Inpatient Falls after Total Knee Arthroplasty

The Role of Anesthesia Type and Peripheral Nerve Blocks

Stavros G. Memtsoudis, M.D., Ph.D., F.C.C.P., Thomas Danninger, M.D., Rehana Rasul, M.P.H., M.A., Jashvant Poeran, M.D., Ph.D., Philipp Gerner, B.S., Ottokar Stundner, M.D., Edward R. Mariano, M.D., M.A.S., Madhu Mazumdar, Ph.D., M.A., M.S.

ABSTRACT

Background: Much controversy remains on the role of anesthesia technique and peripheral nerve blocks (PNBs) in inpatient falls (IFs) after orthopedic procedures. The aim of the study is to characterize cases of IFs, identify risk factors, and study the role of PNB and anesthesia technique in IF risk in total knee arthroplasty patients.

Methods: The authors selected total knee arthroplasty patients from the national Premier Perspective database (Premier Inc., Charlotte, NC; 2006–2010; n = 191,570, >400 acute care hospitals). The primary outcome was IF. Patient- and healthcare system–related characteristics, anesthesia technique, and presence of PNB were determined for IF and non-IF patients. Independent risk factors for IFs were determined by using conventional and multilevel logistic regression.

Results: Overall, IF incidence was 1.6% (n = 3,042). Distribution of anesthesia technique was 10.9% neuraxial, 12.9% combined neuraxial/general, and 76.2% general anesthesia. PNB was used in 12.1%. Patients suffering IFs were older (average age, 68.9 *vs.* 66.3 yr), had higher comorbidity burden (average Deyo index, 0.77 *vs.* 0.66), and had more major complications, including 30-day mortality (0.8 *vs.* 0.1%; all $P < 0.001$). Use of neuraxial anesthesia (IF incidence, 1.3%; n = 280) had lower adjusted odds of IF compared with adjusted odds of IF with the use of general anesthesia alone (IF incidence, 1.6%; n = 2,393): odds ratio, 0.70 (95% CI, 0.56–0.87). PNB was not significantly associated with IF (odds ratio, 0.85 [CI, 0.71–1.03]).

Conclusions: This study identifies several risk factors for IF in total knee arthroplasty patients. Contrary to common concerns, no association was found between PNB and IF. Further studies should determine the role of anesthesia practices in the context of fall-prevention programs. **(Anesthesiology 2014; 120:551-63)**

INPATIENT falls (IFs) bear the risk of severe complications and expose patients to potentially preventable injury. Particularly, patients undergoing a total knee arthroplasty (TKA) may be at risk because this procedure significantly limits their mobility in the perioperative period.[1,2] Despite the recognition that IFs constitute a major problem and have been designated as a potentially preventable event by the Centers for Medicare and Medicaid,[3,4] surprisingly little national research is available to help elucidate associated characteristics and risk factors for this adverse event in the context of TKA. Although we and others have previously attempted to study the extent of the problem, either using nationally representative databases or institutional data,[1,2,5] the role of many potentially contributing factors, such as anesthesia-related variables, has not been captured in these evaluations and thus their impact remains unknown.

It has been suggested that anesthesia-related factors, especially the use of peripheral nerve blocks (PNBs), may contribute to the risk of IFs, by negatively affecting motor function.[6–8] Identifying risk factors for IF is important not only to prevent patients from harm, complications, and severe related injuries but also to avert associated economic damages to patients and the healthcare system. In this context, the Centers for Medicare and Medicaid services have categorized IFs as hospital-acquired conditions and may not reimburse for related costs.[4]

What We Already Know about This Topic

- Inpatient falls after lower extremity total joint surgery are associated with significant morbidity and mortality
- The use of peripheral nerve blockade has been speculated to contribute to the risk of inpatient falls in this patient group

What This Article Tells Us That Is New

- Review of more than 190,000 records from 400 hospitals in an administrative database showed an incidence of inpatient falls of 1.6% in this patient group, associated with morbidity and mortality
- Peripheral nerve block did not alter the risk of inpatient fall, whereas use of neuraxial anesthesia reduced the risk by 30% compared with general anesthesia

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Submitted for publication June 13, 2013. Accepted for publication November 27, 2013. From the Department of Anesthesiology, Hospital for Special Surgery, New York, New York (S.G.M., T.D., and O.S.); Department of Public Health, Division of Biostatistics and Epidemiology, Weill Cornell Medical College, New York, New York (R.R., J.P., and M.M.); Stony Brook University, Stony Brook, New York (P.G.); and Department of Anesthesiology, Perioperative and Pain Medicine, Stanford University School of Medicine, Stanford, California (E.R.M.).

Therefore, we used a large, national database, previously used by our study group for the study of anesthesia-related outcomes,[8–12] that allows for the capture of anesthesia-related procedures to: (1) better characterize patient- and healthcare system–related factors associated with IFs; (2) identify risk factors for this outcome in general; and (3) determine whether the type of anesthesia and use of PNB affect the risk for this event in TKA patients. We hypothesized that, among other factors, older and sicker patients would be at increased risk for IFs, and that the choice of anesthesia and the use of PNB will affect this risk.

Materials and Methods

Data Source and Study Population

Data provided by Premier Perspective Inc. (Charlotte, NC) for this study were collected between January 2006 and September 2010 from approximately 400 acute care hospitals in the United States. The database features information on a patient's hospitalization which includes patient demographics, hospital characteristics, and complete billing information. In addition, International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes and Current Procedural Terminology codes are provided to determine specific information about diagnoses present during the hospitalization and procedures carried out. Data validity is assured through a standardized process before it is included in the database. Specifically, the validation process is made up of a seven-step integrity analysis, after which approximately 100 sampling and statistical validity and integrity assurance crosschecks are performed.* Data used in this study were deidentified and thus compliant with the Health Insurance Portability and Accountability Act,† and therefore this project was exempt from review by our Institutional Review Board (Hospital for Special Surgery, New York, NY). Specific hypotheses and primary outcomes were not evaluated by our Institutional Review Board for this study. The database was queried between February 22, 2013 and June 12, 2013, to collect the necessary data elements.

