Perioperative Nerve Injury after Total Hip Arthroplasty

Regional Anesthesia Risk during a 20-year Cohort Study

Adam K. Jacob, M.D.,* Carlos B. Mantilla, M.D., Ph.D.,†** Hans P. Sviggum, M.D.,‡
Darrell R. Schroeder, M.S.,§ Mark W. Pagnano, M.D.,‖ James R. Hebl, M.D.#

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ABSTRACT

Background: Perioperative nerve injury (PNI) is a recognized complication of total hip arthroplasty (THA). Regional anesthesia (RA) techniques may increase the risk of neurologic injury. Using a retrospective cohort study, the authors tested the hypothesis that use of RA increases the risk for PNI after elective THA.

Methods: All adult patients who underwent elective THA at Mayo Clinic during a 20-yr period were included. The primary outcome was the presence of a new PNI within 3 months of surgery. Multivariable logistic regression was used to evaluate patient, surgical, and anesthetic risk factors for PNI.

Results: Of 12,998 patients undergoing THA, 93 experienced PNI (incidence = 0.72%; 95% CI 0.58–0.88%). PNI was not associated with type of anesthesia (OR = 0.72 for neuraxial-combined *vs.* general; 95% CI 0.46–1.14) or peripheral nerve blockade (OR = 0.65; 95% CI 0.34–1.21). The risk for PNI was associated with younger age (OR = 0.79 per 10-yr increase; 95% CI 0.69–0.90), female gender (OR = 1.72; 95% CI 1.12–2.64), longer operations (OR = 1.10 per 30-min increase; 95% CI 1.03–1.18) or posterior surgical approach (OR = 1.91 *vs.* anterior approach; 95% CI 1.22–2.99). Neurologic recovery was not influenced by the use of RA techniques in patients with PNI.

Conclusions: The risk for PNI after THA was not increased with the use of neuraxial anesthesia or peripheral nerve blockade. Neurologic recovery in patients who experienced PNI was not affected by the use of RA. These results support the use of RA techniques in patients undergoing elective THA given their known functional and clinical benefits.

What We Already Know about This Topic

- Previous studies suggested regional anesthesia may increase the risk of peripheral nerve injury after joint replacement

What This Article Tells Us That Is New

- In a retrospective review of more than 12,000 patients undergoing total hip replacement, the incidence of peripheral nerve injury was less than 1%
- Peripheral nerve injury was not associated with the type of anesthesia or the use of peripheral nerve blockade

PERIOPERATIVE nerve injury (PNI) is a serious adverse complication of surgery that is associated with debilitating, functional impairment and reduced quality of life.[1–3] Several procedure- and patient-related characteristics have been associated with the development of PNI.[3–6] The risk for PNI is higher for orthopedic surgical procedures than for other surgical interventions (*e.g.*, vascular).[7] Total hip arthroplasty (THA) is one of the most commonly performed orthopedic procedures in the United States, with an incidence of postoperative neurologic complications ranging from 0.08% to 7.6%.[8–13] Although most cases of PNI result in a favorable outcome with complete resolution within weeks to months, some patients may be disabled permanently.[14] It is paramount for anesthesia providers to recognize important and potentially modifiable risk factors that may predispose patients to PNI.

Regional anesthesia (RA) has been shown to provide superior analgesia, improve functional outcomes, and facilitate early hospital discharge after THA.[15] As a result,

* Assistant Professor of Anesthesiology, † Associate Professor of Anesthesiology and Physiology, ‡ Anesthesiology Resident, # Associate Professor of Anesthesiology, Department of Anesthesiology, College of Medicine, Mayo Clinic, Rochester, Minnesota. § Assistant Professor of Biostatistics, Department of Health Sciences Research, College of Medicine, Mayo Clinic. ‖ Professor of Orthopedic Surgery, Department of Orthopedic Surgery, College of Medicine, Mayo Clinic.

