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CLINICAL RESEARCH

What are the Risk Factors for Cerebrovascular Accidents After Elective Orthopaedic Surgery?

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Abstract

Background Perioperative cerebrovascular accidents (CVAs) are one of the leading causes of patient morbidity, mortality, and medical costs. However, little is known regarding the rates of these events and risk factors for CVA after elective orthopaedic surgery.

Questions/purposes Our goals were to (1) establish the national, baseline proportion of patients experiencing a 30-day CVA and the timing of CVA; and (2) determine independent risk factors for 30-day CVA rates after common elective orthopaedic procedures.

Methods Patients undergoing elective TKA, THA, posterior or posterolateral lumbar fusion, anterior cervical discectomy and fusion, and total shoulder arthroplasty, from 2006 to 2012, were identified from the American College of Surgeons National Surgical Quality Improvement Program® database. A total of 42,150 patients met inclusion criteria. Thirty-day CVA rates were recorded for each procedure, and patients were assessed for characteristics associated with CVA through univariate analysis. Multivariate regression models were created to identify independent risk factors for CVA.

Results A total of 55 (0.13%) patients experienced a CVA within 30 days of the procedure, occurring a median of 2 days after surgery (range, 1–30 days) with 0.08% of patients experiencing a CVA after TKA, 0.15% after THA, 0.00% after single-level anterior cervical discectomy and fusion, 0.38% after multilevel anterior cervical discectomy and fusions, 0.20% after single-level posterior or posterolateral lumbar fusion, 0.70% after multilevel posterior or posterolateral lumbar fusion, and 0.22% after total shoulder arthroplasty. Independent risk factors for CVA included age of 75 years or older (odds ratio [OR], 2.50; 95% CI, 1.44–4.35; p = 0.001), insulin-dependent diabetes mellitus (OR, 3.08; CI, 1.47–6.45; p = 0.003), hypertension (OR, 2.71; CI, 1.19–6.13; p = 0.017), history of transient ischemic attack (OR, 2.83; CI, 1.24–6.45; p = 0.013), dyspnea (OR, 2.51; CI, 1.30–4.86; p = 0.006), chronic obstructive pulmonary disease (OR, 2.33; CI, 1.06–5.13; p = 0.036), and operative time of 180 minutes or greater (OR, 3.25; CI 1.60–6.60; p = 0.001).

Conclusions Numerous nonmodifiable patient comorbidities and increased operative time were associated with

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CVA after elective orthopaedic procedures. However, the American College of Surgeons National Surgical Quality Improvement Program® database does not code for cardiac arrhythmia or atrial fibrillation, which other studies have suggested may be important predictor variables; those may be important risk factors, although we were unable to evaluate them in our study. Surgeons should counsel patients with these risk factors and limit their operative time to reduce the risk of these adverse events, and future studies should examine other patient characteristics such as arrhythmia and noncoronary heart disease and assess the role of pharmacologic prophylaxis in patients with these risk factors.

Level of Evidence Level III, prognostic study.

Introduction

Cerebrovascular accidents (CVAs) are a leading cause of disability in the United States, affecting almost 800,000 patients annually and contributing to substantial postincidence morbidity, mortality, and more than USD 33 billion in annual medical expenditures [30]. Additionally, stroke is projected to be the second leading cause of worldwide mortality through 2020 while remaining the largest contributor to adult neurologic disability [31]. The perioperative period places patients at an even greater risk of CVA owing to surgery-induced hypercoagulability, general anesthesia, dehydration, stasis and bed rest, and withholding administration of preoperative antiplatelet and anticoagulation agents [38]. Despite advances in surgical techniques and perioperative care, the incidence of stroke has remained stable, varying by the type and complexity of operative intervention [16, 22, 29, 32, 37].

The proportion of patients experiencing a CVA after general surgery procedures range from 0.08% to 0.7% to as much as 10% for complex cardiac operations, yet epidemiologic data concerning orthopaedic surgery have been minimal [8, 14, 23, 26]. Although previous studies directly examining CVA rates and predictors have shown 0.1% to 0.2% of patients experienced a CVA after THA, TKA, and lumbar arthrodesis [24, 29], information regarding other elective inpatient procedures has been limited to small cohorts or case reports [11, 22, 24, 29]. These studies have shown that history of neurologic disorders, congestive heart failure, electrolyte imbalances, noncoronary heart disease, nonelective surgery, general anesthesia, and intraoperative arrhythmia were associated with these events, depending on the procedure. Although CVA rates have been deemed relatively low after orthopaedic intervention [11, 22, 24, 29], determining patients at high risk and CVA timing is crucial for detailed preoperative counseling, thorough perioperative inpatient monitoring and prevention, and appropriate postoperative followup.

