Published in final edited form as:

Reg Anesth Pain Med. 2012 ; 37(6): 577–582. doi:10.1097/AAP.0b013e318263d396.

Adverse Outcomes Associated with Nerve Stimulator-Guided and Ultrasound-Guided Peripheral Nerve Blocks by Supervised Trainees: Update of a Single-Site Database

Steven L. Orebaugh, MD*, Michael L. Kentor, MD*, and Brian A. Williams, MD, MBA*

*University of Pittsburgh School of Medicine, Department of Anesthesiology, Pittsburgh, PA

Introduction

Ultrasound-guided regional anesthesia (UGRA) has been rapidly adopted by anesthesiologists, as evidenced by (i) the promulgation of an international guideline for instruction in UGRA,¹ (ii) the increasing integration of UGRA-specific training curricula,^{2,3} (iii) the predominance of UGRA in reports of recent large-scale, multi-institutional databases,⁴ and (iv) the popularity of this technique at workshops and meetings. While not all published comparative studies have found improved efficacy with UGRA when compared to more traditional guidance techniques, a recent meta-analysis suggests that block failure is less likely with the use of UGRA when compared to peripheral nerve stimulation (PNS) alone.⁵ Other potential benefits of UGRA include faster block performance, reduced local anesthetic doses, and fewer episodes of vascular puncture.^{5–7} However, the theoretical potential for reducing complications with UGRA, related to either nerve injury or local anesthetic systemic toxicity (LAST), has not been evident in most studies published from single or multi-institution experiences.^{8,9} We previously published a retrospective review of our quality assurance (QA) data for peripheral nerve blocks, guided by either UGRA-PNS or landmark(LM)-PNS techniques.¹⁰ That investigation was carried out during the initial phases of a transition period for our practice, from the use of primarily “landmark -PNS” as a guidance method for blocks, to “UGRA-PNS,” utilizing nerve stimulation as a secondary confirmation. We reported a small but significant reduction in major LAST episodes when UGRA was used for upper extremity blocks. This report represents an update of our database. Specifically, this is the final period in the transition from a practice that once utilized nerve stimulation for guidance, to one that will soon exclusively use ultrasound imaging combined with nerve stimulation for confirmation of neural structures. Based on this evolution towards universal use of UGRA in our practice, it will be difficult in the future to compare these 2 techniques in our high-volume clinical practice. This data report from our ambulatory surgery center may provide insight into the impact of UGRA-PNS on adverse occurrences at a single institution where the vast majority of blocks are performed by residents under close supervision of attending anesthesiologists.

Methods

This data query was approved by the University of Pittsburgh institutional review board (Pittsburgh, Pennsylvania). We queried our de-identified departmental quality improvement/patient safety database for adverse outcomes associated with peripheral nerve blocks (PNB). Specified adverse events are recorded by anesthesiologists, nurse anesthetists, and/or

Corresponding author: Steven L. Orebaugh, M.D., University of Pittsburgh School of Medicine, Department of Anesthesiology, UPMC-Southside/Mercy Ambulatory Surgical Center, 2000 Mary Street, Pittsburgh, PA 15203, Phone: 412-488-5799, FAX: 412-488-5796, orebaughsl@anes.upmc.edu.

perioperative nurses, and reported to the database contemporaneously. Subsequently, events that represent sentinel or serious events are reported to the state department of health. After peer review, those events that represent a deviation from the standard of care are reviewed at the departmental patient safety meeting for further evaluation and recommendations for ancillary training for the practitioner involved.

The period from which data were queried for this updated report was the 44-month period from May 2008 to December 2011. These data were then analyzed in combination with the 28-month period immediately preceding (previously described¹⁰), which comprises the 72 months from January 2006 to December 2011. In the period described in our previous report, UGRA-PNS had been introduced, and its frequency in use by our practitioners and trainees had increased from less than 10% of overall blocks to approximately half of all single-injection blocks performed. In the past 4 years, the use of UGRA-PNS has continued to increase at our institution. As of this writing, less than 10% of blocks are performed with landmark-PNS alone (Fig. 1). Exclusion criteria for this data report include block procedures that were planned but aborted for any reason, and block procedures that were carried out by landmarks alone, with neither ultrasound nor PNS guidance (eg, ankle block, subcutaneous saphenous block, paravertebral block).