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Address correspondence to Dr. Jacob: Department of Anesthesiology, Mayo Clinic, 200 First Street, S.W., Rochester, Minnesota 55905. jacob.adam@mayo.edu. This article may be accessed for personal use at no charge through the Journal Web site, www.anesthesiology.org.

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many patients undergoing THA have neuraxial anesthesia and peripheral nerve blockade incorporated into their anesthetic plan. However, the use of neuraxial or peripheral nerve blockade may expose patients to the risk of needle- or catheter-induced mechanical trauma, local anesthetic neurotoxicity, and the blunting of protective reflexes within an anesthetized extremity, all of which may increase the risk for PNI.[16,17]

The overall incidence of neurologic complications after RA for lower extremity procedures has been estimated to be between 0.03% and 1.5%.[18–20] However, it is unclear if the risk for neurologic complications is comparable between central neuraxial techniques and peripheral techniques.[7,18–20] Previous studies evaluating PNI have several limitations. For example, the inclusion of patients undergoing a broad range of surgical procedures within different surgical practices across multiple institutions may confound the assessment of specific surgical-, anesthetic- or patient-related risk factors for PNI.[3,7,18–21] Additional limitations include the lack of a standardized definition for PNI and the variability in which PNI was assessed (*e.g.*, how and when) during the postoperative period.

In a recent study of PNI after total knee arthroplasty, the use of neuraxial or peripheral RA techniques did not increase the risk for PNI. However, complete neurologic recovery was found to be less likely in patients who received peripheral nerve blockade.[21] The association between PNI and RA use for THA has not been studied in large-scale clinical investigations. Therefore, the objective of this single-institution, large-scale, single-procedural cohort study was to test the hypothesis that the use of RA increases the risk for PNI after elective THA.

Materials and Methods

After Mayo Clinic Institutional Review Board approval and written informed consent were obtained, all patients aged ≥18 yr who underwent elective THA at Mayo Clinic from January 1, 1988, to July 1, 2007, were identified using the Mayo Clinic Total Joint Registry. Previous studies have validated the comprehensive data collection methodology of the Total Joint Registry.[21–23] Data included within the Total Joint Registry has been defined prospectively and is ascertained postoperatively at 1, 2, and 5 yr and at 5-yr intervals thereafter and continually updated by four full-time research assistants unaware of the current study hypothesis.[23]

The process of cohort identification, the definition of primary and secondary outcomes, and the method of data collection for study patients were similar to those described previously for patients undergoing total knee arthroplasty.[21] For every patient who underwent THA identified by query of the Total Joint Registry, the first elective THA performed during the study period was used as the index surgery and included in the current report. Patients who underwent a bilateral or "staged" bilateral procedure or denied research authorization were excluded.

Patient, surgical, and anesthetic characteristics were retrospectively collected from the Total Joint Registry and Anesthesia Quality Database for all patients in the cohort. These data included gender, age, height, weight, surgery side and type, and surgeon. Anesthetic technique was classified as one of the following categories: (1) general anesthesia; (2) neuraxial anesthesia (*i.e.*, intraoperative subarachnoid or epidural anesthesia); or (3) combined neuraxial-general anesthesia. In addition, patients who received (1) posterior lumbar plexus (*i.e.*, psoas compartment), (2) anterior lumbar plexus (*i.e.*, fascia iliaca compartment), or (3) sciatic nerve blockade for postoperative analgesia were identified specifically as having undergone peripheral nerve blockade.

