Incidence of Local Anesthetic Systemic Toxicity and Postoperative Neurologic Symptoms Associated With 12,668 Ultrasound-Guided Nerve Blocks

An Analysis From a Prospective Clinical Registry

Brian Daniel Sites, MD, Andreas H. Taenzer, MS, MD, Michael D. Herrick, MD, Constance Gilloon, MD, John Antonakakis, MD, Janeen Richins, MD, and Michael L. Beach, MD, PhD

Background and Objectives: There are varying reports on the incidence of major morbidity associated with peripheral regional anesthesia. Our objective was to contribute to the knowledge regarding the incidence of local anesthetic systemic toxicity and postoperative neurologic symptoms in the setting of ultrasound-guided peripheral regional anesthesia.

Methods: During an 8-year period, 12,668 patients undergoing peripheral regional anesthesia were evaluated. Using a clinical registry, incidence rates of postoperative neurologic symptoms, local anesthetic toxicity, pneumothorax, and vascular trauma were calculated. Univariate analysis was used to identify risk factors for postoperative neurologic symptoms. We defined postoperative neurologic symptoms as any sensory or motor dysfunction present for more than 5 days and anatomically consistent with the possibility of contribution from the nerve block.

Results: The incidence (per 1000 blocks) of adverse events across all peripheral regional anesthetics was 1.8 (95% confidence interval [CI], 1.1–2.7) for postoperative neurologic symptoms lasting longer than 5 days, 0.9 (95% CI, 0.5–1.7) for postoperative neurologic symptoms lasting longer than 6 months, 0.08 (95% CI, 0.0–0.3) for seizure, 0 (95% CI, 0–0.3) for pneumothorax, 0.6 (95% CI, 0.2–1.2) for unintended venous puncture, 1.2 (95% CI, 0.7–2.0) for unintended arterial puncture, and 2.0 (95% CI, 1.2–3.0) for patients having unintended paresthesia during block placement. There were no cardiac arrests.

Conclusions: In the setting of a surgical procedure, ultrasound-guided regional anesthesia is associated with the risk of long-term postoperative neurologic symptoms. Local anesthetic systemic toxicity, however, is extremely uncommon.

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Local anesthetic systemic toxicity (LAST) and postoperative neurologic symptoms (PONSs) are considered the 2 major morbid events associated with peripheral regional anesthesia.[1,2] Although rare, these events continue to be reported.[3]

Large prospective data collections examining these events in adult patients are sparse. With respect to PONS, the frequency during ultrasound-guided regional anesthesia (UGRA) has been reported as 0.4 per 1000 (95% confidence interval [CI], 0.08–1.1 per 1000).[3] This incidence does not seem to be dramatically different from historical frequencies reported using conventional nerve localization techniques. For instance, in 43,946 patients identified by organizational self-reporting, Auroy et al[4] reported a 0.14-per-1000 rate of PONS lasting longer than 6 months.

With respect to LAST, there are currently only 2 large clinical registries in the peer-reviewed literature that contain patients receiving UGRA.[5,6] In a mix of both ultrasound-guided and nerve stimulator–guided blocks (n = 7156), Barrington et al[5] reported an overall LAST incidence of 0.98 per 1000 (95% CI, 0.42–1.9). Rates of LAST events were not statistically different between the nerve stimulation and the ultrasound subgroups. With respect to the overall incidence of LAST, the findings of Barrington et al are consistent with those of Auroy et al who documented a rate of 0.8 per 1000 associated with nonultrasound techniques.[4] The second clinical registry belongs to Orebaugh et al,[6] who reported a reduction in LAST associated with the use of ultrasound. They reported 0 LAST events in 2146 blocks when ultrasound and nerve stimulation were used. This stands in contrast to 5 LAST events in 3290 blocks when landmark-based nerve stimulation techniques were used alone.