The de-identified QA database utilized for this report is the standard record of complications related to anesthesia care at all hospitals of the University of Pittsburgh Medical Center, as described in our previous report.¹⁰ Our department also maintains a billing database that specifies the total number and type of PNB performed. This billing database was de-identified and then used to provide the total number of blocks using UGRA-PNS as well as blocks using landmark-PNS. The billing database contains information for all cases performed; therefore, a “denominator” for the proportion of complications among our cases is reportable. The QI database contains data related only to positive cases (adverse events), thus providing the “numerator.”

The nerve blocks and catheter insertions considered for this analysis were interscalene, axillary, femoral, and sciatic (gluteal, infragluteal, and popliteal). The clinical pathways for performing these blocks specifically called for the use of ropivacaine, or a mixture of mepivacaine and ropivacaine; this latter combination of drugs was used in the particular setting of interscalene block for patients with a history of sleep apnea, in order to obtain a relatively rapid onset with an intermediate duration. Dilute bupivacaine was also occasionally used for single-injection blocks for postoperative analgesia. Epinephrine is not used as an additive for peripheral nerve blockade in our practice. Defined clinical pathways guide our practice for femoral-sciatic blocks for knee surgery,¹¹ brachial plexus blocks for upper extremity procedures, and popliteal-sciatic/saphenous blocks for foot-ankle surgery.

A separate clinical pathway was established to evaluate potential nerve injuries involving both motor and sensory dysfunction.¹² Attending anesthesiologists or residents involved with each case routinely call patients within 2 business days after surgery to determine nerve block resolution without apparent sequelae. If the block has not resolved by the time the call is made, or if there is concern about nerve dysfunction, the patient is contacted later in order to determine the status of block resolution, or any persistent neurologic symptoms. In addition, surgeons are actively encouraged to contact our department any time postoperatively if there is concern about nerve injury or dysfunction. In cases of persistent neurologic dysfunction, prompt patient referral is made to a physiatrist who specializes in chronic pain and nerve injury. Early referral also facilitates formal evaluation with nerve conduction studies and/or electromyography in a timely fashion, if indicated.

During nerve blocks at our institution, patients are monitored with noninvasive blood pressure cuffs and pulse oximetry, as well as electrocardiographic monitoring for those with a history of dysrhythmia or ventricular dysfunction. Oxygen is supplied by face mask, as mild sedation is provided with midazolam and fentanyl, titrated to anxiolysis, while preserving the ability of the patient to interact verbally with the anesthesiologist.

Blocks with LM-PNS guidance were conducted with stimulating needles (Stimuplex, B. Braun USA, Bethlehem, Pennsylvania) and appropriate motor stimulation refined to a current of 0.25 to 0.5 mA before injection of local anesthetic solution at a single location. Nerve stimulator (B. Braun USA) current was initially set at 0.8 to 1.0 mA, with a frequency of 2 Hz and pulse duration of 0.1 milliseconds. Per our clinical pathway, single-stimulation technique was used for all blocks, except axillary brachial plexus blockade, for which a 4-stimulation technique was utilized. Injection of local anesthetic solution then proceeded in small increments, with aspiration between each injection, observing for patient discomfort or unusually high perceived injection pressures (injection pressures were not quantitatively measured).

UGRA entailed the use of a bedside US unit (Micromaxx® or S-Nerve®, Sono-Site®, Bothell, Washington) using a 5–10 or 6–13 MHz linear transducer or, rarely, a 2–5 MHz curvilinear transducer for larger patients during sciatic nerve blockade. An in-plane technique was utilized for single-injection blocks, though out-of-plane technique was occasionally used for catheter insertion. The needle and nerve target were visualized until the needle tip was nearly in contact with the nerve; the nerve stimulator was then turned on to a level between 0.5 and 1.0 mA to elicit motor stimulation for confirmation of the neural structure. The needle was further advanced until its tip was seen to contact the nerve, or until motor stimulation was evident, whichever came first. If needle-nerve contact was evident but no stimulation occurred, the current was increased or the needle-tip placement re-arranged until stimulation occurred. The Doppler setting on ultrasound was used to assess for vascular structures in the vicinity of the target nerves to avert intravascular injection. No attempt was made to refine the motor stimulation to a particular lower threshold of electrical stimulation during this technique. Injection of local anesthetic solution then proceeded in aliquots of 2.5 to 5 mL, ensuring that visible expansion of the tissues was evident. The needle tip was moved as necessary to ensure that the nerve target was surrounded with solution. Paresthesiae were not specifically sought during performance of either the UGRA-PNS or LM-PNS techniques.

