

Peripheral Nerve Blocks in Non-Operative Settings: A Review of the Evidence and Technical Commentary

De QH Tran^{1*}, Francisca Bernucci², Worakamol Tiayprasertkul¹ and Roderick J Finlayson¹

¹Montreal General Hospital, Department of Anesthesia, McGill University, Montreal, Quebec, Canada

²Hospital de Carabineros, Department of Anesthesia, Santiago, Chile

Abstract

This narrative review summarizes and comments the evidence derived from randomized controlled trials pertaining to the efficacy of peripheral nerve blocks in non-operative settings.

The literature search was conducted using the Medline (1966-present), Embase (1980-present), Web of Science (1900-present) and Sciverse Scopus (1996-present) databases. The following search terms were used: ("peripheral nerve block" OR "brachial plexus block" OR "interscalene block" OR "supraclavicular block" OR "infraclavicular block" OR "axillary block" OR "humeral canal block" OR "lumbosacral plexus block" OR "lumbar plexus block" OR "femoral nerve block" OR "lateral femoral cutaneous block" OR "obturator nerve block" OR "sciatic nerve block") AND ("fractures" OR "Emergency Room" OR "Emergency Department" OR "ambulance" OR "prehospital" OR "Intensive Care Unit" OR "Intensive Care"). Only randomized controlled trials were retained for analysis.

Despite methodological shortcomings, the available evidence suggests that peripheral nerve blocks can provide pain control for upper and lower limb trauma in non-operative settings. For instance, brachial plexus blocks offer a useful alternative to procedural sedation for fracture manipulation in the Emergency Department. Lumbar plexus, 3-in-1 and femoral blocks can provide analgesia for patients with hip fractures. Femoral blocks also result in more comfortable ambulance transfers to the hospital for patients suffering from hip and knee trauma. Finally, in very elderly subjects, fascia iliaca blocks can decrease the incidence and duration of perioperative delirium.

Published reports of randomized trials provide evidence to formulate limited recommendations regarding the use of peripheral nerve blocks in non-operative settings. Further well-designed studies are warranted.

Keywords: Peripheral nerve; Nonsteroidal anti-inflammatory drugs; Paracetamol

Introduction

Increasingly, peripheral nerve blocks are being carried out in non-operative settings [1-13]. For instance, Emergency department (ED) physicians and orthopedic surgeons often perform blocks to facilitate fracture manipulation and to provide analgesia for fracture-related pain [7-8]. Expectedly this has fostered heated debates between and within professional societies. In the near future, important questions will demand answers: should peripheral nerve blocks be performed by anesthesiologists only or could they be carried out by other physicians as well? What is the minimum training required to ensure proficiency and safety? Which governing body will legislate technical competency and implement quality insurance? If blocks were the sole domain of Anesthesiology departments, how best to reorganize Acute Pain Services to efficiently meet the growing needs of EDs and Intensive Care units?

Answers to these complex questions require first and foremost proof that nerve blocks improve patient care in non-operative settings. Previous review articles have attempted to succinctly summarize the available information [1-13]. Unfortunately, because of the various backgrounds and experience levels of the operators, the techniques and equipment employed varied substantially. Although it is paramount to ensure that the methods used do not deviate significantly from accepted technical standards, this potential shortcoming has been overlooked by all review articles so far [1-13]. Thus we undertook a systematic review of the literature: our goal was to analyze all level 1 evidence (randomized controlled trials) pertaining to the efficacy of peripheral nerve blocks in non-operative settings. Moreover we sought to compare the block techniques used with those advocated by the best evidence available.

Methods

The literature search for this review article was conducted during the first week of June 2013 using the Medline (1966 to present), Embase (1980 to present), Web of Science (1900 to present) and Sciverse Scopus (1996 to present) databases. The following search terms were used: ("peripheral nerve block" OR "nerve block" OR "peripheral block" OR "block" OR "regional block" OR "regional anesthesia" OR "local anesthesia" OR "local anesthetic" OR "brachial plexus nerve block" OR "brachial plexus block" OR "interscalene block" OR "supraclavicular block" OR "infraclavicular block" OR "axillary block" OR "humeral canal block" OR "brachial canal block" OR "midhumeral block" OR "median nerve block" OR "radial nerve block" OR "ulnar nerve block" OR "musculocutaneous nerve block" OR "lumbosacral plexus block" OR "lumbar plexus block" OR "psoas block" OR "psoas compartment block" OR "psoas sheath block" OR "femoral nerve block" OR "lateral femoral cutaneous block" OR "obturator nerve block" OR "sciatic nerve block" OR "infragluteal block" OR "subgluteal block" OR "popliteal block" OR "ankle block" OR "transversus abdominis plane block" OR "ilioinguinal nerve block" OR "iliohypogastric nerve block" OR

***Corresponding author:** De QH Tran, MD, FRCPC, Montreal General Hospital, Department of Anesthesia, 1650 Ave Cedar, D10-144, Montreal, Quebec, Canada, Tel: (514) 934-1934; Fax: (514) 934-4289; E-mail: de_tran@hotmail.com

Received February 24, 2014; **Accepted** April 01, 2014; **Published** April 03, 2014

Citation: Tran DQH, Bernucci F, Tiayprasertkul W, Finlayson RJ (2014) Peripheral Nerve Blocks in Non-Operative Settings: A Review of the Evidence and Technical Commentary. J Anesth Clin Res 5: 398. doi:10.4172/2155-6148.1000398

Copyright: © 2014 Tran DQH, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

“thoracic paravertebral block” OR “intercostal nerve block”) AND (“fractures” OR “Emergency Room” OR “Emergency Department” OR “ambulance” OR “prehospital” OR “Intensive Care Unit” OR “Intensive Care”).

From this initial search, only randomized controlled trials (RCTs) conducted in human subjects, published in the English language and comparing peripheral nerve blocks to a control group (conventional treatment) were retained for analysis. No RCTs were excluded based on factors such as sample size justification, statistical power, blinding, definition of intervention allocation or primary and secondary outcomes. However non-randomized studies, case reports and cohort studies were eliminated, as were RCTs published in abstract or correspondence form. In addition, trials examining hematoma block, intravenous regional block (i.e. Bier's block), intraarticular infiltration, neuraxial blocks as well as those comparing various concentrations of local anesthetic or various permutations of a given block (i.e. digital block) were excluded. A secondary search for additional material was also undertaken by examining the reference lists of the selected articles as well as our personal files.

Results

Our search criteria yielded 14 RCTs pertaining to peripheral nerve blocks in non-operative settings (Tables 1 and 2). Of these studies (average sample size = 64.9 subjects), only 9 (64.2%) and 4 (28.6%) trials provided sample size justification and blinded assessment, respectively. Most RCTs (85.7%) defined a clear primary endpoint: the latter consisted of pain, incidence of delirium, cumulative opioid consumption or length of stay in the ED. For the control group, the analgesic regimen consisted of intravenous opioids, metamizole, paracetamol or nonsteroidal anti-inflammatory drugs (NSAIDs). As for the treatment group, the peripheral nerve blocks were carried out by ED physicians or orthopedic surgeons in all but 3 trials.