Our fundamental objective was to contribute to the knowledge regarding the incidence of LAST and PONS in the setting of a dedicated ultrasound-guided peripheral regional anesthesia practice. To this end, we analyzed our prospectively maintained clinical registry consisting of 12,668 ultrasound-guided peripheral regional blocks. In addition to the incidence rates of major morbidity, we report the incidence of unintentional vascular puncture, pneumothorax, and unintentional paresthesia.

METHODS

Data were analyzed for patients receiving a peripheral regional anesthetic at Dartmouth Hitchcock Medical Center between July 2003 and February 2011. After approval by Dartmouth College's Committee for the Protection of Human Subjects, we queried our prospective clinical registry. All peripheral regional anesthesia data were prospectively gathered and entered into an electronic database by members of the regional anesthesia service. These members included a group of specialized staff physicians as well as rotating fellows and residents. Data entry was composed of peripheral nerve blocks done in the block area, operating room, and recovery room. The database platform was based on Microsoft Access (Microsoft Corporation, Redmond, Washington) and consisted of predefined fields mandating direct entry or selection from drop-down menus. Our database tracked patient demographics, block characteristics, operator characteristics, and morbidity events.

During the study period, there were between 5 and 6 full-time anesthesiologists responsible for the regional anesthesia service. Our regional anesthesia practice is an academic model in which fellows and residents are under the supervision of staff

From the Department of Anesthesiology, Dartmouth-Hitchcock Medical Center, Lebanon, NH.
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Address correspondence to: Brian Daniel Sites, MD, Dartmouth-Hitchcock Medical Center, Department of Anesthesia and Pain Management, One Medical Center Dr, Lebanon, NH (e-mail: brian.sites@hitchcock.org).
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anesthesiologists. A staff anesthesiologist has discretionary authority regarding when to take over a regional anesthetic procedure from a trainee. In addition, advanced fellows were allowed to supervise regional anesthetic procedures by residents. Medical students and certified nurse anesthetists do not participate in regional anesthetic procedures at our institution. For the duration of the study period, standing sedation orders were in place for patients having regional anesthesia. These orders consisted of 1 to 4 mg of intravenous midazolam and 25 to 100 μg of intravenous fentanyl, which were titrated for patient comfort and anxiolysis. All of the nerve blocks were performed using ultrasound guidance, plus or minus the use of nerve stimulation. For a given nerve block, our practice uses 1 or a combination of the following local anesthetics: 1% lidocaine, 1.5% lidocaine, 2% lidocaine, 2% chloroprocaine, 3% chloroprocaine, 0.2% ropivacaine, 0.5% ropivacaine, 0.25% bupivacaine, and 0.5% bupivacaine. None, 1, or more of the following additives were added to the local anesthetic: clonidine, dexamethasone, epinephrine, and nalbuphine.

For inpatients, postoperative evaluation consisted of a daily visit by a physician member of the regional anesthesia team. Sensory and motor examinations were conducted daily on these patients. For ambulatory patients, a telephone call evaluation was conducted within 3 days of discharge. This telephone call was conducted by a nurse member of the regional anesthesia team and was targeted to confirm sensory and motor block resolution. In addition, we tracked patients about whom we were made aware of possible PONS by patient self-reporting or surgeon notification. If PONS was suspected, the patient was followed up by the surgeons, and recommendations were made for further medical consultation and diagnostic testing. Beyond the aforementioned process, we did not have a systematic examination process to identify non–patient-reported and non–surgeon-reported possible PONS. Table 1 summarizes our postoperative follow-up process and provides an estimate of the rate of success of this process.