As with our earlier report, the decision to perform a block by UGRA-PNS or LM-PNS was not randomized but made by the attending physician, in concert with the resident, before meeting the patient or knowing the patient's physical characteristics or co-morbidities. Both techniques were represented in all of the categories of blocks described; that is, there was no attempt to carry out any of these blocks exclusively with one or the other guidance method. The block technique decision was made based on personal preference and the educational desirability of exposing our trainees to both types of needle guidance. Block technique decisions were sometimes made based on equipment availability. Occasionally, blocks that appeared to have no or minimal anesthetic effect by 20 to 30 minutes were subjected to "re-block" with UGRA (with or without PNS), with caution not to exceed maximum recommended local anesthetic dosages.

As described previously,¹⁰ seizure from LAST was defined as tonic-clonic motion of the patient during or within 60 minutes after PNB, accompanied by loss of consciousness. Milder forms of central system (CNS) toxicity, such as short-lived confusion or tremor, were not reliably captured by the database, and are therefore not part of this report. Cardiovascular toxicity, according to our group standard for entry into the QA database, was

defined as: (i) hypotension requiring inotropic or vasopressor support after PNB, but before induction of anesthesia, or (ii) the appearance of ventricular dysrhythmias or cardiac arrest during this time frame. Unintended neuraxial blockade included signs or symptoms of epidural or spinal blockade after PNB. As in our prior report, peripheral nerve injury reported here was defined as sensory or motor deficit (or both) lasting longer than 6 months, and attributed to the nerve block after referral to the department of physical medicine/rehabilitation. These patients underwent evaluation by the aforementioned physiatrist for diagnosis, follow-up, and rehabilitative therapy as well as EMG and nerve conduction testing, when indicated. In addition, since the classification of nerve injuries is somewhat arbitrary with respect to the time frame, a stricter definition of nerve injury was considered as well: Motor-sensory injury that was evident on EMG testing at or near the site of the nerve block, and which persisted for more than 1 year. Nerve dysfunction with improvement or resolution within the 6-month postoperative time frame was not included in the database as nerve injury.

Statistical Analysis

The sum of all the described adverse outcomes comprised the numerator, per neurolocation technique (LM-PNS vs. UGRA-PNS), with the denominator consisting of the billing-derived caseload per neurolocation technique. Rates of complications are reported as proportions, along with 95% confidence intervals expressed per 1000 blocks. Comparison of reported complication rates between neurolocation techniques was performed with 2-tailed chi square analysis, with Yates' correction; $P < 0.05$ was considered statistically significant. Sample size was not determined *a priori*, because this methodology was specifically a consecutive-case review of the aforementioned QA database.

Results

There were over 9000 peripheral nerve blocks performed by either LM-PNS or UGRA-PNS technique in the 44-month period from May 1, 2008 to December 31, 2011 (Table 1). One seizure related to LM-PNB occurred during this period, at the conclusion of local anesthetic injection for an interscalene block (Table 2). The solution injected was ropivacaine 0.75% in a volume of 40 mL. The seizure promptly responded to intravenous injection of 50 mg of thiopental, and there was no evidence of cardiovascular toxicity.

During the 44-month period of this data collection, there were 4 peripheral nerve injuries, with sensory loss persisting for 6 to 12 months and not attributable to other non-block causes (such as chronic regional pain syndrome, an ill-fitting brace, or surgical positioning or incision). Three of these blocks were conducted via LM-PNS, while 1 was carried out with UGRA-PNS; all of these resolved by 1 year. In addition, 1 nerve injury occurred with LM-PNS guidance and resulted in loss of both motor and sensory function that persisted for more than 1 year (Table 3). An EMG was suggestive of a femoral nerve block as the cause.

During this period, the frequency of nerve injury lasting 6 to 12 months was significantly greater among patients with nerve blocks guided by LM-PNS (LM-PNS 3/2209 vs. US-PNS 1/7092, $P = .003$) (Table 1). This did not hold true for the incidence of nerve injuries lasting longer than 12 months (LM-PNS 1/2209 vs. US-PNS 0/7092, $p = 0.24$), or of seizure (LM-PNS 1/2209 vs. US-PNS 0/7092, $p = 0.24$).