We therefore analyzed a large, national cohort of patients undergoing common elective inpatient orthopaedic procedures through the use of the American College of Surgeons National Surgical Quality Improvement Program® (ACS NSQIP®) database [1]. Specifically, our goals are to (1) establish baseline, national 30-day CVA proportions and timing; and (2) determine independent risk factors for 30-day CVA after common elective orthopaedic procedures.

Patients and Methods

A retrospective cohort analysis of the ACS NSQIP® database from 2006 to 2012 was performed. Patient variables from more than 250 participating institutions nationwide are included in the ACS NSQIP®, and this database has been used to analyze trends and associations in orthopaedic surgery [15, 17, 28]. The method of data abstraction from the ACS NSQIP® participant files has been described [4, 18]. Patients were identified through Current Procedural Terminology (CPT) codes and included patients undergoing TKA (CPT 27447), THA (CPT 27130), single-level posterior or posterolateral lumbar fusion (CPT 22612 with no CPT modifiers), multilevel posterior or posterolateral lumbar fusion (CPT 22612 with a CPT modifier of 22614), single-level anterior cervical discectomy and fusion (CPT 22551 with no CPT modifiers), multilevel anterior cervical discectomy and fusions (CPT 22612 with a CPT modifier of 22552), and total shoulder arthroplasty (CPT 23472). Exclusion criteria included "emergency" or "nonelective" cases (labeled in the ACS NSQIP® database as "emergency surgery occurring within a short interval from diagnosis to surgery, … and outcome is potentially threatened by unnecessary delay and the patient's status could deteriorate unpredictably or rapidly, and … the emergency case variable distinguishes between urgent, semi-elective/elective cases and true emergencies" and each hospital's definition of outpatient, respectively [1]. Exclusion criteria also included outpatient surgery, patients with preoperative sepsis or systemic inflammatory response syndrome, patients with prior surgery within 30 days of the index procedure, cases with missing preoperative or operative variables (n = 49,343; 49.7%), and cases with unrelated additional concurrent procedures (such as bilateral same-day TKA, bilateral same-day THA, and anterior instrumentation in posterior or posterolateral lumbar fusion,). Following these selection criteria, a total of 42,150 patients of an original 99,285 were included in our final analysis (Fig. 1). These included 22,900 (54%) patients

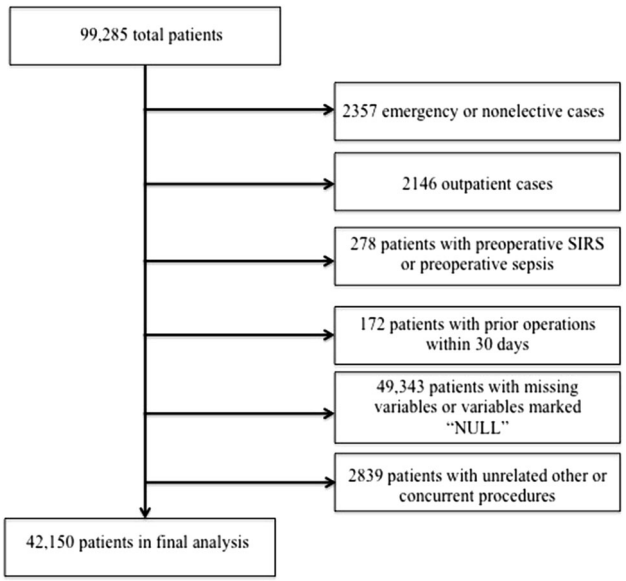

Fig. 1 The flowchart for our study is shown. SIRS = systemic inflammatory response syndrome.

who had TKAs; 13,437 (32%) who had THAs; 604 (1%) who had a single-level anterior cervical discectomy and fusion; 527 (1%) who had multilevel anterior cervical discectomies and fusions; 2042 (5%) who had a single-level posterior or posterolateral lumbar fusion; 853 (2%) who had multilevel posterior or posterolateral lumbar fusions; and 1787 (4%) who had total shoulder arthroplasty.

The primary outcome was CVA within 30 days of the index procedure and was defined by the ACS-NSQIP® participant use files as "an embolic, thrombotic, or hemorrhagic vascular accident or stroke with motor, sensory, or cognitive dysfunction (eg, hemiplegia, hemiparesis, aphasia, sensory deficit, impaired memory) that persists for 24 or more hours" [1]. CVA timing (day of CVA event after surgery and pre- versus postdischarge events) also was recorded. Preoperative and operative variables were captured for each patient, including those previously shown to be associated with perioperative stroke, such as age, prior history of CVA, hypertension, diabetes, prior myocardial infarction, congestive heart failure, and general anesthesia (Table 1) [22, 24, 29, 32, 38].

