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Risk Factors for Acute Nerve Injury after Total Knee Arthroplasty

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Abstract

Introduction—This study identifies potential risk factors for post-total knee arthroplasty (TKA) nerve injury, a catastrophic complication with a reported incidence of 0.3% to 1.3%.

Methods—Patients who developed post-TKA nerve injury from 1998 to 2013 were identified, and each was matched with 2 controls. A multivariable logistic regression model was built to calculate odds ratios (OR).

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Ethical Publication Statement

We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

Results—65 nerve injury cases were identified in 39,990 TKAs (0.16%). Females (OR 3.28, $p=0.003$) and patients with history of lumbar pathology (OR 6.12, $p=0.026$) were associated with increased risk of nerve injury. Tourniquet pressure <300 mmHg and longer duration of anesthesia may also be risk factors.

Discussion—Surgical planning for females and patients with lumbar pathology should be modified to mitigate their higher risk of neurologic complications after TKA. Our finding that lower tourniquet pressure was associated with higher risk of nerve injury was unexpected and requires further investigation.

Keywords

Surgical complication; Total knee arthroplasty; Nerve palsy; Risk factors; Sex; Spine Disease; Tourniquet Pressure; Anesthesia; Acute nerve injury

Introduction

Although uncommon, nerve injury following total knee arthroplasty (TKA) can cause substantial disability.¹ Patients lose mobility, impacting their ability to work, exercise, and enjoy leisure activities. They may experience neuropathic pain as a consequence of these injuries, which often necessitates aggressive pain medication and may lead to systemic and cognitive side effects. Nerve injury may also lead to litigation by the patient.²

The incidence of nerve injury is inconsistent in the literature.^{1,3} According to a more recent publication, the incidence of nerve injury following TKA ranges from 0.3% to 1.3%.⁴ This variability can be attributed to a range of factors including the specific prosthesis used, the size of the study population, and limitations on reporting of incidence.⁵ The reported incidence may be an underestimation given the likely underreporting of post-surgical nerve compromise.⁵

The number of TKAs performed annually in the United States has doubled in the last decade⁶ to approximately 600,000 per year.⁷ Therefore, between 1,800 and 7,800 patients may develop a postoperative nerve injury each year in the United States. The need to address this issue and identify factors to reduce the risk of nerve injury following TKA is pertinent.

Few risk factors of nerve injury following TKA are consistently reported in the literature. The variation in study methodology may confuse the interpretation of surgical, anesthetic, and patient-related risk factors for nerve injury. Therefore, the objective of this case-control study was to identify any risk factors for post-operative nerve injury following TKA.

Materials and Methods

Following approval from our hospital's Institutional Review Board, we sought to identify all TKA patients who developed an acute nerve injury in the operative limb at our institution between January 1, 1998 and December 31, 2013. This was done as a step-wise process: 1) We identified postoperative injuries using our Quality Management department reports to the New York Patient Occurrence Report and Tracking System (NYPORTS), 2) in order to verify that this included all injuries, we also used electronic hospital records to identify all

patients diagnosed with peroneal nerve injury (956.3); mononeuritis of lower limb (355); unspecified disorder of muscle, ligament, and fascia (728.9); lesion of lateral popliteal nerve (355.3); or other nervous system complications (997.09) using ICD-9-CM codes, and 3) we reviewed our Neurology Department's consult records, which documents all in-patient consultations requested of attending neurologists. Using this log we identified consultations in post-TKA patients with complaints of lower extremity numbness/weakness, leg numbness/ weakness, foot numbness/weakness, thigh numbness/weakness, quadriceps numbness/weakness, decreased sensation in lower extremity, foot drop, and neuropathy. All identified potential cases were reviewed by attending neurologists (TS, AW) to ensure that the cases had been properly identified and that the diagnosis had been confirmed by an attending neurologist at the time of injury.