Study Sample

Unique cases from the database were included in the study if they underwent TKA (ICD-9 CM procedure code 81.54) and had information on type of anesthesia used during the procedure: general anesthesia, neuraxial anesthesia, or a combination of general and neuraxial anesthesia, which was identified using billing information. In addition, cases were restricted to routine admissions and elective procedures.

Study Variables

The primary outcome, IF, was defined by ICD-9-CM diagnosis code E849.7 indicative of "accidents occurring in a residential institution." As there is no definitive standard in the reporting of IFs though ICD-9 codes, we used the IF coding as used in our hospital (Hospital for Special Surgery) and as described previsouly.[2] By restricting our sample to routine admissions and nonemergent procedures only, we further attempted to logically exclude patients who fell in another institutionalized setting other than the hospital where the procedure was performed.

Patient demographic variables analyzed were age, sex, and race (white, black, Hispanic, and other). Healthcare-related variables were hospital location (urban or rural), hospital size (<300, 300–499, or ≥500 beds), hospital teaching status, and individual hospital identifier (deidentified to researchers). Procedure-related variables were type of anesthesia (general, neuraxial, or neuraxial/general), PNB use, type of knee arthroplasty (unilateral or bilateral), year of procedure (to account for trend), hospital costs, and length of hospitalization.

Type of anesthesia or use of PNB was defined using a list of all billing descriptions containing the search term "ANES." This list (illustrated in appendix 1) was reviewed independently by one anesthesiologist (S.G.M.), one anesthesiology resident (T.D.), and a physician-epidemiologist (J.P.) to classify the type of anesthesia and, in addition, use of PNB. Further, the list was concatenated with Current Procedural Terminology codes indicating type of anesthesia (appendix 1 for list). Together, they provide a comprehensive definition of anesthesia usage. Only relevant and logic codes were included for analysis. Although we feel this is the best approach to identify anesthesia type in this claims-based dataset, there still are missing data for 28% of cases, which is only moderately higher than the missing rate (19%)[13] on anesthesia type in the comprehensive National Anesthesia Clinical Outcomes Registry‡ specifically designed to capture anesthesia-related information.

Comorbidity variables consisted of two comorbidity measures, that is, grouping according to Deyo–Charlson[14] and Elixhauser,[15] for which a selection of individual comorbidities was taken into account (obesity, [complicated] diabetes mellitus, congestive heart failure, chronic lung disease, renal failure, metastatic cancer, solid tumor without metastasis, coagulation deficiency, fluid and electrolyte abnormalities, alcohol abuse, drug abuse, psychosis, [complicated] hypertension, bloodloss anemia, and deficiency anemia). In addition, a diagnosis of sleep apnea was considered as this comorbidity was considered important but is not included in either index. Complication and outcome variables included major cardiac complications (acute myocardial infarction or other cardiac-related complications), major pulmonary complications (pulmonary embolism, pneumonia, or other pulmonary complications), deep venous thrombosis, cerebrovascular events, infections, acute renal failure, gastrointestinal complications, 30-day mortality, need for blood transfusion, mechanical ventilation, and critical care service usage. Comorbidities were identified using ICD-9 codes as

* Premier Inc., Premier Perspective Database. More information available at: https://www.premierinc.com/wps/portal/premierinc/public/transforminghealthcare/improvingperformance/serviceprograms/researchservices. Accessed October 10, 2013.

† U.S. Department of Health and Human Services: Summary of the HIPAA Privacy Rule. Available at: http://www.hhs.gov/ocr/privacy/hipaa/understanding/summary/privacysummary.pdf. Accessed October 10, 2013.

‡ Anesthesia Quality Institute: National Anesthesia Clinical Outcomes Registry. More information available at: http://www.aqihq.org. Accessed October 10, 2013.

previously reported.[14,15]§ Complication variables were defined using ICD-9 and Current Procedural Terminology codes as listed in appendix 2. Other than missing data for type of anesthesia, no other missing data were present in our current dataset.

Statistics

Inpatient fall risk was quantified in terms of subgroup prevalence and odds ratios (ORs) in a multiple logistic regression model and a multilevel (random intercept) logistic regression model. We specifically did not choose for propensity score analysis because we do not believe it would inform our study more than our current approach because of several reasons put forward by others including risk of considerable sample size reduction and overall similar results in case of large sample sizes.[16–18]

Univariable Analysis

Inpatient fall events were characterized by patient demographics, healthcare- and procedure-related variables, and comorbidity measures. Groups were compared using chi-square and *t* tests for categorical and continuous variables, respectively. Means and SDs were estimated for age, Deyo index, and length of hospital stay. Because hospital cost had a positively skewed distribution, its median and interquartile range were determined, and the Mann–Whitney rank sum test was used to evaluate significance. As Deyo index is a more compact measure (compared with the Elixhauser comorbidity grouping), we chose only to show this comorbidity measure in the univariable analysis.

Multiple Logistic Regression

To determine risk factors associated with IF, a multiple logistic regression model was fitted after the following sequential stages:

First, candidate covariates were chosen based on clinical judgment and significance of P value less than 0.15 in the univariable analyses. These covariates included all patient demographic variables, hospital identifier (hospital-fixed effects), all procedure-related variables, and a selection of comorbidity and complication variables (dementia, sleep apnea, blood transfusion, and individual Elixhauser comorbidities). We chose comorbidity grouping according to Elixhauser[15] (instead of grouping according to Deyo–Charlson[14]) because they yielded slightly higher validity in sensitivity analyses. As previously described, we also considered interactions of blood transfusion with (deficiency) anemia.[19]

Second, we achieved further variable selection through a nonparametric bootstrapping process on the model from the first stage.[20] Specifically, 100 bootstrap samples of size n were randomly drawn with replacement from the original sample of size n. A stepwise procedure was applied to each sample using a forward selection method (with selection entry level of $P = 0.20$). Because a variable included in the model for most bootstrap samples is expected to have higher probability of being prognostically important, candidate covariates were selected if they were included in more than 70% of the 100 bootstrap sample models.[20] Pairwise covariate combinations were evaluated for covariates which failed this 70% cutoff. If the frequency of pairwise combinations was greater than 90%, then the covariate with the higher frequency was selected.