Postoperative neurologic symptom was defined by 2 criteria. First, there had to be a patient-reported or evaluator-identified sensory or motor dysfunction present at a minimum of 5 days after surgery. Second, the neurologic dysfunction had to have an anatomic basis to support the possibility of a block contribution. As an example, a common peroneal nerve–related foot drop after a total knee arthroplasty and femoral nerve block would not have been included as a PONS event. Our clinical registry did not track, nor did it try to determine, relative contributions of various possible etiologies for PONS. We further categorized PONS as long term or possibly permanent if it was present for more than 6 months (PONS-L). Local anesthetic systemic toxicity was defined as any event in which the patient experienced unconsciousness, arrhythmias, seizure, or cardiac arrest associated with the injection of local anesthetic. Unintentional vascular puncture was considered to have occurred when blood was aspirated or flowed in the extension tubing connected to the block needle. Arterial blood was presumed to be bright red in comparison to darker venous blood. All immediate complications, such as LAST, clinically symptomatic pneumothorax, unintentional vascular trauma, and unintentional paresthesia were entered into the database in real time.

Statistical Analysis

All analyses were done using STATA (StataCorp LP, College Station, Texas). Continuous variables are reported as mean (SD). Morbidity rates are reported as mean per 1000 blocks, with a corresponding 95% CI. Categorical exposures (sex, block type, local anesthetic type, additives, paresthesia, neuropathy, chronic pain) that were potential risk factors for PONS were analyzed using a Fisher exact test. Continuous exposures (age and needle attempts) that were potential risk factors for PONS were analyzed using a 2-sample t test. Odds ratios were calculated as appropriate. Two-tailed $P \leq 0.05$ were considered statistically significant without adjustments for multiple comparisons.

RESULTS

We analyzed data of a total of 12,668 patients in our database. Men constituted 49.9% of the population with missing sex data on 197 patients (1.55%). The mean age was 55 (17) years. The mean weight was 88 (23.5) kg. There were 184 blocks performed on patients 16 years old or younger. Additional characteristic of our cohort can be found in Table 2.

The most commonly performed blocks were single-injection femoral (34.6%), single-injection interscalene (15.8%), single-injection supraclavicular (11.9%), and single-injection lateral popliteal (7.7%) blocks, making up almost 70% of all blocks

TABLE 1. Postoperative Patient Evaluation

Event	History Taken	Physical Examination	Potential Action Taken for Positive Finding	Audit Results, % Success (n)*
Nurse telephone call for ambulatory patients†	Yes	No	Regional team investigation and database entry	93 (76)
In-patient anesthesia visit‡	Yes	Yes	Entry into database	90 (112)
Ambulatory postoperative surgical clinic visit§	Yes	Yes	Communication by surgical team member to regional team member and entry into database	98 (195)

*Our audit consisted of 200 randomly selected patients. There were 82 ambulatory patients and 118 inpatients. We performed electronic chart reviews to indicate whether the patient had a documented follow-up interaction. Audit results were based on the year 2006 and later because this time interval was when the nursing postoperative assessment was available electronically. Before this, the nursing follow-up was on a paper record.

†Questions posed to patients on telephone call: (1) When did the block wear off? (2) Do you have any residual numbness, tingling, or unusual sensation in the area of the block? (3) Do you have any weakness? 4() Please rate your satisfaction with your regional anesthesia experience.

‡The regional anesthesia team conducted daily clinical rounds and documented a history and physical examination on patients who underwent a peripheral regional anesthetic. The questions asked of inpatients were designed to match that of the nursing ambulatory follow-up telephone call. All potential complications were recorded and entered into the database.

§All patients were scheduled for ambulatory postoperative surgical follow-up. At this visit, patients received postoperative surgical histories and physical exams. We worked closely with our surgical colleagues to receive electronic communication regarding potential cases of postoperative neurologic symptoms.

TABLE 2. Characteristics of Patients

Characteristic*	n	%
Hypertension	3832	30
CAD	1391	11
Diabetes	1398	11
Chronic Pain	831	7
Neuropathy	788	6
COPD	691	5
Depression	502	4
Renal disease	429	3
Ambulatory status†	82	41

*Information entered into registry based on medical record and patient interview.

†Based on a random audit sample of 200 patients. Ambulatory status was not tracked within the clinical registry.

