Perioperative Nerve Injury After Total Shoulder Arthroplasty

Assessment of Risk After Regional Anesthesia

Hans P. Sviggum, MD, Adam K. Jacob, MD,* Carlos B. Mantilla, MD, PhD,* Darrell R. Schroeder, MS,† John W. Sperling, MD,‡ and James R. Hebl, MD**

Background and Objectives: One of the most debilitating complications after total shoulder arthroplasty (TSA) is perioperative nerve injury (PNI). Interscalene blockade (ISB) improves clinical outcomes after TSA, but it may increase the risk for PNI. The objective of this large-scale, single-institution cohort study was to test the hypothesis that the use of ISB increases the risk for PNI after elective TSA.

Methods: All patients 18 years and older and undergoing primary elective TSA at Mayo Clinic Rochester between 1993 and 2007 were identified. The primary outcome was the presence of new PNI documented within 3 months of the procedural date. The frequency of PNI was summarized using point estimates, along with 95% confidence intervals (CIs) that were calculated using the Poisson approximation. Multivariable logistic regression was used to evaluate potential risk factors for PNI.

Results: A total of 1569 patients underwent elective TSA during the study period; 35 cases met criteria for PNI. The overall incidence of PNI was 2.2% (95% CI, 1.6%–3.1%). Use of ISB was associated with reduced odds for PNI (odds ratio [OR], 0.47; 95% CI, 0.24–0.93; $P = 0.031$). Sex (OR, 0.85; $P = 0.645$) and operative time (OR, 1.07 per 30-minute increase; $P = 0.263$) were not associated with PNI. Most patients with PNI (97%) experienced complete or partial neurologic recovery at last documentation.

Conclusions: The incidence of PNI (2.2%) is consistent with previous estimates in patients undergoing TSA. The use of ISB did not increase the risk for PNI. Most patients with PNI had improvement of their neurologic symptoms. These results further support the use of ISB analgesia for patients undergoing TSA.

(*Reg Anesth Pain Med* 2012;37: 490–494)

Perioperative nerve injury (PNI) is one of the most debilitating complications of surgery that commonly results in functional impairment, chronic pain, and decreased quality of life.[1,2] Several procedural and patient-related characteristics have been implicated in the development of PNI.[3–5] Specifically, orthopedic surgical procedures may place patients at higher risk for PNI because of intraoperative trauma, stretch, or mechanical compression of neural structures.[6] The incidence of neurologic dysfunction after total shoulder arthroplasty (TSA) has been estimated at 0.8% to 4%.[7–10] Although most cases of PNI completely resolve, some patients experience prolonged or permanent disability and pain.[8,11] Because of this, it is important for anesthesia providers to recognize important and potentially modifiable risk factors that may predispose patients to PNI.

Interscalene blockade (ISB) has been shown to provide superior analgesia, reduce nausea, improve functional outcomes and patient satisfaction, and facilitate early hospital discharge after shoulder procedures.[7,12–15] Although ISB is a well-accepted technique for postoperative analgesia after TSA, it may lead to serious complications, including PNI.[4,16] The incidence of neurologic complications after ISB varies depending on the definition of nerve injury and method of detection. Individual studies have estimated nerve injury rates after ISB to be as low as 0.03%[17] and as high as 14%.[12]

Previous studies evaluating PNI after ISB have included patients undergoing a wide range of upper extremity surgical procedures[12,18] across multiple institutions.[17,19] Several studies evaluating the risk of PNI after TSA have also been performed; however, none have evaluated the impact of regional anesthesia.[9,10,20] Furthermore, no studies have compared the risk for neurologic complications between unique patient groups with and without ISB. This makes specific surgical-, anesthetic-, and patient-related risk factors for PNI difficult to assess.[2,9–11,16,17,21] In recent large-scale, single-institution studies of PNI after total knee[22] and total hip arthroplasty,[23] the use of peripheral and neuraxial regional anesthetic techniques did not increase the risk for PNI. However, the association between PNI and ISB for TSA has not been previously examined in large-scale clinical investigations. Therefore, the objective of this single-institution, single procedural cohort study was to test the hypothesis that the use of ISB increases the risk for PNI after elective TSA.

