However, 59%–80% of patients still required oral or IV opioid during the first 24 h, and whether this technique is effective for ambulatory patients remains to be determined.

A final issue will be whether advancing technology renders these techniques obsolete. Long-acting local anesthetics are being investigated for peripheral nerve blocks of 2–7 days' duration (69,70). We speculate that placement and management of a continuous catheter may be more cumbersome than a single injection of a controlled-release analgesic, and commercial introduction of such preparations may obviate continuous catheter techniques.

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