CAD indicates coronary artery disease; COPD, chronic obstructive lung disease

performed. Continuous catheters accounted for 9.8% (femoral 7.5%, interscalene 1.8%) of all blocks. 68% of blocks were performed by a resident, 25% by a fellow, and 7% by a staff anesthesiologist.

Of the 12,668 blocks, a single local anesthetic was used in 10,251, 2 different local anesthetics were used in 2343, and information is missing for 74. Of the blocks that were performed with a single local anesthetic, bupivacaine was used in 7564 (73.8%), ropivacaine was used in 2433 (23.7%), lidocaine was used in 238 (2.3%), and chloroprocaine was used in 16 (0.2%). All blocks were placed with ultrasound imaging. In 4972 blocks (39.25%), a nerve stimulator was used, in addition to the ultrasound. A local anesthetic additive was used in 4949 (39.1%) of the nerve blocks. The mean total volume of local anesthetic across all blocks was 25.2 (9.5) mL. Of all blocks, 3187 (25%) blocks were placed as primary surgical anesthetics, with the remaining 9455 (75%) placed primarily for postoperative analgesia.

Table 3 summarizes the incidence of PONS associated with our regional anesthesia practice. The incidence (per 1000 blocks) of adverse events across all peripheral regional anesthetics was 1.8 (95% CI, 1.1–2.7) for PONSs lasting longer than 5 days, 0.9 (95% CI, 0.5–1.7) for PONSs lasting longer than 6 months, 0.08 (95% CI, 0.0–0.4) for seizure, 0 (95% CI, 0–0.3) for pneumothorax, 0 (95% CI, 0–0.3) for wrong block location, 0.6 (95% CI, 0.2–1.2) for unintended venous puncture, 1.2 (95% CI, 0.7–2.0) for unintended arterial puncture, 2.0 (95% CI, 1.2–3.0) for patients having unintended paresthesia during block placement, and 0 for cardiac arrest (95% CI, 0–0.3).

Using univariate analyses, we found no correlations between the risk for PONS and paresthesia at time of block placement ($P = 0.9$), chronic pain ($P = 0.2$), preexisting neuropathy ($P = 0.5$), sex ($P = 0.2$), age ($P = 0.8$), type of local anesthetic used ($P = 0.2$), use of block additives, such as clonidine ($P = 0.8$), or the number of block attempts ($P = 0.99$). In addition, a subanalysis of PONS-L revealed that none of these factors were associated with an increased risk for injury. There was a trend toward an increased incidence of PONS-L in the continuous nerve blocks (2.4/1000) compared with single-injection nerve blocks (0.7/1000; odds ratio [OR], 3.5; 95% CI, 0.6–14.4; $P = 0.08$).

We conducted an exploratory analysis to determine if there were specific blocks that were associated with a higher incidence of PONS. Interscalene blocks (continuous and single injection combined) were associated with an elevated risk of long-term PONSs (3.1/1000; OR, 6.6 [95% CI, 1.8–26.3; $P = 0.002$] compared with not having an interscalene block 0.5/1000).

Two patients had persistent paresthesia in the first to third fingers after interscalene blocks and shoulder arthroscopies. One patient had persistent numbness in the fifth finger and forearm after a shoulder arthroscopy with an interscalene block. There was 1 report of ear and jaw numbness that persisted after an interscalene block for a total shoulder arthroplasty. Also, after an interscalene block for a total shoulder arthroplasty, 1 patient with preexisting vitamin B_{12} deficiency neuropathy reported decreased sensation in the lateral antebrachial cutaneous dermatome and the inability to extend the thumb. After an interscalene block for a shoulder arthroscopy, 1 patient developed biceps weakness and an electromyogram (EMG) finding of a root-level brachial plexus injury. As previously reported, 1 patient, after an interscalene block and total shoulder arthroplasty, sustained a permanent brachial plexus injury with incapacitating motor and sensory loss.[7] After a popliteal sciatic block for resection of a Haglund deformity, 1 patient had decreased plantar flexion and sensory loss in the tibial and common peroneal nerve distributions. After a popliteal sciatic nerve block for an ankle ligament repair, 1 patient sustained a foot drop associated with an EMG