METHODS

After Mayo Clinic Institutional Review Board approval and written informed consent, all patients 18 years and older who underwent elective TSA at Mayo Clinic between January 1, 1993, and July 1, 2007, were identified using the Mayo Clinic Total Joint Registry. Study inclusion was restricted to the first elective TSA performed at Mayo Clinic for any given patient identified within the Total Joint Registry. Patients who declined research authorization were excluded per state statute (Minnesota). Patients were also excluded if they were younger than 18 years, if a matched anesthesia record (patient name, date of birth, and surgical date) was not identified within the Mayo Clinic Department of Anesthesiology Quality Database, or if they underwent surgery on multiple joints during the same surgery.

Patient demographics (sex, date of birth, height, weight), date of surgery, side of surgery, surgeon, operative time, and type of surgery (primary, revision) were recorded from the Total Joint Registry. Previous studies have validated data collection through the Total Joint Registry.[24] Data included within the Total Joint Registry have been prospectively defined and are collected

From the Departments of *Anesthesiology, †Health Sciences Research, and ‡Orthopedic Surgery, Mayo Clinic, Rochester, MN.
Accepted for publication April 24, 2012.
Address correspondence to: Adam K. Jacob, MD, Department of Anesthesiology, Mayo Clinic, 200 First St SW, Rochester, MN 55905 (e-mail: jacob.adam@mayo.edu).
The authors declare no conflict of interest.
This work represents a collaborative effort of Mayo Clinic's Departments of Anesthesiology, Orthopedic Surgery, and Health Sciences Research.
Support for this study provided from the Department of Anesthesiology, Mayo Clinic, Rochester, Minnesota.
Material from this article was presented at the American Society of Anesthesiology Annual Meeting, October 14–19, 2011, Chicago, Illinois.

ISSN: 1098-7339
DOI: 10.1097/AAP.0b013e31825c258b

postoperatively by manual chart review, written patient questionnaire, and follow-up telephone surveys that are conducted at 1, 2, and 5 years and at 5-year intervals thereafter. The telephone surveys are continually updated by 4 full-time research assistants unaware of the present study hypothesis.

All anesthesia-related data, including the use of ISB, were collected from the Mayo Clinic Department of Anesthesiology Quality Database. All patients underwent general anesthesia as the primary anesthetic. All ISB procedures were used for postoperative analgesia and performed as a single-injection technique.

The primary outcome variable, PNI, was defined as the presence of a new sensory or sensorimotor deficit documented in the medical record within 3 months of the surgical date. Potential cases of PNI were identified using a comprehensive list of complications recorded within the Total Joint Registry. All cohort patients coded in the Total Joint Registry as having a "nerve-related complication" were considered as potential cases of PNI. The medical records of all potential cases of PNI were reviewed in detail by one of the investigators (H.P.S.). Specific neurologic findings based on patient report, physical examination, and electrodiagnostic or imaging studies were collected using a standardized data collection form. Patients with preexisting sensory or motor deficits (eg, diabetic peripheral neuropathy, cervical radiculopathy, multiple sclerosis) that were *unchanged* in the postoperative period or were deficits first appearing more than 3 months after surgery were excluded by manual chart review. New neurologic deficits were classified as either sensory or sensorimotor based on the subjective and/or objective findings documented in the medical record. Subjective findings for neurologic deficit were defined as patient reports of numbness, paresthesias, tingling, or dysesthesias in the surgical limb. Objective findings for neurologic deficit were defined as weakness or decreased sensation documented during physical examination or abnormalities detected during electromyogram or nerve conduction studies.

All cases of PNI were followed until complete resolution of neurologic symptoms, or the date of the last documented follow-up. Documentation of neurologic status was recorded within defined periods (<1, 1–3, 3–6, 6–12, or >12 months) to assess timing of neurologic recovery. The degree of neurologic recovery was defined as complete (ie, neurologic status returned to baseline), partial (ie, symptoms improved but residual deficit remained), or none (ie, deficit unchanged from initial description) consistent with predefined diagnostic criteria as described in prior studies.[12] Neurologic symptoms of brachial plexopathy or symptoms involving a specific nerve root (s) were classified as injuries possibly associated with the ISB. Neurologic symptoms involving a single, peripheral nerve distribution (eg, ulnar nerve) were classified as unlikely related to the ISB.