Finally, the variables selected in the second stage were used to fit the final multiple logistic regression model. Because PNB was not selected in this process, we added this to the final model to assess its effect on IF.

Model Diagnostics

The optimism-corrected c-statistic (discrimination) and the Hosmer and Lemeshow test (calibration) were determined to assess the validity of the final model.[21] A model with a c-statistic greater than 0.7 is indicative of good discriminatory power, that is, how well the model discriminates between observed data at different levels of the outcome. Calibration indicates the ability of a model to match predicted and observed data; a nonsignificant Hosmer and Lemeshow test value indicates a well-calibrated model.

Multilevel Logistic Regression

To additionally check the effect of anesthesia type and PNB on IF, and the identified risk factors for IF, we fitted a multilevel logistic regression model with random intercepts using the SAS GLIMMIX procedure (appendix 3).[22] Multilevel logistic regression is a modification of conventional (single-level) logistic regression; it takes into account the multilevel structure of the Premier Perspective data, for example, procedures per hospital. The technique adjusts for clustering, for example, individuals within hospitals. A random intercept to account for the variation in each hospital was included in the model. Hospitals with less than 50 patients were excluded from this analysis, as previously recommended.[23] To determine risk factors for IF, a forward selection procedure (α inclusion, $P = 0.05$) was used for variable selection from all covariates listed above, except individual hospital identifiers. All statistical analyses were performed using SAS software version 9.3 (SAS Institute, Cary, NC).

Disclosures. As previous studies have shown significantly increased risks for IFs in cohorts of less than 2,000 patients, we assumed (before database query) our database to be sufficiently powered.[6]

On the basis of reviewing the literature (meta-analyses using a mix of observational and interventional trials) evaluating the impact of interventions to prevent IFs, we determined that an alteration of at least 10 to 20% in the OR for IF (in comparison with previously reported IF rates)[24,25] would be clinically significant.[26–28]

Results

We identified 191,570 records for elective TKA which also had information on anesthesia type listed. Of these, 10.9%

§ Healthcare Cost and Utilization Project (HCUP): HCUP comorbidity software Version 3.7; 2012. Available at: http://www.hcup-us.ahrq.gov/toolssoftware/comorbidity/comorbidity.jsp). Accessed October 10, 2013.

Table 1. Patient Demographics, Healthcare-related, Procedure-related, and Comorbidity Measure Variables for Patients Subgrouped by Fall/No Fall

	Fall (N = 3,042)		No Fall (N = 188,528)		
	N*	%*	N*	%*	*P* Value†
Patient demographics					
Age continuous*	68.9	10.3	66.3	10.5	<0.001
Age category, yr					
<45	33	1.1	3,711	2.0	<0.001
45–54	257	8.5	22,483	11.9	
55–64	703	23.1	53,893	28.6	
65–74	1,043	34.3	63,126	33.5	
>75	1,006	33.1	45,315	24.0	
Sex					
Male	1,876	61.7	118,448	62.8	0.589
Female	1,166	38.3	70,080	37.2	
Race					
White	2,333	76.7	143,665	76.2	0.008
Black	242	8.0	14,239	7.6	
Hispanic	95	3.1	4,606	2.4	
Other	372	12.2	26,018	13.8	
Healthcare related					
Hospital location					
Rural	281	9.2	17,099	9.1	0.750
Urban	2,761	90.8	171,429	90.9	
Hospital size					
<299 beds	1,327	43.6	61,179	32.5	<0.001
300–499 beds	1,206	39.7	71,095	37.7	
>500 beds	509	16.7	562,54	29.8	
Hospital teaching status					
Nonteaching	1,983	65.2	111,409	59.1	<0.001
Teaching	1,059	34.8	77,119	40.9	
Procedure related					
Type of anesthesia					
Neuraxial	280	9.2	20,705	11.0	0.002
General	2,393	78.7	143,493	76.1	
Combined	369	12.1	24,330	12.9	
Peripheral nerve block					
No block	2,666	87.6	165,669	87.9	0.693
Block	376	12.4	22,859	12.1	
Year of procedure					
2006	536	17.6	36,297	19.3	<0.001
2007	526	17.3	37,015	19.6	
2008	608	20.0	37,763	20.0	
2009	743	24.4	43,065	22.8	
2010	629	20.7	34,388	18.2	
Type of procedure					
Unilateral	2,765	90.89	173,118	91.83	0.063
Bilateral	277	9.11	15,410	8.17	
Comorbidity measures					
Deyo index (continuous)*	0.77	1.03	0.66	0.97	<0.001
Deyo index category					
0	1,730	56.9	116,311	61.7	<0.001
1	542	17.8	31,113	16.5	
2	562	18.5	30,607	16.2	
≥3	208	6.8	10,497	5.6	

* Continuous variable, mean, and SD instead of N and %, respectively. † Chi-square test for categorical variables, *t* test for continuous variables.

were performed under neuraxial, 12.9% under combined general/neuraxial, and 76.2% under general anesthesia, respectively. Of all patients, 12.1% received a PNB. In 1.6% (n = 3,042) of cases, an IF took place.

Table 1 illustrates patient demographics, healthcare- and procedure-related variables, and comorbidity measure variables for patients who suffered an IF *versus* those who did not. Patients whose course was complicated by an IF were on average older (mean age, 68.9 [SD = 10.3] *vs.* 66.3 [SD = 10.5] yr; $P < 0.001$). The incidence of IFs was higher among patients undergoing their surgery under general *versus* neuraxial or neuraxial/general anesthesia. (1.6% *vs.* 1.3% *vs.* 1.5%; $P = 0.0018$). The proportion of patients suffering an IF who received a PNB or not was not significantly different (1.58 *vs.* 1.62%; $P = 0.6933$). In addition, patients suffering an IF had a higher comorbidity burden (mean Deyo index, 0.77 [SD = 1.03] *vs.* 0.66 [SD = 0.97]; $P < 0.001$), which was also evident by the higher prevalence of individual comorbidities (table 2).