TABLE 3. Postoperative Neurological Symptoms by Block Type

Block Type	n (%)	PONS	PONS-L
Femoral	4377 (34.6)	4 (0.9) [0.2–2.3]	1 (0.2) [0–1.2]
Interscalene	2003 (15.8)	7 (3.5) [1.4–7.3]	5 (2.5) [0.8–5.8]
Supraclavicular	1508 (11.9)	3 (2.0) [0.4–5.8]	0 (0) [0–2.4]
Popliteal (lateral)	977 (7.7)	4 (4.0) [1.1–10.4]	3 (3.1) [0.6–8.9]
Femoral (continuous)	952 (7.5)	1 (1.0) [1.1–10.4]	1 (1.0) [1.1–10.4]
Interscalene (continuous)	230 (1.8)	3 (12.0) [2.7–37.6]	2 (8.7) [1.0–31.1]
Axillary	42 (0.3)	1 (23) [0.6–125.7]	0 (0) [0–84]
Other	2579 (20.4)	0	0
Total	12,668 (100)	23 (1.8) [1.1–2.7]	12 (0.9) [0.5–1.7]

Values for PONS and PONS-L are expressed as n (n/1000) [95% CI].

Other indicates remaining blocks (n) consisting of ankle (1147), wrist (536), popliteal-prone (376), sciatic-nonpopliteal (147), obturator (101), paravertebral (62), infraclavicular (60), transversus abdominus plane (53), infraclavicular-continuous (32), popliteal-continuous (17), intersternocleidomastoid (14), cervical plexus (13), supraclavicular-continuous (13), lateral femoral cutaneous (6), ilioinguinal (1), and suprascapular (1); PONS, any duration postoperative neurologic symptoms; PONS-L, postoperative neurologic symptoms lasting longer than 6 months.

TABLE 4. Characteristics Associated With the Twelve Long-Lasting Neurological Symptoms

#	Block	Procedure	Solution	Additives	NS	Comorbidities	EMG
1	Femoral	ACL repair	0.5% B 30 mL	C, 50 μg	Yes	HTN	Yes
2	Popliteal-lateral	Ankle debridement & ligament repair	0.5% B 30 mL	No	No	None	Yes
3	Popliteal-lateral	Ankle ligament repair	0.5% B 30 mL	No	No	None	Yes
4	Interscalene	Shoulder arthroscopy	0.5% B 30 mL	C, 50 μg E, 150 μg	Yes	None	Yes
5	Interscalene	Shoulder arthroscopy	0.5% R 30 mL	No	No	None	Yes
6	Interscalene-continuous	Total shoulder arthroplasty	0.5% R 30 mL	No	No	Vitamin B_{12} deficiency	Yes
7	Popliteal lateral	Resection of Haglund deformity	0.5% R 30 mL	No	No	HTN	No
8	Interscalene	Total shoulder arthroplasty	0.5% B 30 mL	C, 50 μg	No	DM, COPD, HTN	No
9	Interscalene-continuous	Total shoulder arthroplasty	0.5% B 30 mL	No	No	Fibromyalgia	Yes
10	Femoral-continuous	Total knee arthroplasty	0.2% R 30 mL	No	No	None	Yes
11	Interscalene	Shoulder arthroscopy	0.5% B 30 mL	C, 50 μg	No	HTN	Yes
12	Interscalene	Total shoulder arthroplasty	0.5% B 30 mL	C, 50 μg E, 150 μg	Yes	MS	Yes

Solution: B indicates bupivacaine; R, ropivacaine.

Additive: C indicates clonidine; E, epinephrine.

Comorbidities: COPD indicates chronic obstructive pulmonary disease; DM, diabetes mellitus; HTN, hypertension; MS, multiple sclerosis.