IBM SPSS® Version 22.0 (IBM Corp, Armonk, NY, USA) was used for all descriptive and comparative analyses in this study. In all cases, a p value of 0.05 or less was deemed statistically significant. Patients were split in two groups: those with a 30-day CVA and those without. Univariate analysis of preoperative and operative variables between the two cohorts was conducted through the Fisher's exact test. Multivariate logistic multivariate regression models were created to determine independent risk factors for CVA. Candidate variables were screened from the original univariate analysis, and variables with p less than 0.2 and at least five incidences were included [33]. Hosmer-Lemeshow and c-statistics were calculated to assess the calibration and goodness of fit of the multivariate analysis, respectively [27].

Table 1. Patient characteristics

Variable	Number of patients	Percentage
Male sex	16,799	40%
Age ≥ 75 years	10,283	24%
BMI ≥ 30 kg/m^2	22,534	53%
Functional dependence	1871	4%
Current smoker	4867	12%
Insulin-dependent diabetes mellitus	1659	4%
Noninsulin-dependent diabetes mellitus	4933	12%
Hypertension	26,791	64%
History of myocardial infarction or percutaneous coronary intervention	2694	6%
History of transient ischemic attack	1178	3%
History of cerebrovascular accident	1213	3%
Recent congestive heart failure exacerbation	73	0%
Dyspnea	3530	8%
Peripheral vascular disease or rest pain	309	1%
Current malignancy	184	0%
Ascites or esophageal varices	17	0%
Chronic obstructive pulmonary disease	1654	4%
Dialysis	63	0%
Preoperative creatinine ≥ 2 mg/dL	1488	4%
Chronic steroid use	1301	3%
Bleeding disorder	1018	2%
Preoperative hematocrit ≤ 37%	8752	21%
ASA Class ≥ 3	19,303	46%
Operative time ≥ 180 minutes	3068	7%
General anesthesia	24,507	58%
TKA	22,900	54%
THA	13,437	32%
Single-level anterior cervical discectomy and fusion	604	1%
Multilevel anterior cervical discectomy and fusion	527	1%
Single-level posterior or posterolateral lumbar fusion	2042	5%
Multilevel posterior or posterolateral lumbar fusion	853	2%
Total shoulder arthroplasty	1787	4%

ASA = American Society of Anesthesiologists.

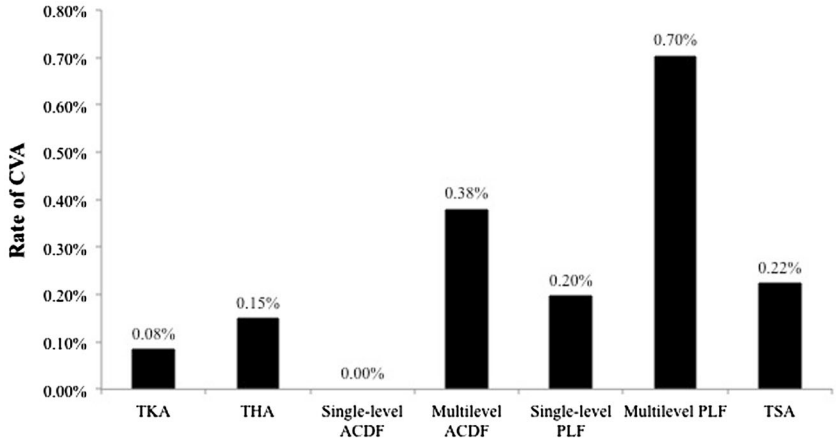

Fig. 2 The proportion of patients with a 30-day cerebrovascular accident (CVA) by procedure is shown. ACDF = anterior cervical discectomy and fusion; PLF = posterior or posterolateral lumbar fusion; TSA = total shoulder arthroplasty.