Discussion

Upper extremity injury

Despite the widespread use of peripheral nerve blocks to provide analgesia for upper extremity injury in the ED, to date, only 2 RCTs (combined n = 83) have compared nerve blocks to conventional treatment [14-15]. In the first trial, Kriwanek et al. [14] randomized 41 pediatric patients (8 years or older) with forearm fractures to deep

sedation or axillary brachial plexus block (AXB) for fracture reduction. In the deep sedation group, the authors administered midazolam (0.1 mg/kg, up to a maximum of 2 mg) and ketamine (initial bolus: 1 mg/kg, followed by additional doses titrated to patient comfort). For AXB, the authors employed a transarterial technique and injected 0.7 mg/kg (up to 40 mL) of adrenalized lidocaine 1%. During fracture manipulation, a pediatric nurse evaluated the patient's pain and distress according to the Children's Hospital of Eastern Ontario Pain Scale (CHEOPS). Kriwanek et al. [14] found no differences in CHEOPS scores. Furthermore, orthopedic and patient satisfaction was also similar between the 2 groups. Interestingly, in the AXB group, 2 patients displayed residual motor function with presence of pain during sensory testing and 2 subjects required supplemental analgesia during fracture manipulation. In 2011, Blaivas et al. [15] randomized 42 adult patients with shoulder dislocation to procedural sedation (etomidate) or interscalene brachial plexus block (ISB). For ISB, the authors employed an ultrasound (US)-guided technique and deposited 20-30 mL of adrenalized lidocaine (concentration unspecified) around the roots of the brachial plexus. Blaivas et al. [15] observed a shorter stay in the ED with ISB (100.3 ± 28.2 vs. 177.3 ± 37.9 minutes; $P < 0.0001$). However post reduction pain levels and patient satisfaction were similar between the 2 groups. Despite the high local anesthetic (LA) volume, the authors observed a 0%-incidence of Horner's syndrome with ISB.

In summary, the available literature suggests that, for fracture manipulation in the ED, brachial plexus blocks provide a useful alternative to conventional procedural sedation.

Technical commentary

Axillary rachial plexus block: An enviable track record for safety explains the historical popularity of AXB. Traditional techniques such as fascial clicks, transarterial injection and elicitation of paresthesia (EP) usually result in low success rates (70-80%) [16]. Prior to the advent of US, peripheral nerve stimulation (PNS) constituted the most reliable adjunct. With PNS, the musculocutaneous, median, radial and ulnar nerves can be independently located and selectively targeted with LA. Extensive work by Sia et al. [17-19] suggests that, for PNS-guided AXB, a triple-stimulation technique offers the best combination of efficacy and efficiency. The introduction of US into clinical practice has revolutionized the performance of AXBs. Four RCTs have compared PNS- and US-guided AXB [20-23]. In the largest trial to date (n=188), Chan et al. [20] performed a 3-injection AXB (with injections around

Authors (year)	Setting	Groups	N	Sample Size Justification	Blinded Assessment	Main Outcome	Main Findings	Technical Remarks
Blaivas et al. [15] (2011)	ED Shoulder dislocation	ISB vs. procedural sedation (etomidate) for shoulder reduction	42	N	N	Length of stay in ED	ISB: shorter length of stay (100.3 ± 28.2 vs. 177.3 ± 37.9 minutes; $p < 0.0001$). Similar post reduction pain and patient satisfaction.	ISB performed by ED physicians. 20-30 mL of lidocaine (unknown concentration). 0% Horner's syndrome in ISB group.
Kriwanek et al [14] (2006)	ED Children with forearm fractures	AXB vs. deep sedation (midazolam/ketamine) for fracture reduction	41	Y	N	Procedural pain and distress during fracture reduction (assessed by a pediatric nurse)	No differences in procedural pain/ distress. No differences in orthopedic/ patient satisfaction.	Transarterial technique used for AXB. AXB performed by ED physicians. AXB: 20% failure rate (patients had residual pain sensation during sensory testing or required supplemental analgesia during fracture manipulation).

AXB = axillary brachial plexus block; ED = Emergency Department; ISB = interscalene brachial plexus block; N = no; Y = yes.

Table 1: Summary of randomized controlled trials pertaining to upper extremity trauma.

Authors (year)	Setting	Groups	N	Sample Size Justification	Blinded Assessment	Main Outcome	Main Findings	Technical Remarks
Chudinov et al. [34] (1999)	Ward Femoral neck fracture	Intermittent LA boluses through a LP catheter (1-2 mg/kg of adrenalized bupivacaine 0.25% q 8 hours) vs. IM meperidine (1mg/kg q 5 hours) and diclofenac for breakthrough pain (1 mg/kg)	40	N	N	?	LP catheters: lower pain scores at 8 and 16 hours during the 48h-preoperative period.	LOR used to identify the space between the quadratus lumborum and psoas muscles. Blocks performed by anesthesiologists.
Luger et al. [37] (2013)	ER Hip fracture in patients > 80 years	Continuous 3-in-1 block (6 ml/h of bupivacaine 0.125%) vs. IV piritramide (0.05 mg/kg) and additional piritramide (3 mg SC) or paracetamol (1 g IV) for breakthrough pain	20	Y	Y	Pain scores	Lower dynamic pain scores and paracetamol consumption (0.1 ± 0.32 vs. 1.7 ± 1.4 mg/d; $p < 0.05$) with 3-in-1 block in the preoperative period. Similar piritramide consumption in the preoperative period.	3-in-1 block: US technique. Success of 3-in-block assessed by testing sensory blockade of femoral, LFC and obturator nerves. 86.7% success rate for 3-in-1 block at 1 hour. Blocks performed by anesthesiologists.
Graham et al. [36] (2008)	ED/ ward Femoral neck fracture	3-in-1 block vs. IV morphine (0.1 mg/kg)	33	N	N	Pain scores	3-in-1 block: lower pain score at 30 minutes ($p = 0.046$). No intergroup differences in pain scores at other measurement intervals during 12-hour assessment period. No intergroup differences in 24-hour opioid consumption	3-in-1 block: PNS technique. Minimal stimulatory threshold not specified. Blocks performed by ED physicians or trainees.
Fletcher et al. [35] (2003)	ED Femoral neck fracture	3-in-1 block vs. IV morphine (5-10 mg hourly)	50	Y	Y	Pain scores	3-in-1 block: quicker time to lowest pain score (2.88 vs 5.81 hours) and lower hourly morphine consumption (0.49 mg/h vs. 1.17 mg/h) during 24-hour study period.	3-in-1 block: EP technique. Blocks performed by ED physicians.
Monzon et al. [38] (2010)	ED Hip fracture	FIB vs. IV NSAIDs	154	Y	Y	Pain scores	NSAIDs: lower pain scores at 15 minutes (6.24 ± 0.17 vs. 2.9 ± 0.16 ; $p < 0.001$). No differences in pain at 2 and 8 hours.	FIB: fascial click technique performed with 21-gauge "intramuscular injection" needle. Performed by ED physicians.
Mouzopoulos et al. [39] (2009)	Ward Hip fracture	FIB: bupivacaine vs. NS	207	N	N	Incidence of perioperative delirium in moderate and high risk patients	FIB: lower incidence of (10.78 vs. 23.8%) and shorter duration (5.22 ± 4.28 vs. 10.97 ± 7.16 days) of delirium. No differences in pain scores.	Fascial click technique performed with a sharp 24-gauge needle. FIB repeated every 24 hours. Performed by orthopedic surgeons.
Foss et al. [40] (2007)	ED Suspected hip fracture (prior to X ray exam)	FIB vs. IM morphine (0.1 mg/kg)	48	Y	Y	Pain scores	FIB: superior analgesia at rest at 60 and 180 minutes (both $p \leq 0.03$). FIB: superior analgesia with 15 degree leg lift at 180 minutes ($p = 0.04$), decreased breakthrough IV morphine consumption (0 vs 6 mg; $p < 0.01$). No differences in nausea/vomiting, sedation ($p = 0.05$), oxygen saturation ($p = 0.08$) and hemodynamics.	Fascial click technique for FIB with a blunt 24-gauge needle. FIB: 67% success at 30 minutes (absence of cold sensation on anterior and lateral thigh). Performed by Anesthesiology residents.