EMG indicates electromyogram; NS, nerve stimulation.

confirming pathology of the common peroneal nerve. This injury was still present after 18 months. One patient had persistent decreased temperature sensation in the dorsum of the foot after a popliteal sciatic block for ankle debridement and ligament repair. After femoral blocks (1 for a total knee arthroplasty and 1 for an ACL repair), 2 patients sustained EMG confirmed femoral neuropathies associated with significant quadriceps weakness. Table 4 summarizes additional key details of patients with PONS-L.

DISCUSSION

Our clinical registry provides additional insight into the contemporary risks associated with UGRA. The 2 main findings of this analysis are (1) the incidence of LAST was very low, at 0.08 per 1000, and (2) the overall incidence of PONS lasting greater than 6 months was 0.9 per 1000.

Our finding of 1 LAST event in 12,668 is consistent with the low incidence reported by both Barrington et al[5] and Orebaugh et al.[6] Barrington et al reported 3 major LAST events of 8189 blocks, whereas Orebaugh et al recorded 0 in 2000 ultrasound-guided blocks. It is interesting to note that most LAST events in the data of Barrington et al reflect the performance of axillary brachial plexus blocks. In our cohort of patients, we rarely performed an axillary plexus block because of our preference for supraclavicular block.

Our 1 case of LAST was in the context of a continuous femoral block, and this brings to light some of the distinct limitations of ultrasound technology. In this patient, the out-of-plane needle insertion technique, in which the local anesthetic was injected through the block needle before catheter advancement, was used. The local anesthetic was not visualized, although the needle tip was apparently seen. The ultrasound beam generated a short-axis view of the shaft of the needle in which the tip was actually intravascular. This limitation of ultrasound illustrates the fact that a 2D ultrasound beam provides little volume information. When imaging the block needle in short-axis, it can be challenging to confirm needle tip location. The events linked to this case of LAST also seem to validate the recommendations of the American Society of Regional Anesthesia (ASRA) with respect to the injection sequence. That is, the ASRA Joint Committee on UGRA recommends that practitioners cease the injection and reposition the needle if the local anesthetic is not sonographically visualized.[8]

With respect to PONS, Brull et al[9] recently reviewed 16 cohort and case-control trials conducted between 1995 and 2005 to examine the incidence of PONS associated with peripheral regional anesthesia. These trials identified 399 events in 22,414 nerve blocks, resulting in an injury rate of 18 per 1000. However, only 1 reported nerve injury that lasted longer than 12 months (0.04/1000). We have identified a long-term PONS rate of 0.9 per 1000 based on a 6-month definition. Our rate represents a potential 22-fold increase in long-term PONS in comparison to the meta-analysis of Brull et al. Obvious difficulties arise when trying to compare rates and events between institutions, such as durational definitions (ie, 6 versus 12 months), neurologic injury definitions, completeness of the postoperative evaluation, and sensitivity of the reporting infrastructure. One concern we have regarding the external validity of the data of Brull et al is that, even if no blocks were performed, we would expect to see a higher risk of nerve injury associated with 44,859 operative procedures. From a comprehensive clinical registry at the Mayo Clinic, Jacob et al[10] reported 47 unresolved nerve injuries in 12,998 total hip replacements, an incidence rate of 3.6 per 1000 with a 95% CI of 2.6 to 4.8 per 1000. Thus, if we assumed conservatively that the baseline rate across all surgery was 50% less than the lower CI bounds of the data from Jacob et al, we would expect to see approximately 29 long-term injuries in the 22,414 patients summarized by Brull et al. Thus, we call into question the data collection strategies and definitions used by the individual authors cited in the meta-analysis of Brull et al. Variances in the rigor of data collection, completeness of follow-up, assignment of causality, and definitions of nerve injuries are likely responsible for differences in risk reporting, especially in the setting of rare occurrences.