Table 3 illustrates the rate of complications for patients who suffered an IF *versus* those who did not. IF patients had higher rates of major complications, including those affecting the cardiac and pulmonary system, 30-day mortality, and higher rates of usage of critical care services. Moreover, IF patients had a significantly increased length of stay (4.7 [SD = 3.2] *vs.* 3.5 [SD = 1.8] days; $P < 0.001$) and higher hospital costs ($17,070 [interquartile range, $13,588–$22,295] *vs.* $14,508 [interquartile range, $12,034, $17,998]; $P < 0.0001$); data not shown.

Table 4 shows patients characterized by use of a PNB. We did not find a difference for age, sex, or Deyo comorbidity burden when comparing patients receiving *versus* not receiving a PNB. However, patients of minority race received a PNB procedure less commonly.

Multiple Logistic Regression

The final multiple logistic regression model (table 5) did not include the use of PNB as a risk factor for IF as this variable did not reach the required predetermined level for inclusion. Year of procedure and hospital identifiers are not shown in table 5, but both were significant additions to the model ($P = 0.015$ and $P < 0.001$, respectively). Advanced age, male sex, and presence of individual comorbidities (fluid and electrolyte abnormalities, psychosis, sleep apnea, obesity, coagulopathy, and bloodloss anemia) were associated with increased odds for IF.

Patients with anemia (and no transfusion) and those receiving a transfusion (without anemia) both had an increased risk for IF (OR, 1.43 [CI, 1.28–1.59] and OR, 1.98 [CI, 1.77–2.21], respectively) compared with patients with no anemia and no transfusion. This risk remained increased for patients with anemia who were transfused.

The use of neuraxial anesthesia was associated with lower odds with regard to IFs compared with the odds with the use of general anesthesia alone (OR, 0.70 [CI, 0.56–0.87]; $P < 0.0012$). When added to the final model, the use of a PNB

Table 2. Prevalence of Selected Comorbidities by Fall/No Fall

	Fall (N = 3,042)		No Fall (N = 188,528)		
	N	%	N	%	*P* Value*
Deyo–Charlson comorbidity grouping					
Myocardial infarction	128	4.21	6,844	3.63	0.092
Peripheral vascular disease	80	2.63	3,135	1.66	<0.001
Cerebrovascular disease	14	0.46	412	0.22	0.005
Dementia	7	0.23	147	0.08	0.003
Chronic obstructive pulmonary disease	485	15.94	27,361	14.51	0.026
Rheumatic disease	122	4.01	7,408	3.93	0.819
Mild liver disease	8	0.26	432	0.23	0.699
Severe liver disease	3	0.10	71	0.04	0.090
Diabetes mellitus	689	22.65	36,930	19.60	<0.001
Complicated diabetes	50	1.64	2,329	1.24	0.044
Renal failure	1	0.02	85	0.04	0.346
Cancer (metastatic cancer, solid tumor without metastasis)	61	2.01	2,986	1.58	0.065
Elixhauser comorbidity grouping					
Hypertension	2,123	69.79	127,724	67.75	0.017
Complicated hypertension	267	8.78	9,804	5.20	<0.001
Anemia	775	25.48	35,078	18.61	<0.001
Pulmonary circulation disorder	164	5.39	3,312	1.76	<0.001
Fluid and electrolyte disorders	653	21.47	21,366	11.33	<0.001
Psychosis	132	4.34	4,110	2.18	<0.001
Other					
Sleep apnea	323	10.62	17,134	9.09	0.013

* Chi-square test.

Table 3. Prevalence of Selected Complications by Fall/No Fall

	Fall		No Fall		
	N	%	N	%	*P* Value*
Combined complications†	1,312	43.13	23,020	12.21	<0.001
Major cardiac complications	502	16.50	11,941	6.33	<0.001
Acute myocardial infarction	43	1.41	474	0.25	<0.001
Cardiac (other)	491	16.14	11,754	6.24	<0.001
Major pulmonary complications	390	12.82	3,210	1.70	<0.001
Pulmonary embolism	108	3.55	953	0.51	<0.001
Pneumonia	189	6.21	1,475	0.78	<0.001
Pulmonary (other)	151	4.96	1,173	0.62	<0.001
Deep venous thrombosis	72	2.37	1,145	0.61	<0.001
Cerebrovascular event	22	0.72	192	0.10	<0.001
Infection	445	14.63	6,780	3.60	<0.001
Acute renal failure	197	6.48	2,748	1.46	<0.001
Gastrointestinal complication	151	4.96	1,226	0.65	<0.001
30-Day mortality	24	0.79	226	0.12	<0.001
Mechanical ventilation	108	3.55	1,141	0.61	<0.001
Critical care services	273	8.97	5,684	3.02	<0.001
Transfusion	839	27.58	31,913	16.93	<0.001

* Chi-square test. † Combined complications include having at least one complication.

(OR, 0.85 [CI, 0.71–1.03; P = 0.0962]) did not alter the odds for IFs.

The optimism-corrected c-statistic associated with the model for the outcome of IFs was 0.85 and the P value for the Hosmer and Lemeshow test for the model was 0.91, indicating good model discrimination and calibration.

Multilevel Logistic Regression

Results of the multilevel (random intercept) logistic regression model are illustrated in appendix 3. This analysis included 190,758 (99.6% of study sample) observations from 273 hospitals. The multilevel model yielded an intercept variance of 2.90 (standard error, 0.35; P < 0.0001). The P value is the result of the test evaluating whether there is a variance of zero; in this case, there was none, suggesting that there are indeed unmeasured explanatory hospital-level variables. However, analogous to the conventional logistic regression, PNB was not a risk factor for IF, and neuraxial anesthesia showed lower risk for IF compared with general anesthesia (OR, 0.71 [CI, 0.57–0.87]; P = 0.0015). Except for bloodloss anemia, all risks found in the single-level conventional regression model were also found in the multilevel model, with similar magnitude and direction of ORs. Also, the c-statistic was similar: 0.85.