Wathen et al. [41] (2006)	ED Children with femoral fracture (proximal, middle or distal)	FIB vs. IV morphine	55	Y	N	Pain scores	FIB: lower pain scores during the 6 hours of the study, longer analgesia and less breakthrough analgesic requirement, and higher satisfaction from the medical staff.	FIB performed with the fascial click technique using an 1-inch short beveled needle. Blocks performed by ED physicians (with instruction by an anesthesiologist).
Barker et al. [45] (2008)	Accident site Knee trauma	Femoral block vs. IV metamizole (1 g)	52	Y	N	Pain scores	Femoral block: decreased pain, anxiety and signs of vasoconstriction during ambulance transport to hospital.	Femoral block: PNS-guided technique (minimal stimulatory threshold = 0.3-0.4 mA; 0.1 ms). Performed by ED physicians.
Mutty et al. [43] (2007)	ED Diaphyseal and distal femoral fracture	Femoral block vs. IV hydromorphone	54	Y	N	Pain scores	Femoral block: lower pain scores at all measurement intervals (last assessment = 90 minutes after block).	Femoral block: PNS technique but minimal stimulatory threshold not specified. Performed by orthopedic residents.
Schiferer et al. [44] (2007)	Accident site hip dislocation/ fracture, femoral fracture, patellar tendon rupture	Femoral block vs. IV metamizole (1 g)	62	Y	N	Pain scores	Femoral block: decreased pain, anxiety and heart rate between the on-site and transport values (both $p < 0.001$).	Femoral block: PNS-guided technique (minimal stimulatory threshold = 0.3-0.4 mA; 0.1 ms). Performed by ED physicians.
Haddad and Williams [42] (1995)	Ward Extracapsular femoral neck fracture	Femoral block vs. PO co-dydramol/ IM pethidine/ IM diclofenac	50	N	N	?	Femoral block: decreased pain at 15 minutes and 2 as well as lower requirements of IM opioids.	Femoral nerve located with double click technique and EP. Block performed by orthopedic residents.

ED = Emergency Department; EP = elicitation of paresthesia; FIB = fascia iliaca block; IM = intramuscular; IV = intravenous; LA = local anesthetic; LOR = loss of resistance; LP = lumbar plexus; N = no; NSAIDs = non-steroidal anti-inflammatory drugs; PNS = peripheral nerve stimulation; PO = per os; US = ultrasonography; Y = yes.

Table 2: Summary of randomized controlled trials pertaining to lower extremity trauma.

the median, radial and ulnar nerves) and randomized the adjunctive technique to PNS, US or combined PNS-US. These authors found that patients in the PNS group consistently displayed the lowest success rate (62.9 vs 80.7-82.8%; $P=0.03$). Subjects in the US and US-PNS groups exhibited similar success rates and incidences of surgical anesthesia (92-95%). However the addition of PNS to US resulted in a longer performance time (12.4 ± 4.8 vs 9.3 ± 4 minutes; $P=0.01$). The 3 other trials found no difference in success rates between PNS and US [21-23]. However both Liu et al. [21] and Imasogie et al. [22] observed a significantly longer performance time with PNS. Furthermore Liu et al. [21] also reported a higher incidence of side effects (paresthesia, vascular puncture, hematoma) with PNS (20 vs 0%; $P=0.03$).

In summary, AXB constitutes a valuable tool to provide analgesia for patients with upper extremity injury. However, in light of the available evidence, preference should be given to US techniques. If an US machine is unavailable, the operator should consider employing a triple-stimulation method. Older techniques should be used sparingly because of their high failure rate. For instance, transarterial injections can result in incomplete brachial plexus blockade in 20-30% cases. Coincidentally, in Kriwanek et al.'s Study [14], 2 patients displayed residual motor function and 2 subjects required supplemental analgesia during fracture manipulation. Thus one can speculate that the AXB would have been more efficacious had these authors selected PNS or US. Finally, AXB requires the patient to abduct the shoulder and flex the elbow. This may result in considerable discomfort in distal humerus/elbow trauma. In these subjects, supraclavicular (SCB) and infraclavicular (ICB) brachial plexus blocks constitute valuable alternatives [24]. However the efficacy/efficiency of SCB and ICB needs

to be formally compared to conventional treatment in a non-operative context.

Interscalene brachial plexus block: The ISB is commonly used to anesthetize the shoulder and proximal humerus. Identification of the brachial plexus in the interscalene groove has been traditionally achieved with EP or PNS [16]. Recently, US have contributed to the surge in popularity of ISB. Compared to PNS, Kapral et al. [25] found that US improved the rate of surgical anesthesia (98.8 vs 91.3%; $P<0.01$) as well as the onset (10 vs 22 minutes; $p<0.05$) and offset times (899 vs 679 minutes; $P<0.05$). Using ropivacaine 0.5%, McNaught et al. [26] reported that, compared to PNS, US decreased the minimal effective volume for analgesia in 50% of patients (MEV_{50}) from 5.4 to 0.9 mL ($P=0.034$). In contrast, after randomizing 219 patients to PNS or US, Liu et al. [27] observed no differences in performance time, surgical anesthesia and patient satisfaction. However patients in the US group required fewer needle passes (1 vs 3; $P<0.001$). Thus, according to the available evidence, it is not clear if US increases the success rate for ISB compared to PNS. However, US seem to provide better efficiency (fewer needle passes, decreased onset time); moreover it allows a decrease in LA volume.