We would like to emphasize that our incidence of PONS represents a perioperative phenomenon in which the exact etiology of the nerve injury is, as usual, unclear. We subscribe to the

theory of Hebl,[11] in that perioperative nerve injury is multifactorial and likely occurs as a result of multiple results, such as preexisting lesions, surgical trauma, block related trauma, local anesthetic effects, and position-related trauma. Thus, beyond methodical differences, our apparent higher rate of PONS compared with historical norms may reflect differences in our institution's surgical approaches, nerve block approaches, anesthetic management, underlying patient characteristics, as well as our definition of what constitutes a reportable adverse regional anesthetic event. From the detailed chart review and interviews of the 12 patients who sustained long-term neurologic symptoms, it is not possible to rule out involvement of the peripheral nerve block. With respect to the nerve block approach, it would be too simplistic to summarize our technique with 1 description. As is true at most institutions, we have a varying and evolving practice with multiple providers. The common approach, however, is the use of ultrasound guidance with or without nerve stimulation. When PONS met our working definition, we deliberately did not attempt to distinguish between a primary surgical-, positional-, or nerve block–related etiology. This approach was influenced by the fact that it is often impossible to determine the exact etiology or to rule out multiple causes. Further, it is our conviction that from a patient's perspective, this is a largely irrelevant distinction. Our fundamental objective should be to provide patients with a conservative estimate of the risk of regional anesthesia in the context of a surgical intervention. Hence, we are reporting all injuries where the nerve block could have conceivably contributed to the adverse event versus reporting only those that are certainly attributable to the block. This inclusive approach should be more helpful in the process of shared decision making compared with an approach that only counts PONSs that are, with absolute certainty, due to the nerve block.

Our results also corroborate the relative safety of the ultrasound-guided supraclavicular nerve block in pneumothorax risk, with 0 cases in 1508 blocks. Conventional landmark techniques have been cited with a risk rate as high as 6%, making this block unpopular in the preultrasound era.[12] From a retrospective view, Perlas et al[13] reported 0 cases of pneumothorax in 510 patients. The ability to easily image the first rib and pleura likely contributes to the safety of this block. It should be noted that our results of 0 cases in 1508 is still consistent with a pneumothorax rate as high 2.4 per 1000, which represents the upper bound of the 95% CI.

Our data represent a retrospective cohort study that is subject to the distinct limitations related to the lack of randomization and possible confounding. The P value of 0.002 associated with an increased PONS risk from an interscalene block should be viewed with caution because of the multiple blocks that were examined and the lack of adjustment for multiple comparisons. In addition, we suspect that the apparent relationship between interscalene blocks and PONS is confounded by multiple variables, such as the surgical procedure. Given the small number of events, multivariate adjustment was not possible. Our technical performance of UGRA likely changed during the 8-year study period, as did the anesthesia and surgical providers. How these institutional changes affected morbidity and quality is unmeasured. Furthermore, we did not track several variables that could have affected our morbidity rates, such as evolving ultrasound technologies, nuances of supervision styles, and specifics of novice behaviors. Finally, our incidence rate of long-term PONS should be viewed as a best-case scenario. That is, our process of identifying patients who sustained neurologic injury likely missed some cases secondary to failed follow-up. This failed follow-up could have arisen from several scenarios, such as inaccurate anesthesia assessment, patient lost to follow-up, or poor surgical communication. The end result is that our findings should be considered an underestimation of the true long-term PONS rate.

In conclusion, in our academic UGRA practice, we report 1 case of LAST in 12,688 patients. The incidence of long-term PONS was found to be 0.9 per 1000, which is higher than that deduced from historical controls and textbook references. Given the low absolute rate of events, the ability to identify independent predictors of LAST and PONS will depend on the collaboration of multiple centers. Such collaboration would ideally exist through the use of a shared clinical registry in which data elements and outcome measures could be standardized. Given the popularity of peripheral regional anesthesia, our shared efforts would likely translate into the ability to truly risk adjust and, perhaps, make a safe practice even safer.

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