Discussion

This analysis of more than 190,000 patients undergoing TKA reveals an overall IF rate of 1.6%. As expected, IFs were associated with worse outcomes as evidenced by higher cardiac and pulmonary complications, 30-day mortality, and higher rates of usage of critical care services. Among other differences in demographic variables, the population suffering from IFs was older with a higher comorbidity burden. When analyzing IFs according to the type of anesthesia, neuraxial anesthesia had lower odds of IF compared with the odds in general anesthesia alone. The usage of PNB had no significant impact on the risk for IFs.

In this study, we found a higher IF prevalence than previously reported in studies using nationally representative and institutional data.[1,2] In a previous analysis, we found an incidence of 0.85% for IFs and Mandl *et al.*[1] reported an incidence of 0.9%.[2] However, in the former study, we reported an increase in incidence over the 10 yr of observation from 0.4% in 1998 to 1.3% in 2007.[2] Thus, these more recent data suggest a further increase in incidence. We can only speculate that this finding may be related to increased rates of reporting and/or increases in IFs due to an increasingly sicker patient population undergoing arthroplasty.[29]

We identified several patient factors that were associated with higher odds for IFs. Patient suffering from an IF were on average older, thus suggesting that age-related factors such as reduced motor strength, impaired reflexes, and balance may play a role. Furthermore, male sex was associated with increased odds for IFs. This finding has previously been reported,[2] but reasons have to remain speculative. However, men may be less likely to ask for help when ambulating or are willing to take more risk and overestimate their capabilities.[30] Interestingly, this sex difference in fall risk has not been observed in nonsurgical populations.[31,32]

We identified a number of comorbidities and conditions that were associated with an increased risk for IFs, including sleep apnea or psychosis. Changes in sensorium such as increased

Table 4. Patient Demographics, Healthcare-related, Procedure-related, and Comorbidity Measure Variables for Patients with a PNB and Those without

	Block (N = 23,235)		No Block (N = 168,335)		
	N*	%*	N*	%*	*P* Value†
Patient demographics					
Age continuous*	66.3	10.55	66.4	10.37	0.167
Age category, yr					
<45	387	1.73	3,357	1.93	0.050
45–54	2,705	11.91	20,035	11.81	
55–64	6,629	28.59	47,967	28.11	
65–74	7,938	33.85	56,231	33.50	
>75	5,576	23.91	40,745	24.65	
Sex					
Male	14,498	62.56	105,826	62.65	0.818
Female	8,737	37.44	62,509	37.35	
Race					
White	19,514	82.53	126,484	73.52	<0.001
Black	1,547	6.80	12,934	7.02	
Hispanic	394	1.91	4,307	3.08	
Other	1,780	8.76	24,610	16.38	
Healthcare related					
Hospital location					
Rural	2,366	4.24	15,014	4.25	0.921
Urban	20,869	95.76	153,321	95.75	
Hospital size					
<299 beds	5,882	26.23	56,624	38.80	<0.001
300–499 beds	11,758	53.32	60,543	38.37	
>500 beds	5,595	20.44	51,168	22.83	
Hospital teaching status					
Nonteaching	15,933	83.40	97,459	77.27	<0.001
Teaching	7,302	16.60	70,876	22.73	
Procedure related					
Type of anesthesia					
Neuraxial	2,184	11.73	18,801	11.56	<0.001
General	18,611	76.49	127,275	73.65	
Combined	2,440	11.79	22,259	14.79	
Year of procedure					
2006	2,871	12.36	33,962	20.18	<0.001
2007	3,681	15.84	33,860	20.12	
2008	4,413	18.99	33,958	20.17	
2009	6,505	28.00	37,303	22.16	
2010	5,765	24.81	29,252	17.38	
Comorbidity measures					
Deyo index (continuous)*	0.64	0.96	0.66	0.97	0.004
Deyo index category					
0	14,528	62.56	103,513	61.80	0.227
1	3,718	16.03	27,937	16.36	
2	3,708	15.99	27,461	16.39	
≥3	1,281	5.42	9,424	5.45	

* Continuous variable, mean, and SD instead of N and %, respectively. † Chi-square test for categorical variables, *t* test for continuous variables.
PNB = peripheral nerve block.

sensitivity to postoperative narcotics and daytime alertness associated with the former and various degrees of altered perceptions of surroundings with the latter are likely contributors. Recently published data even suggested an association between sleep apnea and postoperative delirium, thus providing insight into one potential mechanism.[33,34] Anemia was found to be a contributing factor to IFs in this and several other studies.[35,36] As previously described, also transfusion alone demonstrated an increased risk for adverse outcome, in this case IFs.[19] From our retrospective dataset, however, no clinical inferences can be made as we do not have data on hemoglobin levels and actual transfusion triggers during the procedures.

Table 5. Final Multiple Logistic Regression Model (Adjusted for Year of Procedure and Hospital-fixed Effects through the Hospital Identifier Variable) Displaying OR and 95% CI

	Reference	OR	95% CI
Age category, yr			
<45		0.78	0.54–1.13
55–64	45–54	1.16**	1.00–1.34
65–74		1.46*	1.26–1.68
>75		1.88*	1.63–2.18
Sex			
Female	Male	0.84*	0.78–0.91
Type of anesthesia			
Neuraxial		0.70**	0.56–0.87
Combined	General	1.13	0.98–1.31
Comorbidities/complications			
Electrolyte and fluid abnormalities		1.85*	1.68–2.04
Psychosis	Absence of comorbidity/complication	1.75*	1.45–2.11
Sleep apnea		1.23**	1.08–1.39
Obesity		1.16**	1.06–1.27
Coagulopathy		1.36**	1.13–1.64
Bloodloss anemia		1.22**	1.00–1.49
Interaction			
Anemia, no transfusion		1.43*	1.28–1.59
Anemia, with transfusion	No anemia, no transfusion	1.70*	1.47–1.96
No anemia, with transfusion		1.98*	1.77–2.21

* $P < 0.001$; ** $P < 0.01$.
OR = odds ratio.