The primary outcome variable was the presence of a PNI, defined as a new or progressive sensory or sensorimotor deficit within 3 months of the surgical date. All cohort patients documented in the Total Joint Registry as having a "nerve-related complication" or "peroneal-sciatic nerve palsy" were considered as potential cases of PNI. The clinical records for all potential cases of PNI were then reviewed in detail by one of the investigators (HPS). Specific neurologic findings based upon physical examination (*e.g.*, paresthesia, numbness, tingling, weakness, foot drop), electrodiagnostic or imaging studies, and documentation of symptom resolution within defined periods (less than 1, 1–3, 3–6, 6–12, or more than 12 months) were collected using a standardized data collection form. Preexisting neurologic deficits that were unchanged during the postoperative period or deficits occurring more than 3 months after surgery were excluded. New neurologic deficits were classified as either sensory or sensorimotor based on subjective or objective findings documented within the medical record. The degree of neurologic recovery was defined as complete (*i.e.*, neurologic status returned to baseline), partial (*i.e.*, symptoms improved but residual deficit remained), or none consistent with predefined diagnostic criteria as described previously.[21]

Statistical Analysis

All analyses were performed using SAS version 9.1 (SAS Institute Inc., Cary, NC). The frequency of PNI was determined using point estimates and reported along with corresponding 95% CI calculated using the Poisson approximation to the binomial distribution. To evaluate potential risk factors for PNI, a logistic regression model was generated using the following variables: age, gender, body mass index (weight/height^2, in kg/m^2), type of procedure (primary *vs.* revision surgery), surgical approach (anterior, posterior, other), operative time, type of anesthesia (general *vs.* neuraxial-combined), and use of peripheral nerve blockade. Because the use of peripheral nerve blockade was introduced during the last 5 yr of the study period, the chi-square test was used for a supplemental analysis to compare the frequency of PNI between patients who received peripheral nerve blockade and those who did not during this calendar period. Among patients who experienced PNI, the degree of

Table 1. Incidence of PNI among 12,998 Patients Undergoing Total Hip Arthroplasty during a 20-yr Period

	Primary			Revision		
		PNI			PNI	
	N	n	(%)	N	n	(%)
Overall	9,844	60	(0.61%)	3,154	33	(1.05%)
Gender						
Male	4,731	22	(0.47%)	1,494	11	(0.74%)
Female	5,113	38	(0.74%)	1,660	22	(1.33%)
Age group (years)						
18–49	1,430	18	(1.26%)	416	7	(1.68%)
50–59	1,466	11	(0.75%)	451	4	(0.89%)
60–69	2,912	10	(0.34%)	822	11	(1.34%)
70–79	3,040	19	(0.63%)	1,052	7	(0.67%)
80 and over	996	2	(0.20%)	413	4	(0.97%)
Type of anesthesia						
General	5,429	39	(0.72%)	2,386	26	(1.09%)
Central-neuraxial	4,151	20	(0.48%)	681	5	(0.73%)
Epidural	1,078	5	(0.46%)	337	3	(0.89%)
Spinal	3,052	15	(0.49%)	337	2	(0.59%)
Combined spinal-epidural	21	0	(0.00%)	7	0	(0.00%)
Combined	264	1	(0.38%)	87	2	(2.30%)
Epidural	120	0	(0.00%)	51	2	(3.92%)
Spinal	144	1	(0.69%)	34	0	(0.00%)
Combined spinal-epidural	0	0	(0.00%)	2	0	(0.00%)
Peripheral nerve blockade						
No	7,855	52	(0.66%)	2,699	29	(1.07%)
Yes	1,989	8	(0.40%)	455	4	(0.88%)
Study period						
1988–1992	1,950	2	(0.10%)	766	2	(0.26%)
1993–1997	2,408	18	(0.75%)	882	17	(1.93%)
1998–2002	2,671	23	(0.86%)	827	9	(1.09%)
2003–2007	2,815	17	(0.60%)	679	5	(0.74%)

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.

PNI = perioperative nerve injury.

neurologic recovery (none, partial, complete) and time to maximal recovery (less than 1, 1–3, 3–6, 6–12, more than 12 months) was compared between patient groups using the chi-square test. Two-tailed P values $\leq$0.05 were considered statistically significant. Continuous variables (*e.g.*, age, body mass index, and operative time) are reported as mean ± SD unless indicated otherwise. Categorical variables are reported as frequency percentages.