Statistical Analysis

The frequency of perioperative neurologic complications was summarized using point estimates, along with corresponding 95% confidence intervals (CIs) that were calculated using the Poisson approximation to the binomial distribution. Age, sex, operative time, type of procedure, and the use of ISB were evaluated as potential risk factors for PNI, using univariate analysis. In addition to the use of ISB, sex and operative time were further evaluated as potential risk factors for PNI, using multivariable logistic regression based on previous significance.[10,23] Age and operative time were analyzed as continuous variables, and all other variables were analyzed as nominal variables. Among patients who experienced PNI, the degree of neurologic recovery and time to maximal recovery (<1, 1–3, 3–6, 6–12, or >12 months) was compared using the χ^2 test. Two-tailed $P \leq 0.05$ were considered to be statistically significant. Continuous variables (eg, age and operative time) are reported as mean (SD), unless indicated otherwise. Categorical variables are reported as frequency percentages. All analyses were performed using SAS version 9.1 (SAS Institute Inc, Cary, North Carolina).

RESULTS

A total of 1655 patients underwent elective TSA procedures during the 15-year study period. After excluding 86 patients who declined research authorization or met 1 or more exclusion criteria, the first TSA procedures of 1569 patients were included for study analysis. Patient and surgical characteristics are listed in Table 1. Mean patient age was 66 (12) years. Primary TSA procedures were performed in 1412 (90%) of patients; revision procedures were performed in 157 patients (10%).

Forty potential cases of PNI were initially identified from the Total Joint Registry. After manual chart review, 5 of these cases did not meet inclusion criteria for PNI. Therefore, a total of 35 cases of PNI were included for study analysis. The overall incidence of PNI after TSA was 2.2% (95% CI, 1.6%–3.1%).

TABLE 1. Incidence of PNI Among 1569 Patients Undergoing TSA During a 15-Year Period

		PNI,	Univariate Analysis*		
	N	n (%)	OR	95% CI	*P*
Overall	1569	35 (2.2)			
Sex					0.604
Male	739	18 (2.4)	1.00		
Female	830	17 (2.1)	0.85	0.43–1.64	
Age, y			0.90	0.70–1.16	0.402
18–49	133	4 (3.0)			
50–59	210	7 (3.3)			
60–69	444	7 (1.6)			
70–79	599	12 (2.0)			
≥80	183	5 (2.7)			
Type of surgery					0.775
Primary	1412	32 (2.3)	1.00		
Revision	157	3 (1.9)	0.84	0.25–2.78	
Interscalene blockade					0.017
No	431	16 (3.7)	1.00		
Yes	1138	19 (1.7)	0.44	0.22–0.86	
Operative time, min			1.10	0.98–1.24	0.113
≤120	147	3 (2.0)			
121–180	470	12 (2.6)			
181–240	596	10 (1.7)			
>240	356	10 (2.8)			
Study period					0.417
1993–1997	413	6 (1.5)	1.00		
1998–2002	470	13 (2.8)	1.93	0.73–5.12	
2003–2007	686	16 (2.3)	1.62	0.63–4.17	

N = total of number of patients per patient characteristic and surgery type category; n (%) denotes the number (and %) of patients who experienced PNI within each category.

*Results are from univariate analysis predicting perioperative nerve injury. Age is modeled as a continuous variable with odds ratios presented for a 10-year increase in age. Operative time is modeled as a continuous variable with odds ratios presented for a 30-minute increase in surgical duration.

OR indicates odds ratio; CI, confidence interval; PNI, perioperative nerve injury; TSA, total shoulder arthroplasty.