Demographics and peri-operative factors were reviewed if a patient was identified as having a primary or revision TKA followed by a new postoperative ipsilateral lower extremity nerve injury associated with deficits persisting through discharge. Nerve injury was defined as grade 4/5 or lower motor strength using the Medical Research Council (MRC) grading system of all examined muscle groups in the lower extremity (hip flexors, knee extensors, knee flexors, hip adductors, ankle dorsiflexors, ankle plantar flexors, ankle evertors, ankle invertors, and toe extensors). Review of affected muscle groups allowed localization of nerve injury. We included sciatic, peroneal, and femoral neuropathies but did not differentiate between them for the analyses. Patients with sensory deficit without evidence of motor deficit were excluded. Since TKA is most commonly performed in isolation, we excluded cases with concomitant procedures or hardware removal. Patients were also excluded from the study if their motor weakness largely or fully resolved while in the hospital

Potential risk factors captured through chart review included patient demographics (age, BMI, sex, tobacco use), medical history (diabetes, spine surgery/stenosis/disease, rheumatoid arthritis, Hepatitis B, tibial osteotomy), schedule characteristics (procedure year, day of procedure, time of procedure), intra-operative characteristics (revision, bilateral, length of anesthesia, length of surgery, blood loss, blood pressure, cement used, deep vein thrombosis prophylaxis, tourniquet time, tourniquet pressure), and surgeon experience (years in practice, number of surgical cases from previous year, fellowship training, highest level trainee in operating room (OR), physician's assistant (PA) in OR). We supplemented our diagnosis of lumbosacral spine pathology with spinal MRIs when available.

Each eligible case was matched with 2 control subjects who underwent primary or revision TKA within 7 days of the case's surgical date. Controls were matched on no other information in order to allow for evaluation of as many risk factors as possible. Potential control records were reviewed with the same exclusion criteria applied to cases but with no documentation of nerve injury in their medical record.

Potential risk factors for nerve injury were determined through discussions with attending physicians specializing in orthopedic surgery, neurology, radiology, and anesthesiology and by reviewing literature on nerve injury after TKA.

Continuous variables were tested to determine if the assumption of normality was violated using Shapiro-Wilks tests. Results from those tests confirmed that all continuous variables met the assumption of normality. Comparison of continuous variables between nerve injury cases and controls were analyzed using independent samples t-tests and reported as means and standard deviations. Chi-square and Fisher's exact tests were used for comparison of discrete variables and are reported as frequencies and percentages. Multivariable logistic regression analysis was used to identify potential risk factors and adjust for potential confounding factors. All variables in the bivariate analysis were considered as candidate variables for evaluation in the regression analysis. Because of the exploratory nature of the study, variables that achieved a p-value of $p < 0.10$ following the iterative stepwise procedure, were retained in the final model. Those variables that achieved a p-value of $p \leq 0.05$ were considered statistically significant risk factors for the development of nerve injury. Adjusted odds ratios (OR) and 95% confidence intervals were reported to provide the magnitude of the association. All analyses were performed using SPSS version 22.0 (IBM Corp., Armonk, NY).

Results

39,990 TKAs were performed at our institution and 65 confirmed cases of nerve injury were identified (0.16%). All nerve injuries were mononeuropathies. The nerve injuries included both motor and sensory involvement and were 91% sciatic and/or peroneal and 9% femoral. There were no obturator neuropathies found in this cohort.

Statistical information can be found in Table 1 and supplementary Table 1. In univariate analyses, cases were more likely to be female. The percentage of patients with a previous history of spine disease (lumbar spine disease or spinal stenosis) or spine surgery was found to be higher in cases compared to control patients. While mean tourniquet time was not different between study groups, the mean tourniquet pressure was slightly lower in cases (293.6 mmHg) than controls (307.6 mmHg). There were no differences with regard to BMI, other comorbidities, revision cases, mean length of anesthesia or surgery, or surgeon experience.

After adjusting for age and BMI, multivariable binary logistic regression found females and patients with previous spine disease or spine surgery were at higher risk for post-operative nerve injury following TKA (Figure 1). Compared to tourniquet pressures less than 300 mmHg, patients with higher tourniquet pressures of 300-349 mmHg and 350 mmHg or greater were less likely to have a post-operative nerve injury. Patients with anesthesia time of 2 hours or longer were more likely to have a nerve injury.