Results

A total of 14,097 patients underwent 18,707 elective THA procedures during the study period. After excluding 1,099 patients who met one or more exclusion criteria, the first THA performed at Mayo Clinic was included for the remaining 12,998 patients. A majority (52%) of patients undergoing THA were female, with a mean age of 65 ± 14 yr. Primary THA procedures were performed in 76% of patients; revisions in 24% (table 1). The intraoperative anesthetic technique was general anesthesia in 60%, neuraxial anesthesia in 37%, and combined neuraxial-general anesthesia in 3% of patients. Postoperative analgesic regimens included peripheral nerve blockade in 2,444 (19%) patients. The introduction of posterior lumbar plexus catheters into the practice in 2002 resulted in a significant increase in the number of peripheral nerve blocks performed during the period 2003–2007 (fig. 1).

A total of 166 potential cases of PNI were identified initially from the Total Joint Registry. After manual chart review, 93 cases met predefined criteria for PNI during the study period, for an overall incidence of PNI after elective THA of 0.72% (95% CI 0.58–0.88%). The 20-yr study period was divided into quartiles to assess the incidence of PNI over time. The use of peripheral regional techniques in patients undergoing THA increased over time, from 0.3% of patients for the period of 1988–1992, to 0.1% for the years 1993–1997, to 2.6% (1998–2002), and to 67.1% (2003–2007; $P < 0.001$). Despite a significant increase in the use of peripheral nerve blockade over time, the incidence of PNI did not change significantly ($P = 0.065$) (fig. 1). Because the use of peripheral nerve blockade was substantially higher during the last 5 yr of the study period (fig. 1), a supplemental analysis was performed that was restricted to this calendar

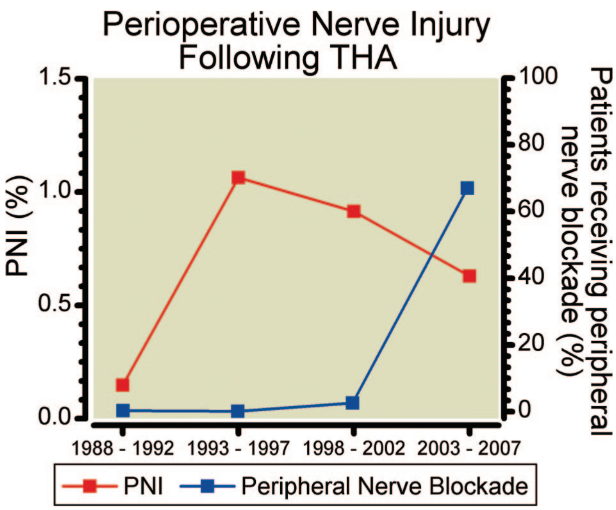

Fig. 1. The incidence of perioperative nerve injury (PNI) after total hip arthroplasty (THA) and the proportion of patients receiving peripheral nerve blockade during the 20-yr cohort study.

period. From this analysis, the rate of PNI was not found to differ significantly between patients who received peripheral nerve blockade (0.5%, 11 of 2,343) and those who did not (1.0%, 11 of 1,151; $P = 0.09$).

Table 1 lists the incidence of PNI according to patient, anesthetic, and surgical characteristics. After multivariable logistic regression, younger age, female gender, longer operative time, and posterior surgical approach were associated with an increased risk for PNI (table 2). The type of intraoperative anesthesia was not associated with increased risk for PNI (OR = 0.72; 95% CI 0.46–1.14 for neuraxial-combined *vs.* general anesthesia), nor was the use of lower extremity peripheral nerve blockade (OR = 0.65; 95% CI 0.34–1.21).

Table 3 summarizes the characteristics and clinical course of all 93 nerve injuries. A combined sensorimotor deficit was the most common presentation of PNI (n = 77; 83%). The majority of these deficits (59 of 77; 77%) were documented during the patient's hospitalization. The remaining 16 (17%) cases of PNI presented as sensory deficits only, with only 3 (19%) cases being documented before hospital dismissal.