When comparing the types of anesthesia used for TKA, neuraxial anesthesia was associated with a reduced risk for IFs. Recent studies have identified neuraxial anesthesia to be associated with reduced risks for many perioperative complications in the orthopedic population.[8,37] However, no data on the risk for IFs were available from these analyses. The reduced risk for IFs may be associated with differential influence on the risk for postoperative cognitive function and delirium.[38]

Importantly, the use of PNB had no significant influence on IFs in the studied population. This is in contrast to previously published data.[39,40] For example, one study suggested that continuous lumbar plexus blockade was associated with four times greater relative risk of fall compared with groups receiving noncontinuous or no blockade.[6] This information suggests that the type of PNB may play an important role in the propensity to cause motor weakness and thus increase the risk for falls.[41] Although further research is needed to identify the optimal technique to balance adequate pain control with the risk for motor dysfunction, our data should provide encouragement to not shy away from the use of PNB. It should also be kept in mind that the choice of anesthesia type and the usage of the type of blocks can and should be viewed only as parts of a comprehensive fall-prevention program. Such programs have been instituted across many hospitals with great success.[42–44]

The multilevel model in appendix 3 suggested unmeasured explanatory hospital-level variables, which was also indicated by fitting the final single-level model. By including hospital identifiers in the single-level model, we noticed it to influence the effect of anesthesia type on IF. When assessing the final model without including hospital identifiers, the associations between neuraxial *versus* general anesthesia were consistent with the results presented. However, the ORs of neuraxial/general *versus* general anesthesia showed a significantly protective association (OR, 0.86 [CI, 0.77–0.96]; $P = 0.0073$). By including hospital identifiers, the c-statistic greatly improved and results were more consistent with the multilevel model. The association between PNB and IF was consistently nonsignificant between all models. From this exercise, the question arises on what hospital-level factors in particular are influencing the effect of anesthesia type on IF risk, and how this differs between hospitals. As a *post hoc* exploration, we modeled a logistic regression to evaluate the crude (unadjusted) association between IF and type of anesthesia within each hospital using an interaction. Only hospitals with 10 or more IFs were included which yielded 87,359 patients from 78 hospitals. The interaction between anesthesia type and hospital identifier was significant ($P < 0.001$). There were lower odds for IF for patients with neuraxial *versus* general anesthesia in 85% of hospitals. However, the odds of neuraxial/general *versus* general anesthesia for IF widely varied by hospital; significantly reduced odds in 41% of hospitals. These exploratory results must remain inconclusive due to a bias toward selecting larger hospitals or hospitals with higher IF rates and also because only crude (unadjusted) estimates could be performed due to low IF frequencies. For every covariate to be taken into account, an increment of 10 IF cases would be needed, therefore, requiring an even stricter selection of hospitals. Thus, the hospital-level factors influencing the effect of anesthesia type on IF risk remain to be elucidated.

Our analysis is burdened by a number of limitations. The database used contains limited clinical information and thus some important factors cannot be taken into account.

Furthermore, no causal relations can be established from our data source, and associations between identified risk factors and IFs have to remain speculative. In this context, from the data used, we cannot clearly determine which mechanism contributes to the lower risk of IFs in conjunction with type of anesthesia. With regard to information concerning PNB, specific details on the exact type of block, if it was a continuous or single-shot application and doses and type of local anesthetics used, are not readily discernible. Furthermore, we do not have information on the presence of IF prevention programs in the participating hospitals which are likely to influence results.

Furthermore, the lack of more detailed clinical data might have influenced our results, and there may be unobserved confounding. Moreover, IF patients seem to have a higher comorbidity burden as has been demonstrated for patients undergoing knee arthroplasty with general anesthesia.[10] To some extent, the addition of hospital identifiers to the multiple logistic regression, and the multilevel regression analysis may have accounted for this in terms of unmeasured confounders at the hospital level. Neuraxial anesthesia remained a factor with a lower risk of IF, and PNB still was not associated with IF. Moreover, the same risk factors identified in the conventional logistic regression model were also seen in the multilevel model.

Some limitations are inherent to the analysis of secondary databases and are related to the use of ICD-9 codes for various outcomes and patient demographics, such as complications and comorbidities. Most importantly, this limitation refers to the ICD-9 definition of IFs. We chose to use the definition as used in our own facility and as reported previsouly.[2] However, this definition may vary across hospitals.[45] Moreover, one previous study has shown the positive predictive value of IFs determined by ICD-9 coding to be only 54%.[24] This study, however, is burdened by a highly selective and local group of patients. In addition, not all codes used in the mentioned study are unanimously representative of falls (*e.g.*, E887 "Fracture, cause unspecified"). As a sensitivity analysis, we studied the difference in the number of IFs using the definition from the aforementioned study (resulted in 243 extra IFs, 8%) and repeated the multivariate regression analysis. This approach yielded similar results regarding effects of anesthesia, PNB, and risk factors. An additional factor counteracting this limitation is that we do not expect variability in coding to be related to the type of anesthesia or PNB use. Moreover, the IF prevalence we observed in the current study (1.6%) is similar to recent studies using either ICD-9 codes (1.8%)[24] or data from a central event reporting system (1.5%).[25]

The general limitations regarding analysis of secondary databases and use of ICD-9 codes have been described extensively elsewhere. In particular, as with any observational analysis of a complex clinical outcome, unexplained variation remains, demonstrated by, for example, the c-statistic of 0.85. To minimize any untoward influence beyond the usual level of concern, we have used methodologies that have previously been either published or validated in this study.