Discussion

Damage to a nerve may occur by means of direct perioperative traction on the nerve, direct pressure on the nerve from post-operative dressing, or traction on the surrounding soft tissue leading to vascular compromise of the nerve.^{3,8} Stretching of the soft tissue surrounding the nerve may lead to compression of the nerve or its vascular supply, resulting in neural ischemia.^{3,9}

Fortunately, nerve injury is an uncommon complication of TKA. However, the individuals who sustain these injuries may face substantial disability, and the limited improvement can be frustrating for the patient. The rate of axonal regeneration is estimated to be 1 mm per day.¹⁰ However, this rate can vary depending on the severity of the injury and the duration of denervation.¹⁰ Furthermore, axonal regeneration does not equate to return to function.¹⁰ Thus, the identification and conscientious modification of risk factors for injury is necessary to alter the incidence of this injury.

Few risk factors for nerve injury following TKA have been consistently identified in the literature. This may be due to limited sample sizes and inaccurate reporting of incidence. This study, with its case-control study design, is ideally suited to studying rare outcomes and evaluating multiple risk factors for these rare outcomes. Because controls were selected randomly as patients who underwent TKA within 7 days of the case's operative date and were not matched on any other criteria, we were able to study all available risk factors for nerve injury. One previous case-control study, Idusuyi and Morrey, (2006), matched 32 nerve injury cases with 100 control subjects based on age, sex, and operating surgeon, which eliminated their ability to assess these as risk factors for nerve injury.¹¹

Sex was distinguished as a significant risk factor in our population. This has not previously been identified as a risk factor,¹² though it has been identified as a risk factor for nerve injury following THA.¹³ Our findings may reflect the hypotheses that women are more susceptible to nerve injury due to their reduced muscle bulk, different vascular anatomy, and shorter limbs.¹⁴ Age was not significantly different between cases and controls in our study. This is contrary to previous reports that younger age is associated with greater risk for nerve injury.^{12,15} BMI was not different between cases and controls, which is in line with other publications.¹²

Studies have previously postulated many other risk factors for nerve injury, including history of lumbar spine disease/lumbar spine surgery, peri- and post-operative anesthesia, tourniquet time, diabetes, rheumatoid arthritis, and blood loss.^{3,4,9,16} Of these, only a history of lumbar spine disease and length of anesthesia were identified as risk factors for our cohort of patients. Our results indicate that a history of lumbar spine disease/spinal stenosis or prior lumbar spine surgery may be a risk factor for foot-drop. Lumbar spine architecture bears a distinct anatomic influence on foot-drop given the motor nerve innervation to the affected muscles. Therefore, pre-operative screening of lumbar spine via careful history and imaging should be considered. Duration of anesthesia greater than 2 hours was confirmed in our findings as a risk factor. Minimizing exposure to anesthetic agents should also be considered in surgical planning.

Many studies have analyzed pneumatic tourniquet pressure and duration of application as a potential risk factor, although the significance varies from study to study. Among patients who developed nerve injury following TKA in previous studies, the average tourniquet pressure was between 300 and 450 mm Hg.⁵ In contrast to these results, a tourniquet pressure of 300 mmHg or above led to a lower risk of post-operative nerve injury in our population. This finding is counterintuitive to the common belief that a higher tourniquet pressure may lead to a greater risk of nerve injury; however, in a prior study examining a

series of nerve injuries, the investigators also found that higher pressures were associated with fewer injuries.¹⁷ We hypothesize that higher pressures are usually used in larger thighs, which may provide more soft tissue protection to the nerve. In accordance with studies assessing neural and muscular injuries, our results demonstrate that the duration of tourniquet use is not a significant risk factor for nerve injury.⁵ The use of a tourniquet for 2 hours or less remains the standard of care until a more optimal clinical time can be determined through randomized controlled trials.

While this study's strengths include a 15-year experience of motor neuropathies at a high volume institution, we acknowledge that there are limitations. Because of the retrospective study design, available documentation did not allow reliable determination of surgical approach, incision length, use of a minimally invasive technique, eversion and resurfacing of patella, preservation of posterior cruciate ligament, type of implant fixation, and use of computer navigated assistance. Quality control of the data may have been a limitation, as a substantial amount of data collection was performed prior to implementation of a standardized electronic medical record system at our institution. Because of the rare incidence rate of motor neuropathies following TKA, sample size issues may still play a role in the precision of the estimates of our findings. Also, although we used multiple methods to identify post-operative nerve injuries, there may have been injuries not reported to NYPORTS, not captured by the five ICD-9-CM codes, or not identified through our review of the Neurology Department's consultation log. This may partially explain our institution's low incidence of injury. However, other large scale studies (>8,000 records reviewed) at a high-volume academic medical center found rates more similar to ours (0.3%).¹⁸

Understanding the implications of the tourniquet timing and pressure, pre-operative identification of patients at risk due to history of lumbar spine disease/surgery, evaluation of the role of sex in peri-operative outcome, as well as planning of anesthetic duration should be considered in reduction of post-operative morbidity. Existing TKA registries, such as the American Joint Replacement Registry, should capture these data elements and include nerve injury among reported complications.¹⁹ This would allow for efficient high-quality data capture to help answer these remaining questions.