There were no cases reported to the database of pneumothorax, local tissue injury or unintentional neuraxial blockade related to peripheral nerve blockade. Three femoral nerve catheters were removed postoperatively before discharge of the patient to home, due to bleeding around the catheter that could not be controlled with digital pressure. None of these

patients developed a hematoma or any other complications. There were no episodes of cardiac arrest or ventricular dysrhythmia related to peripheral nerve block.

In our previous report, there were 8 major complications of nerve blocks: 3 prolonged nerve injuries after popliteal-sciatic block and 5 seizures, 4 of which were in association with brachial plexus block (Table 2).¹⁰ All of these outcomes occurred with blocks guided by landmark-PNS technique. Two of the three nerve injuries from that report persisted for longer than 1 year (Table 3).

When comparing the outcomes and neurolocation techniques for the entire 6-year period, there were 9069 blocks performed by UGRA-PNS and 5436 by LM-PNS (Table 4). Neither nerve injuries lasting 6 to 12 months (LM-PNS, 4/5436 vs. US-PNS, 1/9069; $P=0.13$) nor nerve injuries lasting longer than 1 year was different between the 2 techniques (LM-PNS technique 3/5436 vs. US-PNS 0/9069, $P=.10$). However, the incidence of seizure was found to be higher with LM-PNS technique during the entire data collection period (LM-PNS, 6/5436 vs. US-PNS, 0/9238; $P=0.0061$).

Discussion

Based on this query of our QI and billing databases, in more than 6 years of performing blocks with UGRA-PNS, there have been no episodes of major LAST in our university-based (ie, supervised trainees), primarily orthopedic anesthesia practice. Previously, a frequency of 1 to 3 seizures per year (based on 3000–4000 blocks per year) was representative of the period during which landmark-PNS guidance was our primary block technique. Postoperative motor-sensory neurologic dysfunction lasting longer than 1 year was very infrequent in our data set, and was not different when the 2 techniques were compared.

We believe that this may be the largest single-center series of ultrasound-guided nerve blocks reported for the purpose of adverse outcome analysis. The large number of cases and paucity of adverse occurrences is evidence for the safety of UGRA-PNS in a training program for anesthesiology residents. This current analysis cannot declare associations of UGRA-related outcomes in the absence of PNS confirmation, however.

Moving forward from this data analysis in our institution, it will become much more challenging to meaningfully compare UGRA-PNS cases with LM-PNS guidance because the latter method represents only a small and diminishing fraction of our overall number of block cases. However, given this evolution, we believe that performing a large number of peripheral blocks with UGRA-PNS has conferred a high degree of patient safety.

The next logical database query for our institution would be to test UGRA-PNS versus UGRA without PNS confirmation, which is commonly used at other centers.¹³ It seems unlikely that safety differences would become apparent when comparing UGRA-PNS versus UGRA-only. However, there may be valuable economic analyses achievable with respect to time for block placement with trainees, block success rate, block duration, and cost of equipment used (assuming UGRA without PNS uses inexpensive non-insulated non-stimulating needles).¹³ It may be useful, when forging new research directions of block efficacy research, to incorporate more perineural analgesics (such as clonidine, buprenorphine, and low-dose dexamethasone, now known to be non-toxic *in vitro*¹⁴) in order to evaluate the duration of analgesia. Vieira et al recently reported in a study with UGRA that dexamethasone, added to bupivacaine-clonidine-epinephrine, provided an additional 7 hours of postoperative analgesia.¹⁵ To compare various combinations of perineural analgesics in the overriding context of UGRA versus UGRA-PNS would represent a timely and necessary advance in perineural analgesia duration research, which to

this point has been largely untapped and singularly focused on local anesthetics and varying drug dose volumes-concentrations.