In 2008, Riazi et al. [28] set out to investigate the optimal LA volume for ISB. Using a combination of PNS and US, these authors compared injectates of 5 and 20 mL of ropivacaine 0.5%. There were no differences in pain scores, sleep quality and postoperative morphine requirements up to 24 hours after surgery. However, patients receiving 5 mL presented a lower rate of diaphragmatic paralysis (45 vs 100%), fewer side effects (Horner's syndrome, hoarseness, respiratory distress) as well as smaller reductions in forced expiratory volume, forced vital

capacity, peak expiratory flow and postoperative oxygen saturation (all $P < 0.05$) [28]. In contrast, Sinha et al. [29] compared volumes of 10 and 20 mL of adrenalized 0.5% ropivacaine and found no differences in the incidence of diaphragmatic paralysis (93%) [29].

In summary, ISB constitutes a valuable tool to provide analgesia for patients with shoulder injury. In light of the improved efficiency, preference should be given to US techniques. If an US machine is unavailable, the operator should consider employing a PNS method. Thus, in their 2011 RCT, Blaivas et al. [15] selected an appropriate technique for their ISB group. However the non-blinded assessment and patient follow-up represents a confounding variable. For instance, the authors noted a 0% incidence of Horner's syndrome despite using 20-30 mL of lidocaine. In the literature, complete absence of Horner's syndrome has been only been reported with very low volumes (5 mL) [28]. The authors' potential bias favoring ISB could have led them to under record the occurrence of adverse events and to discharge their patients more promptly from the ED. In fact, Blaivas et al. [15] opined that "it might be helpful to explore safe alternatives such as regional anesthesia to decrease the length of stay in the ED" and that "complications such as respiratory depression and aspiration can potentially be avoided with US-guided regional anesthesia". However one should not forget that, with high LA volumes (34-52 mL), ipsilateral phrenic paralysis is inevitable [30]. Moreover, as demonstrated by Riazi et al. [28], even LA volumes as low as 5 mL can block the phrenic nerve in 45% of subjects. Thus ISB should be viewed as an additional analgesic tool to efficiently manage patients with shoulder trauma and not a modality to expedite discharge by circumventing post-procedural patient monitoring. Moreover, due to its inherent risk of phrenic paralysis, ISB should be used with caution in patients with preexisting pulmonary compromise. In these subjects, combined infraclavicular-suprascapular [31] or axillary-suprascapular [32,33] blocks could be employed to anesthetize the shoulder. However their efficacy and efficiency require further validation in non-operative settings.

Lower extremity trauma

Except for 1 trial that tackled knee trauma, RCTs investigating the use of peripheral nerve blocks in lower extremity injury have focused exclusively on the hip joint and femur. Four nerve blocks have been studied so far: lumbar plexus, 3-in-1, fascia iliaca and femoral blocks.

Lumbar plexus block (LPB): In 1999, Chudinov et al. [34] randomized 40 patients with femoral neck fractures to intermittent LA boluses administered through a LPB catheter (1-2 mg/kg of adrenalized bupivacaine 0.25% every 8 hours) or intramuscular meperidine (1 mg/kg every 5 hours) combined with diclofenac (1 mg/kg for breakthrough pain). In the experimental group, the psoas compartment was identified with loss of resistance. Chudinov et al. [34] reported that patients randomized to LPB achieved lower pain scores at 8 and 16 hours during the 48-hour preoperative period (both $P < 0.05$).

3-in-1 Block: Three RCTs have investigated the role of 3-in-1 blocks in the setting of hip and femoral fractures [35-37]. In 2 trials (combined $n=83$) comparing single-injection 3-in-1 blocks to intravenous morphine, patients randomized to the former experienced a quicker onset of analgesia [35] and lower pain scores at 30 minutes [36]. While one study observed decreased hourly consumptions of morphine (0.49 mg/h vs. 1.17 mg/h) with 3-in-1 blocks [35], the other found no differences in 24 hour-cumulative morphine consumption or pain levels after 30 minutes [36]. In 2013, Luger et al. [37] randomized 20 very elderly patients (> 80 years) with hip fractures to an US-guided continuous 3-in-1 block or intravenous piritramide (0.05 mg/kg). The

perineural catheters were bolused with 30 mL of bupivacaine 0.25% and infused with 6 mL/h of bupivacaine 0.125%. In the preoperative period, Luger et al. [37] found lower dynamic pain scores (all $P < 0.05$) and daily paracetamol consumption (0.1 ± 0.32 vs. 1.7 ± 1.4 mg/d; $P < 0.05$) with 3-in-1 blocks. However there were no intergroup differences in pain scores at rest or daily piritramide requirements (0.75-3.4 mg/d). Thus, compared to conventional treatment, 3-in-1 blocks seem to provide better initial pain management (especially with movement) as well as a shorter onset of analgesia. However cumulative opioid consumption may not be decreased.

Fascia Iliaca Block (FIB): Because of their ease of performance, FIBs have been extensively studied in non-operative settings (4 RCTs; combined $n=464$) [38-41]. In adult patients with hip fractures, 3 trials have compared FIB to parenteral analgesics (opioids or NSAIDs) with mixed results. Monzon et al. [38] observed that, compared to intravenous NSAIDs, a single-injection FIB (0.3 mL/kg of bupivacaine 0.25%) resulted in a slower analgesic onset: at 15 minutes, the FIB group displayed higher pain levels (6.24 ± 0.17 vs. 2.9 ± 0.16 ; $P < 0.001$). However, subsequent pain scores were similar at 2 and 8 hours. Similarly, Mouzopoulos et al. [39] found no differences in pain scores when 207 patients were randomized to daily FIB with bupivacaine or normal saline. However the authors did notice a decrease in the incidence (10.8 vs. 23.8%) and duration (5.22 ± 4.28 vs. 10.97 ± 7.16 days) of delirium in the treatment group. In contrast, when comparing single-injection FIB (40 mL of mepivacaine 1%) to intramuscular morphine (0.1 mg/kg), Foss et al. [40] reported improved static analgesia at 60 and 180 minutes (both $P \leq 0.03$) with the former. Furthermore pain relief with a 15-degree leg lift was also superior with FIB at the 3-hour mark ($P=0.04$). Although subjects in the FIB group required less breakthrough morphine ($P < 0.01$), no intergroup differences were noted in terms of oxygen saturation, sedation, nausea/vomiting and hemodynamic parameters. The analgesic benefits of FIB reported by Foss et al. [40] mirror those of an RCT conducted in pediatric patients. In 2006, Wathen et al. [41] randomized 55 children with proximal, middle or distal femoral fracture to receive FIB (0.25-0.50 mL/kg of ropivacaine 0.5%) or intravenous morphine (0.1 mg/kg). Throughout the 6-hour study period, pain scores were consistently lower in FIB subjects. The latter also experienced a longer analgesic duration (313 vs. 60 minutes) and required less breakthrough analgesia [41]. Thus, due to conflicting results, the current evidence does not permit definitive conclusions as to the analgesic benefits of FIB. Although FIB can decrease the incidence/duration of delirium in very elderly patients, its routine use has not been shown to impact sedation or oxygen saturation.