Because the use of ISB may have become more common over time, the 15-year study period was divided into tertiles to assess the incidence of PNI in each 5-year period. Interscalene nerve blockade was performed in 53%, 76%, and 82% of TSA patients during the periods 1993 to 1997, 1998 to 2002, and 2003 to 2007, respectively. Despite a progressively higher percentage of patients receiving ISB during the periods, the incidence of PNI did not differ significantly over time ($P = 0.407$; Table 1).

Univariate analysis found that potential PNI risk factors of age, sex, type of procedure (primary versus revision), and operative time were not associated with PNI (Table 1). Use of ISB was significantly associated with lower odds for PNI (OR, 0.44; 95% CI, 0.22–0.86). After adjusting for sex and operative time in multivariable logistic regression, use of ISB was still significantly associated with lower odds for PNI (OR, 0.47; 95% CI, 0.24–0.93; Table 2).

The characteristics and clinical course of all nerve injuries are summarized in Table 3. A combined sensorimotor deficit was the most common presentation of PNI (n = 29, 83%). Most sensorimotor deficits (24/29, 83%) were documented during the patient's hospitalization. Six cases (17%) presented as an isolated sensory deficit, with only 1 patient (17%) having his/her deficit documented before hospital dismissal. Overall, 14 patients (40%) had deficits within the distribution of a single peripheral nerve, whereas 21 patients (60%) had more diffuse neurologic symptoms, including deficits involving more than 1 peripheral nerve or a partial or complete brachial plexopathy.

Median (25th, 75th) length of follow-up was 2.6 (1.6, 5.3) years. Of the 35 patients with PNI, 25 (71%) had complete neurologic recovery, 9 (26%) experienced partial recovery, and 1 (3%) had no improvement in symptoms at the last documented follow-up (36 months after surgery). Six months after surgery, 18 patients (52%) had achieved maximal neurologic recovery, with 14 experiencing complete recovery. Twelve months after surgery, an additional 12 patients (34%) achieved maximal neurologic recovery, with 9 experiencing complete recovery. Five patients (14%) required more than 12 months to achieve their maximal degree of neurologic recovery, with 2 patients experiencing complete recovery. There was no significant difference in the maximal degree of neurologic recovery in patients with sensorimotor deficits compared with patients with isolated sensory deficits ($P = 0.148$).

Nineteen patients who received an ISB experienced a PNI. Ten (53%) experienced neurologic deficits or symptoms possibly related to the ISB; the remaining 9 deficits (47%) were in a nerve distribution unrelated to the ISB. Of the 19 patients who received ISB and experienced a PNI, 14 (74%) had complete neurologic recovery. Eight (57%) of these injuries completely recovered within 6 months after surgery, 5 (36%) recovered within 12 months, and 1 (7%) took more than 12 months to achieve complete recovery. In addition to those who experienced complete recovery, 4 patients (21%) experienced partial recovery. Of these 4 patients, 2 (50%) experienced maximal recovery within 6 months after surgery, 1 (25%) within 12 months after surgery, and 1 (25%) took more than 12 months to experience maximal recovery. One patient (5%) who received ISB experienced a sensory neuropathy in the fourth and fifth fingers of her ipsilateral hand and had no improvement in neurologic symptoms after 3 years. Of the 16 patients who did not receive an ISB and experienced a PNI, 11 (69%) had complete neurologic recovery. Six (55%) of these injuries recovered within 6 months after surgery, 4 (37%) recovered within 12 months, and 1 (9%) took more than 12 months to achieve complete recovery. In addition to those who experienced complete recovery, 5 patients (31%) experienced partial recovery. Of these 5 patients, 2 (40%) experienced maximal recovery within 6 months after surgery, 1 (20%) within 12 months after surgery, and 2 (40%) took more than 12 months to experience maximal recovery. Overall, the use of ISB did not influence the type of neurologic deficit ($P = 0.499$), the maximal degree of neurologic recovery ($P = 0.532$), or the time to maximal resolution of neurologic deficits ($P = 0.750$).

TABLE 2. Multivariable Analysis of Patient and Procedural Risk Factors for PNI in Patients Undergoing TSA

Characteristic	OR	95% CI	*P*
Female	0.85	0.44–1.67	0.645
Operative time	1.07	0.95–1.21	0.263
Interscalene blockade	0.47	0.24–0.93	0.031

Results are from a multivariable logistic regression predicting perioperative nerve injury. Operative time is modeled as a continuous variable with odds ratios presented for a 30-minute increase in surgical duration.