Median (25th, 75th) length of follow-up was 4.9 (2.1, 7.5) yr. Five patients had less than 1 yr of follow-up (one patient lost to follow-up; four patient deaths). Overall, 46 (50%) of the 93 cases of PNI experienced complete neurologic recovery. Seventeen (37%) of these 46 patients had complete recovery within 6 months of surgery, 17 (37%) within 12 months of surgery, and the remaining 12 (26%) more than 1 yr after surgery. In addition, 43 (46%) of 93 patients experienced partial recovery during the follow-up period. Seven (16%) of these experienced maximal neurologic recovery within 6 months after surgery, 24 (56%) within 12 months after surgery, and the remaining 12 (28%) more than 1 yr after surgery. Four (4%) of 93 patients with PNI had no improvement in their neurologic symptoms at a median (twenty-fifth, seventy-fifth) follow-up of 2.2 (0.8, 2.2) yr. The median time to maximal resolution of an isolated sensory deficit (7.3 yr) was significantly longer than the median time to resolution of a combined sensorimotor deficit (4.0 yr) ($P = 0.027$).

Twelve patients undergoing peripheral nerve blockade experienced a PNI (1 sensory deficit, 11 combined sensorimotor deficits). Of these, nine (75%) patients experienced a neurologic deficit in a distribution *unrelated* to the peripheral nerve block (*e.g.*, peroneal nerve injury after psoas compartment blockade). In contrast, three (25%) patients experienced neurologic injury in a distribution that may have been related to the nerve block (*e.g.*, injury in a femoral nerve distribution after psoas compartment blockade). In patients with PNI after RA, eight (66%) experienced complete neurologic recovery. Four (50%) of these injuries completely recovered within 6 months after surgery, and the remaining four (50%) injuries recovered within 12 months. All three patients with a PNI in a distribution possibly related to the nerve block experienced complete neurologic recovery. In addition to those who experienced complete recovery, three (25%) patients experienced partial neurologic recovery. One of these three (33%) experienced maximal recovery within 6 months after surgery and the remaining two (67%) within 12 months after surgery. One (8%) patient who received a psoas compartment block experienced peroneal nerve injury and

Table 2. Patient and Procedural Risk Factors for PNI in Patients Undergoing THA

	OR	95% CI	*P* Value
Age	0.79	0.69 to 0.90	<0.001
Gender			0.014
Male	1.00		
Female	1.72	1.12 to 2.64	
Body mass index	1.02	0.86 to 1.22	0.810
Type of surgery			0.321
Primary	1.00		
Revision	1.28	0.79 to 2.07	
Operative time	1.10	1.03 to 1.18	0.003
Surgical approach			0.017
Anterior	1.00		
Posterior	1.91	1.22 to 2.99	
Other	1.43	0.69 to 2.97	
Type of anesthesia			0.163
General	1.00		
Neuraxial-combined	0.72	0.46 to 1.14	
Lower extremity block			0.172
No	1.00		
Yes	0.65	0.34 to 1.21	

Results are from a multivariable logistic regression predicting perioperative nerve injury. Age, body mass index, and operative time are modeled as continuous variables with odds ratios presented for a 10-yr increase in age, 5-kg/m^2 increase in body mass index, and 30-min increase in operative time. The analysis includes only patients with complete data for all risk factors (N = 12,815).

CI = confidence interval; OR = odds ratio; PNI = peripheral nerve injury; THA = total hip arthroplasty.