Perhaps there is a role for future studies to determine the utility of preoperative electrodiagnosis as a screening tool and postoperative electrodiagnostic monitoring for patients with neurologic symptoms.²⁰ Future studies can also include the use of intraoperative electrodiagnostic monitoring during TKA procedures to prevent postoperative nerve deficit, as has been demonstrated in arthroplasty of other joints.^{21, 22}

This study identifies several novel risk factors which should be factored into surgical decision making. Specifically, female patients and those with concomitant lumbar spine disease should be counseled that there may be an increased risk of nerve injury following TKA. Patients undergoing TKA with known risk factors for nerve injury should be treated with all potential safeguards peri-operatively and monitored closely post-operatively by clinical staff.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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List of Acronyms

BMI	Body Mass Index
ICD-9-CM	International Classification of Diseases, Ninth Revision, Clinical Modification
MRC	Medical Research Council
NYPORTS	New York Patient Occurrence Report and Tracking System
OR	Odds Ratio
PA	Physician's Assistant
SPSS	Statistical Package for the Social Sciences
TKA	Total Knee Arthroplasty

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Figure 1.

Multivariable regression model for risk factors of nerve injury following TKA. Odds ratios, 95% Confidence Intervals, and p-values are reported. Results are adjusted for age and BMI.

Table 1

Patient and intra-operative characteristics of nerve injury cases and controls.

TKA Characteristic		CONTROLS (130)		CASES (65)			
		Mean or N	SD or %	Mean or N	SD or %	P-value	
Patient Demographics	Patient Age at Procedure	67.1	10.6	66.9	10.7	0.921	
	<50	7	8%	4	6%	0.603	
	50-59	12	13%	13	20%		
	60-69	33	37%	17	26%		
	70-79	31	34%	25	38%		
	80+	7	8%	6	9%		
	BMI	30.2	5.7	31.0	7.0	0.418	
	<25	16	18%	11	17%	0.901	
	25 to 29	33	37%	22	34%		
	30+	41	46%	32	49%		
	Sex (Male)	39	41%	12	18%	0.003	
	History of/Current use of Tobacco	25	19%	13	20%	0.918	
	Patient Medical History of:	Diabetes	11	8%	4	6%	0.777
		Spine Surgery/Spinal Stenosis/Spine Disease	7	5%	9	14%	0.042
		Rheumatoid Arthritis	10	8%	2	3%	0.343
Hepatitis B		1	1%	0	0%	1.000	
Tibial Osteotomy		0	0%	0	0%	NA	
Revision TKA (vs Primary)		2	2%	3	5%	0.415	
Deep Vein Thrombosis (DVT) Prophylaxis		Aspirin DVT prophylaxis	26	20%	10	16%	0.447
		Received Coumadin DVT Prophylaxis	114	88%	61	94%	0.218
		Low molecular weight heparin use after surgery	1	1%	5	8%	0.017
		Tourniquet Time (min)	58.3	21.9	58.9	22.1	0.879
Intra-Operative Characteristics	<60 min	63	61%	33	56%	0.566	
	60-89 min	31	30%	22	37%		
	90+ min	10	10%	4	7%		

TKA Characteristic	CONTROLS (130)		CASES (65)		P-value
	Mean or N	SD or %	Mean or N	SD or %	
Tourniquet Pressure (mmHg)	307.6	42.1	293.6	44.5	0.054
<300 mmHg	30	30%	30	51%	0.011
300-349 mmHg	36	36%	10	17%	
350+ mmHg	35	35%	19	32%	
Surgeon Years in Practice to Procedure	18.9	9.8	19.9	9.4	0.551
Surgeon Volume from Previous Year	98.4	68.5	117.6	100.0	0.164