Other large database studies have not detected a difference in the occurrence of LAST incidents when ultrasound guidance was compared to other forms of nerve block guidance. In the 2009 report by Barrington et al, which involved over 8000 cases from multiple institutions, there were 8 cases of LAST, none of which were cardiovascular in nature and were equally distributed between ultrasound and non-ultrasound groups.⁴ Of note, only 2 seizures occurred in this group, both of which occurred after blocks guided by non-ultrasound means, while 1 patient lost consciousness after a UGRA block. In the largest database of peripheral nerve block outcomes, with approximately 41,000 blocks guided by LM-PNS, major LAST occurred very infrequently, with an incidence of seizures of 1/3000 to 1/10,000, depending on the type of block.¹⁶ These low rates make it clear that randomized controlled trials would have to include impractically large numbers of procedures in each group in order to find meaningful differences in incidence of such complications. Such large-scale, prospective, randomized trials are unlikely to be carried out. As such, with the continually increasing popularity of UGRA, it is useful to document the paucity of adverse outcomes with this technique in and of itself.

Furthermore, even nonrandomized databases, with patient numbers sufficiently large to detect a difference in infrequent complications between groups, are relatively rare. More common are small, observational studies with dozens to hundreds of patients. Some of these studies point to a more common occurrence of LAST than noted above, whether ultrasound or PNS are utilized for guidance.^{17,18} Mulroy, in a review of LAST, noted an incidence of such events of 0.75 to 2 per 1000 cases with PNB,¹⁹ similar to our overall rate for the LM-PNS technique. A number of case reports document the occurrence of LAST despite the use of UGRA.^{20,21} Indeed, some authors have noted the visualization of intravascular injection during UGRA.²²

Large observational studies, nonetheless, may play an important role in the analysis of outcomes related to patient safety. Mangano et al documented important adverse outcomes related to the use of aprotinin in cardiac surgery, which had not previously been evident in smaller, randomized trials.²³ Similarly, the prospective database reported by Barrington et al⁴ has shed light on the occurrence of adverse outcomes in peripheral nerve blockade guided by both UGRA and PNS.

LAST is a multifactorial occurrence, which may occur from direct intravascular injection or from the absorption of local anesthetic solution into the bloodstream over time.²⁴ As such, the lower doses of local anesthetic necessary to conduct nerve blocks with ultrasound^{5, 25,26} may impact the likelihood of this occurrence, particularly by the latter mechanism. Indeed, in the patient who manifested seizure with interscalene block in our most recent database report, the dose of local anesthetic was substantially higher than would have been used if the block had been guided by ultrasound. Because some 45% of episodes of LAST reported in the literature are delayed,²⁷ and therefore more likely to be secondary to absorption over time, the lower doses/concentrations permitted by ultrasound could potentially make a very important contribution to patient safety. The altered trajectory of needle insertion required by ultrasound guidance, for instance with ISB, may impact the likelihood of encountering deeper (and therefore unsuspected) blood vessels as well. Thus, the trajectory adjustment may reduce the likelihood of intravascular injection.²⁸ However, it must be acknowledged that particularly when supervising trainees, it is not always possible to have the needle tip accurately imaged, which may increase the risk of inadvertent intravascular injection.³

Limitations of this investigation include use of outcomes retrospectively collected from a QI database and the non-random allocation of patients to each guidance technique, which allows for potential bias in terms of patient and operator characteristics, as well as surgical variables. It is important to note that LAST may be the result of many factors, not only the needle guidance technique. While characteristics of affected patients (and the surgeries and blocks they underwent) are reported, we are not able to provide these variables for the entire population of patients considered in this study, making multivariate regression impossible.

Aspects of our practice that may limit the generalizability of our findings include the high proportion of blocks performed by residents and the somewhat limited slate of blocks that we perform in our sports medicine-orthopedic setting, resulting in a narrow portfolio of frequently-recurring surgical procedures. The nature of such a practice is that more young and healthy patients are encountered than older patients, whose co-morbidities may influence their risk of LAST. Finally, we do not utilize epinephrine in our local anesthetic solutions, although many practitioners of regional anesthesia believe that the inclusion of epinephrine may favorably reduce the risk of LAST by limiting systemic uptake or acting as a marker of vascular injection.²⁹ The use of ultrasound to monitor local anesthetic deposition during PNB may provide an acceptable level of patient safety, though it must be noted that existing guidelines continue to recommend the use of epinephrine in the injectate.²⁴

In conclusion, we report a large series of ultrasound-guided nerve blocks (with peripheral nerve stimulation used for confirmation) from a single hospital center where blocks are primarily provided by supervised residents, without occurrence of major LAST episodes. Prolonged nerve injury was rare with both guidance methods. We believe that such observational databases, while lacking the compelling evidence of randomized, controlled trials, nonetheless allow increased confidence in the safety of utilizing UGRA with PNS confirmation for nerve blocks in residency training programs.