In conclusion, in this study, we were able to identify independent risk factors for IFs in patients undergoing TKA including advanced age and increasing comorbidity burden. The presence of sleep apnea, psychosis, obesity, coagulopathy, electrolyte abnormalities, and anemia also increased the risk of IFs. The type of anesthesia may represent a modifiable risk factor and the use of neuraxial over general anesthesia may be considered in the context of a fall-prevention program. Contrary to some publications and beliefs, the use of PNB did not significantly alter the risk of IFs in the context of actual clinical practice as shown in this analysis. These data can be used not only to risk stratify patients but also to support the use of interventions to avoid this complication.

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Competing Interests

The authors declare no competing interests.

Correspondence

Address correspondence to Dr. Memtsoudis: Department of Anesthesiology, Hospital for Special Surgery, 535 East 70th Street, New York, New York 10021. memtsoudiss@hss.edu. This article may be accessed for personal use at no charge through the Journal Web site, www.anesthesiology.org.

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Appendix 1. List of All Billing Descriptions Containing the Search Term "ANES"; Classified into "General Anesthesia," "Neuraxial Anesthesia," "General and Neuraxial Anesthesia Combined," or Neither

General Anesthesia

From billing items:
- 'ANES GENERAL xx[TIME]xx'
- 'ANES GENERAL ADDL xx[TIME]xx'
- 'ANES GENERAL EMERGENCY xx[TIME]xx'
- 'ANES GENERAL EMERGENCY ADDL xx[TIME]xx'
- 'ANES GENERAL FLAT RATE'
- 'ANES GENERAL INTENSIVE xx[TIME]xx'
- 'ANES GENERAL INTENSIVE ADDL xx[TIME]xx'
- 'ANES GENERAL INTENSIVE FLAT RATE'
- 'ER REMOVE VENTILATING TUBE GEN ANES'
- 'MACHINE ANESTHESIA'
- 'MANIPULATION KNEE JOINT W/GEN ANES'
- 'MANIPULATION KNEE JOINT W/GEN ANES OP'
- 'MASK ANESTHESIA'
- 'PF MANIPULATION KNEE JOINT W/GEN ANES'
- 'TRAY ANES GENERAL'
- 'TUBING ANES BREATHING CIRCUIT ADULT'

From CPT codes:
- 31500 'Intubation, endotracheal, emergency procedure'

Neuraxial Anesthesia

From billing items:
- ER INJ ANES EPIDURAL LUMBAR/CAUDAL CONTINUOUS
- ER INJ ANES EPIDURAL LUMBAR/CAUDAL SINGLE
- ER INJ ANES LUMBAR/ THORACIC
- ER INJ ANES SUBARACHNOID/SUBDURAL CONTINUOUS
- ER INJ ANES SUBARACHNOID/SUBDURAL DIFFERENTIAL
- ER INJ ANES SUBARACHNOID/SUBDURAL SINGLE
- INJ ANES EPIDURAL LUMBAR/CAUDAL CONTINUOUS
- INJ ANES EPIDURAL LUMBAR/CAUDAL CONTINUOUS OP
- INJ ANES EPIDURAL LUMBAR/CAUDAL SINGLE
- INJ ANES EPIDURAL LUMBAR/CAUDAL SINGLE OP
- INJ ANES LUMBAR/ THORACIC
- INJ ANES LUMBAR/ THORACIC OP
- INJ ANES SUBARACHNOID/SUBDURAL CONTINUOUS
- INJ ANES SUBARACHNOID/SUBDURAL CONTINUOUS OP
- INJ ANES SUBARACHNOID/SUBDURAL DIFFERENTIAL
- INJ ANES SUBARACHNOID/SUBDURAL DIFFERENTIAL OP
- PF INJ ANES EPIDURAL LUMBAR/CAUDAL CONTINUOUS
- PF INJ ANES EPIDURAL LUMBAR/CAUDAL SINGLE
- PF INJ ANES LUMBAR/ THORACIC
- PF INJ ANES SUBARACHNOID/SUBDURAL CONTINUOUS
- PF INJ ANES SUBARACHNOID/SUBDURAL DIFFERENTIAL
- PF INJ ANES SUBARACHNOID/SUBDURAL SINGLE
- TRAY ANES EPIDURAL
- TRAY ANES SPINAL
- TRAY ANES SPINAL W/ANESTHETIC

From CPT codes
- 62318 'INJECTION, INCLUDING CATHETER PLACEMENT, CONTINUOUS INFUSION OR INTERMITTENT BOLUS, NOT INCLUDING NEUROLYTIC SUBSTANCES, WITH OR WITHOUT CONTRAST (FOR EITHER LOCALIZATION OR EPIDUROGRAPHY), OF DIAGNOSTIC OR THERAPEUTIC SUBSTANCE(S) (INCLUDING ANESTHETIC, ANTISPASMODIC, OPIOID, STEROID, OTHER SOLUTION), EPIDURAL OR SUBARACHNOID; CERVICAL OR THORACIC'
- 62319 'INJECTION, INCLUDING CATHETER PLACEMENT, CONTINUOUS INFUSION OR INTERMITTENT BOLUS, NOT INCLUDING NEUROLYTIC SUBSTANCES, WITH OR WITHOUT CONTRAST (FOR EITHER LOCALIZATION OR EPIDUROGRAPHY), OF DIAGNOSTIC OR THERAPEUTIC SUBSTANCE(S) (INCLUDING ANESTHETIC, ANTISPASMODIC, OPIOID, STEROID, OTHER SOLUTION), EPIDURAL OR SUBARACHNOID; LUMBAR, SACRAL (CAUDAL)'

(*Continued*)

Appendix 1. (*Continued*)