OR indicates odds ratio; CI, confidence interval; PNI, perioperative nerve injury; TSA, total shoulder arthroplasty.

TABLE 3. Characteristics and Clinical Course of PNI After TSA

Characteristic	PNI Cases (n = 35)
Type of peripheral nerve blockade	
None	16 (46)
Interscalene	19 (54)
Type of nerve injury	
Sensory	6 (17)
Sensorimotor	29 (83)
Neurologic deficit documented before hospital discharge	
No	11 (31)
Yes	24 (69)
Neurology consultation obtained	
No	27 (77)
Yes	8 (23)
EMG obtained	
No	24 (69)
Yes	11 (31)
Degree of neurologic recovery	
None	1 (3)
Partial	9 (26)
Complete	25 (71)

Values are n (%).

EMG indicates electromyogram; PNI, peripheral nerve injury; TSA, total shoulder arthroplasty.

DISCUSSION

This single-center, single-procedure, large-scale cohort study identified an incidence of PNI of 2.2% after elective TSA, which is comparable to previous studies.[9–11] Furthermore, the odds of PNI did not increase with the use of ISB. Although previous studies have evaluated the incidence of PNI after ISB,[12,14,17,18] this is the first large-scale study that specifically examines the association of PNI and ISB in a cohort of patients undergoing

TSA. In patients who developed neurologic complications, more than 95% experienced complete or partial neurologic recovery by the time of the last documented follow-up visit. Finally, the type of neurologic deficit, the time to maximal neurologic recovery, and the degree of neurologic recovery were not associated with the use of ISB.

Interscalene blockade is the most commonly used regional anesthetic technique for postoperative analgesia after shoulder surgery. Improvements in short-term clinical and functional outcomes are well described.[7,12–15] A survey of patients who underwent shoulder surgery with and without ISB reported a preference for ISB, citing improved analgesia and less nausea and vomiting with the use of ISB.[15] Previous prospective studies have demonstrated an association of PNI and ISB.[12,14] The incidence of persistent neurologic sequelae unrelated to surgery 1 month after ISB was determined to be 7.9% by Borgeat et al[12] and 3.3% by Candido et al.[14] However, it is unclear how much, if any, additional risk nerve blockade places on patients in addition to other known patient and surgical risk factors.[4,10,14] The absence of increased risk for PNI after ISB identified in the present study is consistent with previous speculation by Borgeat and Blumenthal,[25] that neurologic injury during TSA may be more likely to result from improper patient positioning or neural stretch from surgical exposure during placement of the glenoid component instead of mechanical or toxic injury related to ISB.

Most cases of nerve injury identified in the present study were combined sensorimotor deficits. This is consistent with previous investigations that have reported a greater proportion of neurapraxic injuries resulting in sensorimotor deficits after TSA.[8–11] However, prospective observational studies by Candido et al[14] and Borgeat et al[12,26] examining neurologic sequelae after ISB found that most nerve injuries involved only sensory deficits (eg, paresthesia, dysesthesia). Nonetheless, only a small proportion of patients in each of these studies underwent TSA. This might further suggest that TSA procedures carry greater inherent procedure-related risk for neuropraxic injuries compared with less invasive procedures (eg, arthroscopic rotator cuff repair).

Although most experts agree that the overall incidence of neurologic complications after PNB is low,[17,21] the estimated rates of nerve injury should be interpreted in the context of study limitations. Surveys that use physician self-reporting introduce reporting bias, whereas short-term data collection (eg, 48 hours after surgery) could fail to recognize late-onset deficits and therefore introduce a timing bias. Indeed, some cases of PNI may not become apparent until several days or even weeks after the surgical event.[10,12,14] For example, 26% of PNI cases after knee surgery[22] and 33% of PNI cases after hip surgery[23] were reported after hospital discharge. In addition, a large number of patients are needed to reliably capture the true incidence of rare events like nerve injury. Furthermore, data capture methods that rely on patient referral to neurology or pain medicine specialists run the risk of identifying only those patients with severe neurologic deficits. Finally, multicenter studies[17,21] may lack standardization of both anesthesia and surgical practices and potentially introduce bias. These limitations are not present within a single-center study design, such as the present study where a large cohort of patients experiencing PNI and undergoing a single surgical procedure was assembled.