Acknowledgments

The authors wish to acknowledge Pamela Harding, P.A., and Tammy Bregon for their assistance in the preparation of this manuscript.

Funding: This study was supported by departmental funds. Support for statistical analysis was provided by the Clinical Translational Sciences Institute of the University of Pittsburgh, supported by the National Institutes of Health through Grant Numbers UL1 RR024153 and UL1TR000005.

References

1. Sites BD, Chan VW, Neal JM, Weller R, Grau T, Koscielniak-Nielsen ZJ, Ivani G. The American Society of Regional Anesthesia and Pain Medicine Joint Committee recommendations for education and training in ultrasound-guided regional anesthesia. *Reg Anesth Pain Med.* 2010; 35:S74–S80. [PubMed: 20216029]
2. Sites BD, Spence BC, Gallagher JD, Wiley CW, Bertrand ML, Blike GT. Characterizing novice behavior associated with learning ultrasound-guided peripheral regional anesthesia. *Reg Anesth Pain Med.* 2007; 34:107–115. [PubMed: 17350520]
3. Orebaugh SL, Williams BA, Kentor ML, Bolland MA, Mosier SK, Nowak TP. Interscalene block using ultrasound guidance: Impact of experience on resident performance. *Acta Anaesth Scand.* 2009; 53:1268–1274. [PubMed: 19594465]
4. Barrington MJ, Watts SA, Gledhill SR, Thomas RD, Said SA, Snyder GL, Tay VS, Jamrozik K. Preliminary results of the Australasian Regional Anaesthesia Collaboration. *Reg Anesth Pain Med.* 2009; 34:534–541. [PubMed: 19916206]