Femoral Block (FB): To date, 4 RCTs (combined $n = 218$) have investigated the role of FB in the management of lower limb trauma [42-45]. Haddad and Williams [42] and Mutty et al. [43] compared FB (bupivacaine 0.25-0.5%) to systemic analgesia (opioids/NSAIDs) in patients with extracapsular femoral neck fractures and diaphyseal/distal femoral fractures, respectively. In both trials, FB resulted in lower pain scores during the first 1.5-2 hours. In a subsequent study, Schiferer et al. [44] randomized 62 patients with lower extremity injury (hip dislocation/fracture, femoral fracture, patellar tendon rupture) to FB (20 mL of levobupivacaine 0.5%) performed at the accident site or intravenous metamizole (1 g). Schiferer et al. [44] found that, unlike the control group, there was a significant decrease in pain and anxiety between the on-site and transport values for patients who received a FB (both $P < 0.001$). Subsequently, the same authors proceeded to compare FB and metamizole for the ambulance transfer of patients with knee trauma [45]. Again, pain and anxiety were only decreased in patients receiving FB. Thus the available evidence suggests that, compared to

conventional management, FB provides better pain control for patients suffering from hip and knee trauma.

Technical commentary

Lumbar plexus block: The hip joint is innervated by articular branches derived from the femoral, obturator, accessory obturator, superior gluteal and quadratus femoris nerves [46]. Because it anesthetizes the femoral, obturator and accessory obturator nerves with a single injection, the LPB provides an elegant analgesic option for hip fracture and trauma.

The LPB can be localized using loss of resistance or PNS. In 2011, Danelli et al. [47] set out to compare the 2 modalities. In all subjects, a bolus of 20 mL of mepivacaine 1.5% was injected after obtaining the desired endpoint. Danelli et al. [47] observed that the onset time to complete sensorimotor block was shorter with PNS (12 ± 6 vs. 22 ± 6 minutes; $P=0.03$). Although more patients achieved complete block at 30 minutes with PNS (80 vs. 40%), this difference failed to reach statistical significance ($P=0.113$) due to the small sample size ($n=30$). Danelli et al.'s results seem to suggest that the analgesic difference reported by Chudinov et al. [34] (lower pain scores at 8 and 16 hours in the LPB group) might have been weakened because loss of resistance was employed instead of PNS. Therefore future trials investigating LPB in non-operative settings should rely on PNS to identify the lumbar plexus. Although US is increasingly used for LPBs [48], further investigative comparisons with PNS are required prior to its routine implementation outside of the operating room. Finally, LPBs carry an inherent risk of LA spread to the epidural space (1-16%), renal puncture and psoas hematoma [49]. Thus they should be reserved for experienced operators.

3-in-1 Block: In 1973, Winnie et al. [50] suggested that LA injection inside the sheath of the femoral nerve, coupled with cephalad angulation of the needle and distal manual compression, would result in rostral migration of LA molecules towards the lumbar plexus. Since the 3 main branches of the latter (femoral, lateral femoral cutaneous and obturator nerves) could be anesthetized with a single injection, this technique was named “3-in-1 block” or “anterior approach to the lumbar plexus”.

To date, 6 RCTs have compared single-injection anterior and posterior LPBs [51-56]. While both methods seem to reliably anesthetize the femoral nerve, obturator blockade is more readily achieved with the posterior approach [51-56]. Although 3 RCTs noted an improved sensory block of the obturator nerve (77-80% vs. 20-50%; $P<0.05$) with the posterior approach [52-54], caution must be exercised when interpreting these data since the femoral nerve, and not the obturator nerve, supplies the medial thigh in 47% of patients [57,58]. Thus testing the skin of the medial thigh with cold or pinprick stimuli might have reflected femoral rather than obturator blockade. In 3 studies, improved obturator motor blockade (63-100% vs. 0-30%; $P<0.05$) was also observed with the posterior approach [51-52,55].

The unreliable obturator block seen with the 3-in-1 technique stems from the fact that, contrary to Winnie's hypothesis [50], LA anesthetizes the lateral femoral cutaneous and obturator nerves through lateral/medial spread, deep to the fascia iliaca and not via proximal diffusion [59]. Therefore, with the 3-in-1 block, LA may distribute preferentially in a lateral direction and spare the obturator nerve [54]. Thus, the posterior approach constitutes the only reliable method to anesthetize the lumbar plexus. Terms such as “anterior lumbar plexus block” and “3-in-1 block” are therefore antiquated and should no longer be used.

In summary, since the so-called 3-in-1 blocks dependably

anesthetize the femoral nerve, they do provide some analgesic effect in hip/femoral fractures, as evidenced by Fletcher et al.'s [35], Graham et al.'s [36] and Luger et al.'s [37] results. However the unreliable obturator nerve block might have led to an inconsistent reduction in breakthrough opioid requirements. For instance, if obturator blockade were achieved, hourly consumption of morphine would be decreased [35]. In contrast, an absent obturator block coupled with strong representation of obturator innervation in the hip joint (obturator and accessory obturator nerves) could explain why Graham et al. [36] and Luger et al. [37] failed to detect decreases in morphine and piritramide requirements, respectively. Thus future trials should compare LPB (or combined femoral-obturator blocks) to isolated femoral nerve block for analgesia after hip fracture. Moreover, obturator blockade should be assessed using motor rather than sensory testing. However a motor evaluation may be somewhat problematic as most patients with fractured hips would be reluctant to adduct the injured limb.

Fascia iliaca block: In an effort to improve the obturator block seen with the 3-in-1 technique, Dalens et al. [60] introduced the FIB, a method whereby LA is injected immediately dorsal to the fascia iliaca while firm compression is applied distal to the puncture site. In 120 children randomized to a 3-in-1 block or a FIB, Dalens et al. [60] reported similar rates of complete sensory block for the femoral nerve (100%); unfortunately, the clinical test for motor blockade of the obturator nerve (elicitation of adduction at the end of surgery) did not allow for definitive conclusions. Subsequently, the same comparison was carried out in 100 adults by Capdevila et al. [61]. Again, the rates of femoral block were comparable (88-90%). However, motor blockade of the obturator nerve showed no difference (20-32%). Thus, obturator block remains elusive even with FIB.

In 2008, Dolan et al. [62] randomized 80 patients to FIB using loss of resistance or US. The latter resulted in an improved motor block of the obturator ($P=0.033$) and femoral ($P=0.006$) nerves. The authors hypothesized that the subcutaneous fascia might in fact consist of several layers separated by adipose tissue: thus blind penetration of any of these layers could have been mistaken for that of the fascia iliaca [62]. Interestingly, in the literature, the 2 RCTs that compared FIB to parenteral analgesia for hip fracture and that found no differences in pain control used an “intramuscular” or a sharp needle to identify the fascia iliaca compartment [38,39]; in contrast, the 2 trials that detected a beneficial effect with FIB employed a blunt needle [40,41]. Thus future trials investigating FIB in non-operative settings should use blunt needles as well as US to reliably detect penetration of the appropriate fascial layers (fascia lata and iliaca).