Table 3. Characteristics and Clinical Course of PNI after THA

	Primary THA (N = 60)		Revision THA (N = 33)		Overall (N = 93)	
	n	(%)	n	(%)	n	(%)
Type of peripheral nerve blockade						
None	52	(87%)	29	(88%)	81	(87%)
Psoas compartment block*	7	(12%)	4	(12%)	11	(12%)
Psoas compartment and sciatic block*	1	(1%)	0		1	(1%)
Type of nerve injury						
Sensory	9	(15%)	7	(21%)	16	(17%)
Sensorimotor	51	(85%)	26	(79%)	77	(83%)
Neurologic deficit documented before hospital discharge						
No	19	(32%)	12	(36%)	31	(33%)
Yes	41	(68%)	21	(64%)	62	(67%)
Neurology consultation obtained						
No	41	(68%)	24	(73%)	65	(70%)
Yes	19	(32%)	9	(27%)	28	(30%)
EMG obtained						
No	35	(58%)	21	(64%)	56	(60%)
Yes	25	(42%)	12	(36%)	37	(40%)
Degree of neurologic recovery						
None	2	(3%)	2	(6%)	4	(4%)
Partial	32	(53%)	11	(33%)	43	(46%)
Complete	26	(44%)	20	(61%)	46	(50%)

* All psoas compartment blocks were continuous; all sciatic nerve blocks were single injection.
EMG = electromyogram; PNI = peripheral nerve injury; THA = total hip arthroplasty.

had no improvement in neurologic symptoms after 2.1 yr. Overall, the type of intraoperative anesthesia did not affect the degree of neurologic recovery ($P = 0.165$) or time to resolution of neurologic deficits ($P = 0.187$). Similarly, the use of peripheral nerve blockade did not influence the degree of neurologic recovery ($P = 0.252$) or time to resolution of neurologic deficits ($P = 0.165$).

Discussion

This single-center, single-procedure, retrospective cohort study identified a low incidence of PNI (0.72%) after elective THA. Risk factors for the development of PNI included younger age, female gender, longer operative time, and a posterior surgical approach. Importantly, the use of neuraxial or peripheral nerve blockade did not increase the risk for PNI. In addition, of the patients who experienced neurologic complications, more than 95% experienced complete or partial neurologic recovery by the time of the last follow-up visit. Finally, the degree of neurologic recovery was not associated with the use of peripheral nerve blockade or neuraxial regional techniques.

The risk factors for PNI identified in the current study are similar to those reported in previous studies,[11,12,24–26] including several risk factors related directly to the surgical technique. For example, the current study identified that a posterior surgical approach and longer operative time were associated with increased risk for PNI. An association between revision THA and PNI has been demonstrated in previous retrospective reviews.[26,27] Although the precise etiology of these findings is unclear, investigators have hypothesized that the increased risk of PNI may result from greater surgical complexity attributable to preexisting scarring, altered anatomy, and relative immobility of the tissue within the surgical field.[26] In addition, complex bone grafting and reconstruction may predispose these patients to direct nerve injury. Although we did not demonstrate an association between revision THA and PNI, it is possible that longer operative times demonstrated in our results are more reflective of surgical complexity.

In addition to surgical risk factors for PNI, we also found that the risk for PNI was greater for younger patients and females. The association between female gender and increased risk for PNI has been reported previously.[13,24,25] However, it is unclear if this association is confounded by a higher prevalence of developmental hip dysplasia (another potential risk factor) within females.[24] The underlying etiology of PNI in females (*vs.* males) is unknown. Some investigators have postulated that the higher incidence of PNI in females may be attributed to reduced muscle mass, vascular anatomic variations, or potentially shorter limbs.[13,28]

Several studies have attempted to quantify the incidence of PNI.[7,18,19,29] Many have focused on neuraxial (spinal and epidural) blockade in their analysis and estimation of overall incidence. Many of these studies used self-reporting surveys of thousands of practitioners from hundreds of medical centers.[18–20] Unfortunately, this methodology introduces the possibility of reporting bias and the problems associated with nonstandardization of both anesthesia and surgical practices. The current investigation, which represents a single institution with a large-volume orthopedic surgical practice, is less susceptible to these sources of bias.