In the current study, we identified an overall incidence of PNI of 2.2%—a value similar to previously reported prospective rates of nerve injury in patients undergoing ISB for a variety of elective shoulder procedures.[12] This may suggest that our methodology and ability to identify all possible cases of PNI using prospectively collected data through the Mayo Clinic Total Joint Registry was robust. Overall, most (71%) neurologic deficits completely resolved during the median follow-up of 2.6 years, with an additional 26% of patients experiencing partial recovery. The proportion of injuries with complete recovery in the present study is similar to previously reported rates of PNI recovery after shoulder arthroplasty[9] and other major joint surgery.[22,23]

It is important to recognize the limitations of the current study. First, the method of data collection in the Total Joint Registry introduces the possibility of missing transient yet clinically significant events that may not have been reported by the patient or documented by the surgical team in daily progress notes, dismissal summaries, or outpatient clinic notes. Therefore, even trained abstractors will not be able to identify events that were clinically present and *not* documented by the surgeon or anesthesiologist. Despite a large series of patients, we identified relatively few cases of PNI and even fewer PNI cases that received ISB. Therefore, it is possible that our analysis may have been underpowered to detect a true association of ISB on PNI. Given the prevalent use of regional anesthesia at the authors' institution, a selection bias may have existed in choosing suitable candidates for ISB analgesia. Therefore, the seemingly protective effect of ISB for PNI may be because TSA patients who were at a perceived increased risk (eg, preexisting neurologic disorder, diabetes mellitus, cervical spine pathology) for PNI may have been counseled against the use of regional anesthesia. Finally, other unmeasured patient, surgical, or anesthetic risk factors for PNI, which were not accounted for in the final analysis, may have existed.

In summary, the use of ISB does not increase the risk for PNI in patients undergoing TSA. Therefore, the known functional and clinical benefits of ISB for patients undergoing TSA can be achieved without increasing the risk of neurologic injury. If PNI does occur after TSA, most patients will experience complete or partial neurologic recovery within 12 months of surgery.

ACKNOWLEDGMENT

The authors thank the assistance of Andrew Hanson (Analyst, Department of Biostatistics, Mayo Clinic, Rochester, Minnesota) for statistical support.

REFERENCES

1. Warner MA, Martin JT, Schroeder DR, Offord KP, Chute CG. Lower-extremity motor neuropathy associated with surgery performed on patients in a lithotomy position. *Anesthesiology.* 1994;81:6–12.
2. Warner MA, Warner ME, Martin JT. Ulnar neuropathy. Incidence, outcome, and risk factors in sedated or anesthetized patients. *Anesthesiology.* 1994;81:1332–1340.
3. Neal JM, Bernards CM, Hadzic A, et al. ASRA Practice Advisory on Neurologic Complications in Regional Anesthesia and Pain Medicine. *Reg Anesth Pain Med*. 2008;33:404–415.
4. Neal JM, Gerancher JC, Hebl JR, et al. Upper extremity regional anesthesia: essentials of our current understanding, 2008. *Reg Anesth Pain Med*. 2009;34:134–170.
5. Sorenson EJ. Neurological injuries associated with regional anesthesia. *Reg Anesth Pain Med*. 2008;33:442–448.
6. Welch MB, Brummett CM, Welch TD, et al. Perioperative peripheral nerve injuries: a retrospective study of 380,680 cases during a 10-year period at a single institution. *Anesthesiology.* 2009;111:490–497.
7. Bishop JY, Sprague M, Gelber J, et al. Interscalene regional anesthesia for shoulder surgery. *J Bone Joint Surg Am*. 2005;87:974–979.