Femoral block: In clinical practice, the femoral nerve is most commonly located using PNS or US.

In a dose finding study, the MEV_{50} of ropivacaine 0.5% resulting in sensory and motor block of the femoral nerve was lower with US compared to PNS (15 vs. 26 mL; $P=0.002$) [63]. A recent RCT compared US to a combination of PNS and US [64,65]. Although both techniques provided similar efficacy, the combined modalities increased the performance time (188 vs. 148 seconds; $P=0.01$) and number of needle passes (4.1 vs. 1.1; $P<0.01$).

In the literature, the 4 RCTs comparing FB to conventional treatment for lower extremity trauma have arrived at similar conclusions [42-45]. This situation seems at odds with the one afflicting 3-in-blocks and FIBs. One potential explanation lies in the predictability of FBs. Unlike their 3-in-1 counterparts, FBs do not aspire to anesthetize the obturator nerve; thus LA spread medially (towards the obturator nerve)

Upper Extremity Trauma	<ul style="list-style-type: none"> • Comparison between SCB, ICB and conventional treatment • Comparison between SCB, ICB and AXB • Comparison between SSB, combined ICB-SSB, combined axillary nerve block-SSB and conventional treatment for shoulder trauma • Comparison between ISB, combined ICB-SSB and combined axillary nerve block-SSB for shoulder trauma • Comparison between continuous and single-shot brachial plexus blocks
Lower Extremity Trauma	<ul style="list-style-type: none"> • Comparison between LPB, FB and combined FB-obturator nerve block for hip/femur trauma • Comparison between LPB and combined LPB-PSB for hip/femur trauma • Comparison between sciatic nerve block and conventional treatment for leg/ankle/foot trauma • Comparison between sciatic nerve block and combined sciatic nerve block-saphenous nerve block for leg/ankle/foot trauma • Comparison between continuous and single-shot lower extremity nerve blocks

AXB: Axillary Brachial Plexus Block; FB: Femoral nerve Block; ICB: Infraclavicular Brachial Plexus Block; ISB: Interscalene Brachial Plexus Block; LPB: Lumbar Plexus Block; PSB: Parascapular Block; SCB: Supraclavicular Brachial Plexus Block; SSB: Suprascapular Nerve Block

Table 3: Areas pertaining to the use of peripheral nerve blocks in non-operative settings warranting further investigation with randomized trials.

or rostrally (towards the roots of the lumbar plexus) becomes a non-issue. More importantly, 3 out the 4 RCTs employed PNS to locate the femoral nerve [43-45]. Because muscular contractions were sought, the endpoint was objective. In contrast, a traditional FIB requires the operator to search double fascial click: such tactile recognition could depend on technical experience and the use of a blunt needle. Thus, one lesson that can be learned from the literature pertaining to FB/FIB and transposed to future RCTs as well as other peripheral nerve blocks is that the investigator should select blocks with predictable patterns of LA spread and techniques with reproducible endpoints (PNS, US). This may be especially important in non-operative settings where physicians perform nerve blocks only sporadically.

Conclusion

Despite multiple reports advocating the use of peripheral nerve blocks in non-operative settings, only a handful of RCTs have formally compared nerve blocks to conventional treatment at the accident site, in the ED or on the surgical wards. Unfortunately most of these trials suffered from potential observer bias due to the lack of blinded assessment. Furthermore 36% of available RCTs also failed to provide sample size justification and thus could have been statistically underpowered. More importantly, the true analgesic benefits of some nerve blocks could have been underestimated due to an unreliable technique (transarterial injection for AXB, loss of resistance for LPB, 3-in-1 block, double fascial click for FIB) or suboptimal equipment (sharp needle for FIB). The variable techniques and experience levels of the operators also constitute prohibitive obstacles for the conduct of a metaanalysis. Despite these shortcomings, the available evidence seems to suggest that peripheral nerve blocks can provide pain control for upper and lower limb trauma in non-operative settings. For instance, brachial plexus blocks offer a useful alternative to procedural sedation for fracture manipulation in the ED. Lumbar plexus blocks, 3-in-blocks and FBs can provide analgesia for patients with hip fractures. Femoral blocks also result in more comfortable ambulance transfers to the hospital for patients suffering from hip and knee trauma. Finally, in very elderly subjects, FIBs can decrease the incidence and duration of perioperative delirium.

Increasingly, anesthesiologists, ED physicians and orthopedists will be called upon to perform peripheral nerve blocks in non-operative settings. It is not the goal of this review article to determine which specialties should carry out these nerve blocks. However, for the sake of patient care, it suffices to say that residency programs should

provide their trainees with sufficient exposure to basic nerve blocks. Training should encompass technique, selection of LA, post procedural monitoring as well as management of possible complications. To ensure that the learner achieves technical proficiency, strict training and testing guidelines will need to be developed. Anesthesiologists often use a cumulative experience of 50-60 blocks to denote competency [65]; however this technical benchmark remains somewhat arbitrary. Perhaps, similarly to transoesophageal echocardiography, a validated examination administered by a governing body can remedy the situation.

In summary, a critical survey of the available RCTs provides an effective tool to validate the use of peripheral nerve blocks in non-operative settings. Despite current best evidence, many issues remain unresolved and require further elucidation (Table 3). Further well-designed and meticulously executed RCTs are warranted. Future trials should provide a clear research hypothesis, sample size justification as well as blinded assessment. Furthermore peripheral nerve blocks should be carried out by operators with adequate training using appropriate equipment and evidenced-based techniques with a proven record of safety and efficacy. Only then can a learned dialogue be undertaken between and within professional societies to determine who should perform nerve blocks in non-operative settings.

References

1. De Buck F, Devroe S, Missant C, Van de Velde M (2012) Regional anesthesia outside the operating room: indications and techniques. *Curr Opin Anaesthesiol* 25: 501-507.
2. Stundner O, Memtsoudis SG (2012) Regional anesthesia and analgesia in critically ill patients: a systematic review. *Reg Anesth Pain Med* 37: 537-544.
3. Gregoret C, Decaroli D, Miletto A, Mistretta A, Cusimano R, et al. (2007) Regional anesthesia in trauma patients. *Anesthesiol Clin* 25: 99-116.
4. Schulz-Stübner S (2006) The critically ill patient and regional anesthesia. *Curr Opin Anaesthesiol* 19: 538-544.
5. Davidson EM, Ginosar Y, Avidan A (2005) Pain management and regional anaesthesia in the trauma patient. *Curr Opin Anaesthesiol* 18: 169-174.
6. Cohen SP, Christo PJ, Moroz L (2004) Pain management in trauma patients. *Am J Phys Med Rehabil* 83: 142-161.
7. Tirado A, Nagdev A, Henningsen C, Breckon P, Chiles K (2013) Ultrasound-guided procedures in the emergency department-needle guidance and localization. *Emerg Med Clin North Am* 31: 87-115.
8. Grabinsky A, Sharrar SR (2009) Regional anesthesia for acute traumatic injuries in the emergency room. *Expert Rev Neurother* 9: 1677-1690.