Block Anesthesia
From billing items:
'ER INJ ANES LUMBAR PLEXUS CONT INFUSION BY CATH'
'ER INJ ANES PARAVERTEBRAL MULTI'
'ER INJ ANES PARAVERTEBRAL SINGLE'
'ER INJ ANES SCIATIC SINGLE'
'INJ ANES FEMORAL NERVE CONT INFUSION BY CATHETER'
'INJ ANES FEMORAL NERVE SINGLE'
'INJ ANES LUMBAR OR THORACIC PARAVERT SYMPATHETIC) '
'INJ ANES LUMBAR PLEXUS CONT INFUSION BY CATHETER'
'INJ ANES PARAVERTEBR MULTI'
'INJ ANES PARAVERTEBRAL MULTI'
'INJ ANES PARAVERTEBRAL MULTI OP'
'INJ ANES PARAVERTEBRAL SING'
'INJ ANES PARAVERTEBRAL SINGLE'
'INJ ANES PARAVERTEBRAL SINGLE OP'
'INJ ANES SCIATIC CONT INFUSION BY CATHETER'
'INJ ANES SCIATIC SING'
'INJ ANES SCIATIC SINGLE'
'INJ ANES SCIATIC SINGLE OP'
'PF ANES FOR NERVE BLOCK/INJ NOT PRONE'
'PF ANES FOR NERVE BLOCK/INJ PRONE POS'
'PF ANES KNEE/POPLITEAL SKIN'
'PF ANES REGIONAL LIMB'
'PF INJ ANES FEMORAL NERVE CONT INFUSION BY CATH'
'PF INJ ANES FEMORAL NERVE SINGLE'
'PF INJ ANES LUMBAR PLEXUS CONT INFUSION BY CATH'
'PF INJ ANES PARAVERTEBRAL MULTI'
'PF INJ ANES PARAVERTEBRAL SINGLE'
'PF INJ ANES SCIATIC CONT INFUSION BY CATHETER'
'PF INJ ANES SCIATIC SINGLE'
'TRAY ANES NERVE BLOCK'
'TRAY NERVE BLOCK #478201'
'TRAY REGION/BLOCK ANES'
From CPT codes:
64445 'Injection, anesthetic agent; sciatic nerve, single
64446 'Injection, anesthetic agent; sciatic nerve, continuous infusion by catheter (including catheter placement)'
64447 'Injection, anesthetic agent; femoral nerve, single'
64448 'Injection, anesthetic agent; femoral nerve, continuous infusion by catheter (including catheter placement)'
64449 'Injection, anesthetic agent; lumbar plexus, posterior approach, continuous infusion by catheter (including catheter placement)'
64450 'Injection, anesthetic agent; other peripheral nerve or branch'

CPT = current procedural terminology.

Appendix 2. ICD-9-CM Diagnosis Codes for Major Complications and Outcomes

Event	ICD-9-CM Diagnosis Codes
Pulmonary embolism	415.1
Deep vein thrombosis	451.1, 451.2, 451.8, 451.9, 453.2, 453.4, 453.8, 453.9
Cerebrovascular event	433.01, 433.11, 433.21,433.31, 433.81, 433.91, 434.01, 434.11, 434.91, 997.02
Pulmonary compromise	514, 518.4, 518.5, 518.81, 518.82
Sepsis	038, 038.0, 038.1x, 038.2, 038.3, 038.40, 038.41, 038.42, 038.43, 038.44, 038.49, 038.8, 038.9, 790.
Cardiac (nonmyocardial infarction)	426.0, 427.41, 427.42, 429.4, 997.1, 427.4, 427.3, 427.31, 427.32
Acute myocardial infarction	410.XX
Pneumonia	481, 482.00- 482.99, 483,485, 486, 507.0, 997.31, 997.39
All infections	590.1, 590.10, 590.11,590.8,590.81, 590.2, 590.9, 595.0, 595.9, 599.0, 567.0 480, 480.0, 480.1, 480.2, 480.8, 480.9, 481, 482.0, 482.1, 482.2, 482.3, 482.30, 482.31, 482.32, 482.39, 482.4, 482.40, 482.41, 482.42, 482.49, 482.5, 482.8, 482.81, 482.82, 482.83, 482.84, 482.89, 482.9, 483, 483.0, 483.1, 483.8, 485, 486, 487, 997.31, 038, 038.0, 038.1, 038.10, 038.11, 038.12, 038.19, 038.2, 038.3, 038.4, 038.40, 038.41, 038.42, 038.43, 038.44, 038.49, 038.8, 038.9, 790.7, 998.0, 958.4, 998.5, 998.59, 998.89, 785, 785.50, 785.52, 785.59, 999.39, 999.31, 999.3
Acute renal failure	584, 584.5, 584.9
Gastrointestinal complication	997.4, 560.1, 560.81, 560.9, 536.2, 537.3
Mechanical ventilation	93.90, 96.7, 96.70, 96.71, 96.72, (CPT Code) 94002, 94656, 94003, 94657

CPT = current procedural terminology; ICD-9-CM = International Classification of Diseases, Ninth Revision, Clinical Modification.

Appendix 3. Results from the Multilevel Regression Model (Adjusted for Year of Procedure) with OR and 95% CI

	Reference	OR	95% CI
Age category, yr			
<45		0.80	0.55–1.16
55–64	45–54	1.16**	1.00–1.35
65–74		1.45*	1.26–1.68
>75		1.88*	1.63–2.18
Sex			
Female	Male	0.85*	0.78–0.91
Type of anesthesia			
Neuraxial		0.71**	0.57–0.87
Combined	General	1.13	0.97–1.30
Comorbidities/complications			
Electrolyte and fluid abnormalities	Absence of comorbidity/complication	1.86*	1.69–2.04
Psychosis		1.76*	1.45–2.12
Sleep apnea		1.22**	1.07–1.38
Obesity		1.16**	1.05–1.27
Coagulopathy		1.35**	1.12–1.64
Interaction			
Anemia, no transfusion		1.43*	1.28–1.59
Anemia, with transfusion	No anemia, no transfusion	1.69*	1.47–1.96
No anemia, with transfusion		1.99*	1.78–2.22

* $P < 0.001$; ** $P < 0.01$.
OR = odds ratio.