5. Abrahams MS, Aziz MF, Fu RF, Horn J-L. Ultrasound-guidance compared with electrical neurostimulation for peripheral nerve block: A systematic review and meta-analysis of randomized controlled trials. *Br J Anaesth.* 2009; 102:408–417. [PubMed: 19174373]
6. Koscielniak-Nielsen ZJ. Ultrasound-guided peripheral nerve blocks: What are the benefits? *Acta Anaesth Scand.* 2008; 52:727–737. [PubMed: 18477070]
7. Marhofer P, Chan VW. Ultrasound-guided regional anesthesia: Current concepts and future trends. *Anesth Analg.* 2007; 104:1265–1269. [PubMed: 17456684]
8. Liu SS, Zayas VM, Gordon MA, Beathe JC, Maalouf DB, Paroli L, Liguori G, Ortiz J, Buschiazio V, Ngeow J, Shetty T, Deau JT. A prospective, randomized, controlled trial comparing ultrasound versus nerve stimulator guidance for interscalene block for ambulatory shoulder surgery for postoperative neurologic symptoms. *Anesth Analg.* 2009; 109:265–271. [PubMed: 19535720]
9. Chan VWS, Perlas A, McCartney CJL, Brull R, Xu D, Abbas S. Ultrasound guidance improves success rate of axillary brachial plexus block. *Can J Anaesth.* 2007; 54:176–182. [PubMed: 17331928]
10. Orebaugh SL, Williams BA, Vallejo M, Kentor ML. Adverse outcomes associated with stimulator-based peripheral nerve blocks with versus without ultrasound visualization. *Reg Anesth Pain Med.* 2009; 34:251–255. [PubMed: 19587625]
11. Williams BA, Matusic B, Kentor ML. Regional anesthesia procedures for ambulatory knee surgery: Effects on In-hospital outcomes. *Int Anesthesiol Clin.* 2005; 43:153–160. [PubMed: 15970752]
12. Mayfield JB. Diagnosis and management of peripheral nerve block complications. *Int Anesthesiol Clin.* 2005; 43:119–126. [PubMed: 15970749]
13. Swenson JD, Davis JJ. Getting the best value for consumable supplies in regional anesthesia. *Int Anesthesiol Clin.* 2011; 49:94–103. [PubMed: 21697673]
14. Williams BA, Hough KA, Tsui BY, Ibinson JW, Gold MS, Gebhart GF. Neurotoxicity of adjuvants used in perineural anesthesia and analgesia in comparison with ropivacaine. *Reg Anesth Pain Med.* 2011; 36:225–230. [PubMed: 21519308]
15. Vieira PA, Pulai I, Tsao GC, Manikantan P, Keller B, Connelly NR. Dexamethasone with ropivacaine prolongs duration of analgesia in ultrasound-guided interscalene brachial plexus blockade. *Eur J Anaesth.* 2010; 27:285–288.
16. Auroy Y, Benhamou D, Bargues L, Ecoffey C, Falissard B, Mercier F. Major complications of regional anesthesia in France: the SOS Regional Anesthesia Hotline Service. *Anesthesiology.* 2002; 97:1274–1280. [PubMed: 12411815]
17. Chan VW, Perlas A, Rawson R, Odukoya O. Ultrasound-guided supraclavicular brachial plexus block. *Anesth Analg.* 2003; 97:1514–1517. [PubMed: 14570677]
18. Borgeat A, Ekatothramis G, Kalberer F, Benz C. Acute and nonacute complications associated with interscalene block and shoulder surgery. *Anesthesiology.* 2001; 95:875–880. [PubMed: 11605927]
19. Mulroy MF, Hejtmanek MR. Prevention of local anesthetic systemic toxicity. *Reg Anesth Pain Med.* 2010; 35:177–180. [PubMed: 20216035]
20. Gnaho A, Eyrieux S, Gentili M. Cardiac arrest during an ultrasound-guided sciatic nerve block combined with nerve stimulation. *Reg Anesth Pain Med.* 2009; 34:278. [PubMed: 19436190]
21. Zetlaoui PJ, Labbe JP, Benhamou D. Ultrasound guidance for axillary plexus block does not prevent intravascular injection. *Anesthesiology.* 2008; 108:761–762. [PubMed: 18362610]
22. Baciarello M, Danelli G, Fanelli G. Real-time ultrasound visualization of local anesthetic during a peripheral nerve block. *Reg Anesth Pain Med.* 2009; 34:278–279. [PubMed: 19436189]
23. Mangano DT, Vuytsteke A, Tudor IC, Juneja R, Filipescu D, Hoeft A, Fontes ML, Hillel Z, Ott E, Titov T, Dietzel C, Levin J. Mortality associated with aprotinin during 5 years following coronary artery bypass graft surgery. *JAMA.* 2007; 297:471–479. [PubMed: 17284697]
24. Neal JM, Bernardis CM, Butterworth JF, Di Gregorio G, Drasner K, Hejmanek MR, Mulroy MF, Rosenquist RW, Weinberg GL. ASRA practice advisory on local anesthetic systemic toxicity. *Reg Anesth Pain Med.* 2010; 35:152–161. [PubMed: 20216033]
25. Marhofer P, Schrogendorfer K, Wallner T, Koinig H, Mayer N, Kapral S. Ultrasonographic guidance reduces the amount of local anesthetic for 3-in-1 blocks. *Reg Anesth Pain Med.* 1998; 23:584–588. [PubMed: 9840855]

26. Casati A, Baciarello M, Di Cianni S, Danelli G, De Marco G, Leone S, Rossi M, Fanelli G. Effects of ultrasound guidance on the minimum effective anesthetic volume required to block the femoral nerve. *Br J Anaesth*. 2007; 98:823–827. [PubMed: 17478453]
27. Di Gregorio G, Neal JM, Rosenquist RW, Weinberg GL. Clinical presentation of local anesthetic systemic toxicity. *Reg Anesth Pain Med*. 2010; 35:181–187. [PubMed: 20301824]
28. Neal JM. Ultrasound-guided regional anesthesia and patient safety. *Reg Anesth Pain Med*. 2010; 35(Supplement 1):S59–S67. [PubMed: 20216027]
29. Kahn RI, Quinn T. Minimizing seizure incidence during peripheral nerve blockade (letter). *Reg Anesth Pain Med*. 2010; 35:321–322. [PubMed: 20460976]

Figure 1.

Proportion of specified nerve blocks conducted by peripheral nerve stimulation-landmark technique (versus ultrasound-nerve stimulation technique) during the period January 2008–December 2011. “N” denotes occurrence of nerve injury, “S” denotes occurrence of seizure.

Table 1

Frequency and techniques of peripheral nerve blocks with complications April 2008–December 2011.