9. Malchow RJ, Black IH (2008) The evolution of pain management in the critically ill trauma patient: Emerging concepts from the global war on terrorism. *Crit Care Med* 36: S346-357.
10. Wiebalck A, Grau T (2007) Ultrasound imaging techniques for regional blocks in intensive care patients. *Crit Care Med* 35: S268-274.
11. Schulz-Stübner S, Boezaart A, Hata JS (2005) Regional analgesia in the critically ill. *Crit Care Med* 33: 1400-1407.
12. Clark F, Gilbert HC (2001) Regional analgesia in the intensive care unit. Principles and practice. *Crit Care Clin* 17: 943-966.
13. Burton AW, Eappen S (1999) Regional anesthesia techniques for pain control in the intensive care unit. *Crit Care Clin* 15: 77-88, vi.
14. Kriwanek KL, Wan J, Beaty JH, Pershad J (2006) Axillary block for analgesia during manipulation of forearm fractures in the pediatric Emergency Department. A prospective randomized comparative trial. *J Pediatr Orthop* 26: 737-740.
15. Blaivas M, Adhikari S, Lander L (2011) A prospective comparison of procedural sedation and ultrasound-guided interscalene nerve block for shoulder reduction in the emergency department. *Acad Emerg Med* 18: 922-927.
16. Neal JM, Hebl JR, Gerancher JC, Hogan QH (2002) Brachial plexus anesthesia: essentials of our current understanding. *Reg Anesth Pain Med* 27: 402-428.
17. Sia S, Bartoli M (2001) Selective ulnar nerve localization is not essential for axillary brachial plexus block using a multiple nerve stimulation technique. *Reg Anesth Pain Med* 26: 12-16.
18. Sia S (2006) A comparison of injection at the ulnar and the radial nerve in axillary block using triple stimulation. *Reg Anesth Pain Med* 31: 514-518.
19. Sia S1, Lepri A, Magherini M, Doni L, Di Marco P, et al. (2005) A comparison of proximal and distal radial nerve motor responses in axillary block using triple stimulation. *Reg Anesth Pain Med* 30: 458-463.
20. Chan VW, Perlas A, McCartney CJ, Brull R, Xu D, et al. (2007) Ultrasound guidance improves success rate of axillary brachial plexus block. *Can J Anaesth* 54: 176-182.
21. Liu FC, Liou JT, Tsai YF, Li AH, Day YY, et al. (2005) Efficacy of ultrasound-guided axillary brachial plexus block: a comparative study with nerve stimulator-guided method. *Chang Gung Med J* 28: 396-402.
22. Imasogie N, Ganapathy S, Singh S, Armstrong K, Armstrong P (2010) A prospective, randomized, double-blind comparison of ultrasound-guided axillary brachial plexus blocks using 2 versus 4 injections. *Anesth Analg* 110: 1222-1226.
23. Casati A, Danelli G, Baciarello M, Corradi M, Leone S, et al. (2007) A prospective, randomized comparison between ultrasound and nerve stimulation guidance for multiple injection axillary brachial plexus block. *Anesthesiology* 102: 992-996.
24. Bhattarai BK, Baral PR (2006) Brachial plexus block as a sole anaesthetic technique in upper extremity fracture/dislocation in children: subclavian perivascular vs. parascapular approach. *Kathmandu University Med J* 4: 426-430.
25. Kapral S, Greher M, Huber G, Willschke H, Kettner S, et al. (2008) Ultrasonographic guidance improves the success rate of interscalene brachial plexus blockade. *Reg Anesth Pain Med* 33: 253-258.
26. McNaught A, Shastri U, Carmichael N, Awad IT, Columb M, et al. (2011) Ultrasound reduces the minimum effective local anaesthetic volume compared with peripheral nerve stimulation for interscalene block. *Br J Anaesth* 106: 124-130.
27. Liu SS, Zayas VM, Gordon MA, Beathe JC, Maalouf DB, et al. (2009) A prospective, randomized, controlled trial comparing ultrasound versus nerve stimulator guidance for interscalene block for ambulatory shoulder surgery for postoperative neurological symptoms. *Anesth Analg* 109: 265-271.
28. Riazi S, Carmichael N, Awad I, Holtby RM, McCartney CJ (2008) Effect of local anaesthetic volume (20 vs 5 ml) on the efficacy and respiratory consequences of ultrasound-guided interscalene brachial plexus block. *Br J Anaesth* 101: 549-556.
29. Sinha SK, Abrams JH, Barnett JT, Muller JG, Lahiri B, et al. (2011) Decreasing the local anesthetic volume from 20 to 10 mL for ultrasound-guided interscalene block at the cricoid level does not reduce the incidence of hemidiaphragmatic paresis. *Reg Anesth Pain Med* 36: 17-20.
30. Urmey WF, Talts KH, Sharrock NE (1991) One hundred percent incidence of hemidiaphragmatic paresis associated with interscalene brachial plexus anesthesia as diagnosed by ultrasonography. *Anesth Analg* 72: 498-503.
31. Martínez J, Sala-Blanch X, Ramos I, Gomar C (2003) Combined infraclavicular plexus block with suprascapular nerve block for humeral head surgery in a patient with respiratory failure: an alternative approach. *Anesthesiology* 98: 784-785.
32. Price DJ (2008) Combined suprascapular and axillary nerve blockade. *Arthroscopy* 24: 1316-1317.
33. Price DJ (2007) The shoulder block: a new alternative to interscalene brachial plexus blockade for the control of postoperative shoulder pain. *Anaesth Intensive Care* 35: 575-581.
34. Chudinov A, Berkenstadt H, Salai M, Cahana A, Perel A (1999) Continuous psoas compartment block for anesthesia and perioperative analgesia in patients with hip fractures. *Reg Anesth Pain Med* 24: 563-568.
35. Fletcher AK, Rigby AS, Heyes FL (2003) Three-in-one femoral nerve block as analgesia for fractured neck of femur in the emergency department: a randomized, controlled trial. *Ann Emerg Med* 41: 227-233.
36. Graham CA, Baird K, McGuffie AC (2008) A pilot randomised clinical trial of 3-in-1 femoral nerve block and intravenous morphine as primary analgesia for patients presenting to the emergency department with fractured hip. *Hong Kong J Emerg Med* 15: 205-210.
37. Luger TJ, Kammerlander C, Benz M, Luger MF, Garoscio I (2012) Peridural Anesthesia or Ultrasound-Guided Continuous 3-in-1 Block: Which Is Indicated for Analgesia in Very Elderly Patients With Hip Fracture in the Emergency Department? *Geriatr Orthop Surg Rehabil* 3: 121-128.
38. Godoy Monzón D, Vazquez J, Jauregui JR, Iserson KV (2010) Pain treatment in post-traumatic hip fracture in the elderly: regional block vs. systemic non-steroidal analgesics. *Int J Emerg Med* 3: 321-325.
39. Mouzopoulos G, Vasiliadis G, Lasanianos N, Nikolaras G, Morakis E, et al. (2009) Fascia iliaca block prophylaxis for hip fracture patients at risk for delirium: a randomized placebo-controlled study. *J Orthop Traumatol* 10: 127-133.
40. Foss NB, Kristensen BB, Bundgaard M, Bak M, Heiring C, et al. (2007) Fascia iliaca compartment blockade for acute pain control in hip fracture patients: a randomized, placebo-controlled trial. *Anesthesiology* 106: 773-778.
41. Wathen JE, Gao D, Merritt G, Georgopoulos G, Battan FK (2007) A randomized controlled trial comparing a fascia iliaca compartment nerve block to a traditional systemic analgesic for femur fractures in a pediatric Emergency Department. *Ann Emerg Med* 50: 162-171.
42. Haddad FS, Williams RL (1995) Femoral nerve block in extracapsular femoral neck fractures. *J Bone Joint Surg Br* 77: 922-923.
43. Mutty CE, Jensen EJ, Manka jr MA, Anders MJ, Bone LB (2007) Femoral nerve block for diaphyseal and distal femoral fractures in the Emergency Department. *J Bone Joint Surg Am* 89: 2599-2603.
44. Schiferer A, Gore C, Gorove L, Lang T, Steinlechner B, et al. (2007) A randomized controlled trial of femoral nerve blockade administered preclinically for pain relief in femoral trauma. *Anesth Analg* 105: 1852-1854, table of contents.
45. Barker R, Schiferer A, Gore C, Gorove L, Lang T, et al. (2008) Femoral nerve blockade administered preclinically for pain relief in severe knee trauma is more feasible and effective than intravenous metamizole: a randomized controlled trial. *J Trauma* 64: 1535-1538.
46. Gardner E (1948) The innervation of the hip joint. *Anat Rec* 101: 353-371.
47. Danelli G, Ghisi D, Bellinghieri F, Borghi B, Fanelli G, (2011) The nerve stimulation technique versus the loss of resistance technique for the posterior approach to lumbar plexus block: a randomized, prospective, observer-blinded pilot study. *Minerv Anesthesiol* 77: 959-963.
48. Karmakar MK, Ho AM, Li X, Kwok WH, Tsang K, et al. (2008) Ultrasound-guided lumbar plexus block through the acoustic window of the lumbar ultrasound trident. *Br J Anaesth* 100: 533-537.
49. Capdevila X, Coimbra C, Choquet O (2005) Approaches to the lumbar plexus: success, risks, and outcome. *Reg Anesth Pain Med* 30: 150-162.
50. Winnie AP, Ramamurthy S, Durrani Z (1973) The inguinal paravascular technic of lumbar plexus anesthesia: the "3-in-1 block". *Anesth Analg* 52: 989-996.