The incidence of neurologic complications after peripheral nerve blockade was examined by Capdevila *et al.* in 2005.[29] The authors prospectively reviewed 1,416 continuous peripheral nerve catheters and reported an incidence of hypoesthesia or numbness in 3% and 2.2% of patients, respectively, and paresthesias in 1.5% of patients. Three neural lesions were noted after continuous femoral nerve blockade, two of which were performed on anesthetized patients, with subsequent resolution ranging from 36 h to 10 weeks. It should be noted that data were collected only up to 5 days after surgery, except in those patients in whom a prolonged neurologic deficit already was documented. Although most cases of nerve injury likely would present during this time period, some cases of neuropathy become apparent only several days or weeks after surgery.[30]

Welch *et al.* recently reported the results of a 10-yr retrospective review of more than 380,000 consecutive patients undergoing all types of procedures and anesthetics.[7] They reported an overall incidence of PNI of 0.03%, with an incidence of 0.05% in orthopedic procedures. In addition, they found that the use of general anesthesia or epidural anesthesia increased the risk of postoperative neuropathy, but there was no difference with the use of peripheral nerve blockade. It should be noted that the authors excluded nerve injuries resulting from the surgical procedure, a factor that may falsely decrease their estimated incidence. Similar to the findings of the study by Capdevila *et al.*,[29] the authors sought information on peripheral neuropathies that were identified only during the first 48 h after surgery. Previous studies have shown that many cases of perioperative neuropathy are first identified more than 48 h after THA surgery.[11,14,25,26]

Although most experts agree that the overall incidence of neurologic complications is quite low, the estimated rates of nerve injury should be interpreted in the context of study limitations. Surveys that use physician self-reporting raise the issue of reporting bias, whereas short-term data collection potentially could fail to recognize late-onset deficits and thus introduce a timing bias. In addition, because of the low complication rate, large numbers of patients are needed to capture the true incidence. Finally, depending upon the method of identifying patients with PNI, only cases of severe injury referred for evaluation may be captured by a search method reliant on hospital diagnoses or billing codes, thus resulting in a severity bias. Together, these issues make it difficult for a single institution to assemble a cohort of patients that have experienced PNI for additional study.

The current study design has a number of strengths. We take advantage of an extremely large volume of elective orthopedic surgical cases at a single tertiary care medical center. Therefore, the variation in both orthopedic and anesthetic practice(s) is limited to a relatively few number of providers. In addition, by including all patients 18 yr of age or older for elective orthopedic surgical procedures, we have not excluded patients at higher risk of experiencing perioperative nerve dysfunction. Finally, our study design relies on the abstraction of procedural complications by unbiased, trained medical record abstractors and thus limits the potential for reporting bias.

There are also some important limitations to our study. First, the retrospective collection of information introduces the possibility of missing transient, yet clinically significant, events that may not be documented by surgeons in hospital dismissal summaries or outpatient clinic notes. Therefore, even trained abstractors may not identify events that were (1) clinically present and *not* documented by the surgeon or (2) initially documented 3 months after surgery. Therefore, we recognize the potential for the underreporting of transient neurologic events (*i.e.*, short-term deficits). Despite a large series of patients, we identified relatively few cases of PNI and even fewer ones in patients who received a regional technique. Therefore, it is possible that our analysis may have been underpowered to detect a true association of RA and PNI. In addition, it is not possible to determine a causal relationship between the use of RA and PNI in retrospective studies. However, only a few cases of neurologic injury in our study were potentially attributed to the RA technique and not to patient or surgical factors. The lack of an association between RA and PNI was also shown for patients who received repeated axillary plexus blockade.[31]

In summary, the use of peripheral nerve blockade or neuraxial anesthesia did not increase the risk of postoperative neurologic complications in patients undergoing elective THA. Fortunately, more than 90% of patients who experienced a PNI experienced partial or complete neurologic recovery. Importantly, the degree of neurologic recovery was not found to be associated with the use of peripheral nerve blockade, type of intraoperative anesthesia, or type of neurologic deficit. Therefore, the documented benefits of RA for patients undergoing THA[15] can be achieved without increasing the risk of neurologic injury.

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