	ISB	AxB	Fem	Sci	PFB	Total	Nerve Injury 6-12 months: n (95% CI)	Nerve injury >12 months: n (95% CI)	Seizure: n (95% CI)
LM-PNS	872	87	677	463	47	2209	3 (0.49–4.0)	1 (0.11–2.5)	1 (0.11–2.5)
US-PNS	3810	757	1260	974	122	7092	1 (0.03–0.78)	0 (0.04–0.52)	0 (0.04–0.52)
Total	4682	844	1937	1437	169	9069	P = .003	P=0.24	P=0.24

“n” denotes the number of complications in each category; 95% CI denotes the 95% confidence interval for each complication, expressed per 1000 blocks. LM-PNS indicates guidance by landmark-peripheral nerve stimulation; US-PNS indicates guidance by ultrasound with nerve stimulation for confirmation; ISB indicates interscalene block, AxB indicates axillary brachial plexus block; Fem indicates femoral nerve block; Sci indicates transgluteal or infragluteal sciatic nerve block; PFB indicates popliteal fossa-sciatic nerve block. 95% CI indicates 95% confidence interval, expressed per 1000 cases.

Table 2
Characteristics of Patients who Developed Seizures During Landmark-Based Peripheral Nerve Stimulator Blocks

Age	Sex	Co-morbidity	Block	Volume	Agent (additive)	Time Course
57	Male	HTN	Interscalene	36 mL	Ropivacaine 0.75%	During Block
25	Male	None	Femoral	30 mL	Ropivacaine 0.5% (Clonidine)	Immediately after block
49	Female	Obese/OSA	Interscalene	30 mL	Ropivacaine 0.75%	At cessation of injection
26	Male	None	Axillary	30 mL	Ropivacaine 1% mixed 1:1 with Mepivacaine 1.5%	Immediately after block
71	Female	CAD/Diabetes/GERD	Interscalene	30 mL	Ropivacaine 0.75%	Immediately after block
47	Male	HTN/OSA/GERD	Interscalene	40 mL	Ropivacaine 0.75%	Immediately after block

HTN denotes hypertension; OSA denotes obstructive sleep apnea; CAD denotes coronary artery disease; GERD denotes gastroesophageal reflux disease.

Table 3

Characteristics of Patients With Nerve Injury Persisting More Than One Year

Age	Sex	Co-Morbidity	Block	Surgery	Symptoms	Volume	Agent (Additive)	Threshold
45	Male	Smoking	PFB	Achilles Repair	Pain, Sensory Weakness of foot	40 mL	Ropivacaine 1.0% Mepivacaine 1.5% mixed 1:1 (Clonidine)	0.38 mA
53	Male	Asthma, HTN	PFB	ORIF Foot Fracture	Sensory loss, plantar foot, Weakness of foot	40 mL	Ropivacaine 1.0% Mepivacaine 1.5% mixed 1:1	0.35 mA
22	Female	Asthma, HTN	Femoral	Patellar Realignment	Quadriceps Weakness	20 mL	Ropivacaine 0.5% (Clonidine)	0.4 mA

HTN denotes hypertension; PFB denotes popliteal fossa sciatic nerve block; ORIF denotes open reduction-internal fixation; ml denotes milliliters; mA denotes milliamperes of current.

Table 4

Frequency and techniques of peripheral nerve blocks with complications January 2006–December 2011.

	ISB	AxB	Fem	Sci	PFB	Total	Nerve Injury 6–12 months: n (95% CI)	Nerve injury >12 months: n (95% CI)	Seizure: n (95% CI)
LM-PNS	1764	183	1854	1113	522	5436	4 (0.3–1.9)	3 (0.2–1.6)	6 (0.5–2.4)
US-PNS	4903	977	1537	1129	523	9069	1 (0.03–0.6)	0 (0.003–0.41)	0 (0.003–0.41)
Total	6667	1160	3391	2242	1045	14505	p = 0.13	p = 0.10	p = .006

“n” denotes the number of complications in each category; 95% CI denotes the 95% confidence interval, expressed per 1000 blocks. LM-PNS indicates guidance by landmark-peripheral nerve stimulation; US-PNS indicates guidance by ultrasound with nerve stimulation for confirmation; ISB indicates interscalene block, AxB indicates axillary brachial plexus block; Fem indicates femoral nerve block; Sci indicates transgluteal or infragluteal sciatic nerve block; PFB indicates popliteal-sciatic nerve block. 95% CI indicates the 95% confidence interval, expressed per 1000 cases.