51. Parkinson SK, Mueller JB, Little WL, Bailey SL (1989) Extent of blockade with various approaches to the lumbar plexus. *Anesth Analg* 68: 243-248.
52. Tokat O, Türker YG, Uckunkaya N, Yilmazlar A (2002) A clinical comparison of psoas compartment and inguinal paravascular blocks combined with sciatic nerve block. *J Int Med Res* 30: 161-167.
53. Ali AM, Tahoun HM, Ahmed AA, Hussein KH (2003) Comparative study between the analgesic efficacies of nerve stimulator-guided 3-in-1 block, ultrasonographic-guided 3-in-1 block and posterior approach lumbar plexus block following total hip arthroplasty. *Eg J Anaesth* 19: 39-43.
54. Ganidagli S, Cengiz M, Baysal Z, Baktiroglu L, Sarban S (2005) The comparison of two lower extremity block techniques combined with sciatic block: 3-in-1 femoral block vs. psoas compartment block. *Int J Clin Pract* 59: 771-776.
55. Cappelleri G, Aldegheri G, Ruggieri F, Carnelli F, Fanelli A, et al. (2008) Effects of using the posterior or anterior approaches to the lumbar plexus on the minimum effective anesthetic concentration (MEAC) of mepivacaine required to block the femoral nerve: a prospective, randomized, up-and-down study. *Reg Anesth Pain Med* 33:10-16.
56. Biboulet P, Morau D, Aubas P, Bringuier-Branchereau S, Capdevila X (2004) Postoperative analgesia after total-hip arthroplasty: Comparison of intravenous patient-controlled analgesia with morphine and single injection of femoral nerve or psoas compartment block. a prospective, randomized, double-blind study. *Reg Anesth Pain Med* 29: 102-109.
57. Bouaziz H, Vial F, Jochum D, Macalou D, Heck M, et al. (2002) An evaluation of the cutaneous distribution after obturator nerve block. *Anesth Analg* 94: 445-449.
58. Choquet O, Capdevila X, Bennourine K, Feugeas JL, Bringuier-Branchereau S, et al. (2005) A new inguinal approach for the obturator nerve block: anatomical and randomized clinical studies. *Anesthesiology* 103: 1238-1245.
59. Marhofer P, Nasel C, Sitzwohl C, Kapral S (2000) Magnetic resonance imaging of the distribution of local anesthetic during the three-in-one block. *Anesth Analg* 90: 119-124.
60. Dalens B, Vanneuville G, Tanguy A (1989) Comparison of the fascia iliaca compartment block with the 3-in-1 block in children. *Anesth Analg* 69: 705-713.
61. Capdevila X, Biboulet P, Bouregba M, Barthelet Y, Rubenovitch J, et al. (1998) Comparison of the three-in-one and fascia iliaca compartment blocks in adults: clinical and radiographic analysis. *Anesth Analg* 86: 1039-1044.
62. Dolan J, Williams A, Murney E, Smith M, Kenny GN (2008) Ultrasound guided fascia iliaca block: a comparison with the loss of resistance technique. *Reg Anesth Pain Med* 33: 526-531.
63. Casati A, Baciarello M, Di Cianni S, Danelli G, De Marco G, et al. (2007) Effects of ultrasound guidance on the minimum effective anaesthetic volume required to block the femoral nerve. *Br J Anaesth* 98: 823-827.
64. Sites BD1, Beach ML, Chinn CD, Redborg KE, Gallagher JD (2009) A comparison of sensory and motor loss after a femoral nerve block conducted with ultrasound versus ultrasound and nerve stimulation. *Reg Anesth Pain Med* 34: 508-513.
65. Konrad C, Schüpfer G, Wietlisbach M, Gerber H (1998) Learning manual skills in anesthesiology: Is there a recommended number of cases for anesthetic procedures? *Anesth Analg* 86: 635-639.