8. Bohsali KI, Wirth MA, Rockwood CA. Complications of total shoulder arthroplasty. *J Bone Joint Surg Am*. 2006;88:2279–2292.
9. Chin PY, Sperling JW, Cofield RH, Schleck C. Complications of total shoulder arthroplasty: are they fewer or different? *J Shoulder Elbow Surg*. 2006;15:19–22.
10. Lynch NM, Cofield RH, Silbert PL, Hermann RC. Neurologic complications after total shoulder arthroplasty. *J Shoulder Elbow Surg*. 1996;5:53–61.
11. Boardman ND, Cofield RH. Neurologic complications of shoulder surgery. *Clin Orthop Related Res*. 1999;368:44–53.
12. Borgeat A, Ekatodramis G, Kalberer F, Benz C. Acute and nonacute complications associated with interscalene block and shoulder surgery: a prospective study. *Anesthesiology.* 2001;95:875–880.
13. Brown AR, Weiss R, Greenberg C, Flatow EL, Bigliani LU. Interscalene block for shoulder arthroscopy: comparison with general anesthesia. *Arthroscopy.* 1993;9:295–300.
14. Candido KD, Sukhani R, Doty R, et al. Neurologic sequelae after interscalene brachial plexus block for shoulder/upper arm surgery: the association of patient, anesthetic, and surgical factors to the incidence and clinical course. *Anesth Analg*. 2005;100:1489–1495.
15. Tetzlaff JE, Yoon HJ, Brems J. Patient acceptance of interscalene block for shoulder surgery. *Reg Anesth*. 1993;18:30–33.
16. Fredrickson MJ, Krishnan S, Chen CY. Postoperative analgesia for shoulder surgery: a critical appraisal and review of current techniques. *Anaesthesia*. 2010;65:608–624.
17. Auroy Y, Benhamou D, Bargues L, et al. Major complications of regional anesthesia in France: the SOS Regional Anesthesia Hotline Service. *Anesthesiology.* 2002;97:1274–1280.
18. Liu SS, Zayas VM, Gordon MA, et al. A prospective, randomized, controlled trial comparing ultrasound versus nerve stimulator guidance for interscalene block for ambulatory shoulder surgery for postoperative neurological symptoms. *Anesth Analg*. 2009;109:265–271.
19. Barrington MJ, Watts SA, Gledhill SR, et al. Preliminary results of the Australasian Regional Anaesthesia Collaboration: a prospective audit of more than 7000 peripheral nerve and plexus blocks for neurologic and other complications. *Reg Anesth Pain Med*. 2009;34:534–541.
20. Ladermann A, Lubbeke A, Melis B, et al. Prevalence of neurologic lesions after total shoulder arthroplasty. *J Bone Joint Surg Am*. 2011;93:1288–1293.
21. Auroy Y, Narchi P, Messiah A, Litt L, Rouvier B, Samii K. Serious complications related to regional anesthesia: results of a prospective survey in France. *Anesthesiology.* 1997;87:479–486.
22. Jacob AK, Mantilla CB, Sviggum HP, Schroeder DR, Pagnano MW, Hebl JR. Perioperative nerve injury after total knee arthroplasty: regional anesthesia risk during a 20-year cohort study. *Anesthesiology.* 2011;114:311–317.
23. Jacob AK, Mantilla CB, Sviggum HP, Schroeder DR, Pagnano MW, Hebl JR. Perioperative nerve injury after total hip arthroplasty: regional anesthesia risk during a 20-year cohort study. *Anesthesiology.* 2011;115:1172–1178.
24. Mantilla CB, Horlocker TT, Schroeder DR, Berry DJ, Brown DL. Frequency of myocardial infarction, pulmonary embolism, deep venous thrombosis, and death following primary hip or knee arthroplasty. *Anesthesiology.* 2002;96:1140–1146.
25. Borgeat A, Blumenthal S. Nerve injury and regional anaesthesia. *Curr Opin Anaesthesiol*. 2004;17:417–421.
26. Borgeat A, Dullenkopf A, Ekatodramis G, Nagy L. Evaluation of the lateral modified approach for continuous interscalene block after shoulder surgery. *Anesthesiology.* 2003;99:436–442.