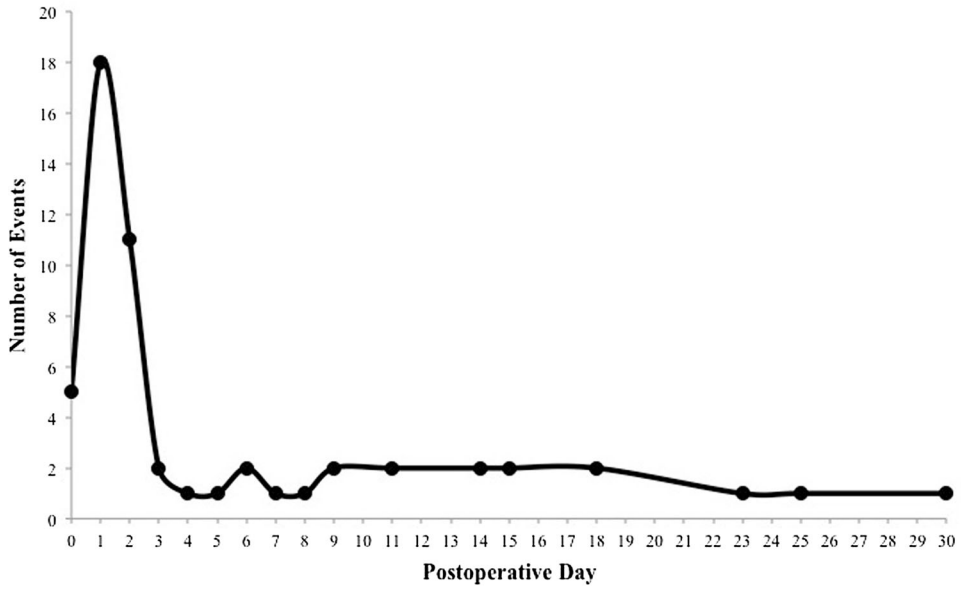

Fig. 3 Distribution of timing of cerebrovascular accidents is shown.

Results

Fifty-five of 42,150 patients (0.13%) experienced a CVA within 30 days of the procedure, which is comparable to proportions of patients experiencing CVA after general surgery procedures. The proportion of patients with a 30-day CVA was 0.08% for TKA, 0.15% for THA, 0.00% for single-level anterior cervical discectomy and fusion, 0.38% for multilevel anterior cervical discectomies and fusions, 0.20% for single-level posterior or posterolateral lumbar fusion, 0.70% for multilevel posterior or posterolateral lumbar fusions, and 0.22% for total shoulder arthroplasty (Fig. 2). CVA occurred a median of 2 days (range, 1–30 days) after the index procedure, with the majority of events occurring on postoperative Day 1 (Fig. 3). A total of 15 events (27%) occurred after hospital discharge and four patients (7%) who had a CVA died during the 30-day surveillance period.

After controlling for potentially confounding variables, specific patient and procedural characteristics were shown to be independent risk factors for 30-day CVA after elective orthopaedic surgery. These variables included age of 75 years or older (odds ratio [OR], 2.50; 95% CI, 1.44–4.35; p = 0.001), insulin-dependent diabetes mellitus (OR, 3.08; CI, 1.47–6.45; p = 0.003), hypertension (OR, 2.71; CI, 1.19–6.13; p = 0.017), history of transient ischemic attack (OR, 2.83; CI, 1.24–6.45; p = 0.013), dyspnea (OR, 2.51; CI, 1.30–4.86; p = 0.006), chronic obstructive

Table 2. Multivariate analysis of risk factors for CVA

Preoperative or operative variable	Odds ratio	95% confidence interval	p Value
Male sex	1.26	0.73–2.18	0.402
Age ≥ 75 years	2.50	1.44–4.35	0.001*
Insulin-dependent diabetes mellitus	3.08	1.47–6.45	0.003*
Hypertension	2.71	1.19–6.13	0.017*
History of myocardial infarction or percutaneous coronary intervention	1.67	0.81–3.42	0.164
History of transient ischemic attack	2.83	1.24–6.45	0.013*
Dyspnea	2.51	1.30–4.86	0.006*
Chronic obstructive pulmonary disease	2.33	1.06–5.13	0.036*
General anesthesia	1.57	0.81–3.05	0.181
Operative time ≥ 3 hours	3.25	1.60–6.60	0.001*
TKA	0.61	0.33–1.12	0.108
Multilevel anterior cervical discectomy and fusion	2.66	0.62–11.48	0.190
Multilevel posterior or posterolateral lumbar fusion	1.84	0.69–4.94	0.224

* Statistical significance ($p \leq 0.05$); CVA = cerebrovascular accident.

pulmonary disease (OR, 2.33; CI, 1.06–5.13; p = 0.036), and operative time of 180 minutes or more (OR, 3.25; CI 1.60–6.60; p = 0.001) (Table 2). The c-statistic was calculated to be 0.879, showing good model predictability.

Discussion

Stroke is one of the most dreaded complications after surgery, and to provide adequate preventive and therapeutic measures, it is essential that surgeons ascertain which patients are at high risk for these adverse events. Postoperative stroke rates have varied depending on research methodology and surgical population and have remained stable despite surgical advances, potentially reflecting an aging population with increasing concomitant comorbidities [30, 37]. Unfortunately, relatively few orthopaedic studies have examined perioperative cerebrovascular events [11, 22, 24, 29, 32]. We therefore sought to assess the rates and predictors of CVA after common elective inpatient orthopaedic procedures to provide physicians a more accurate glimpse of this potential morbidity. Recognition of the incidence, risks, and timing of CVA after surgery is crucial for informed consent, patient preoperative counseling, treatment decisions, and potential prophylaxis in the critical postoperative period for patients at high-risk.

When evaluating our results, the limitations must be kept in mind, most of which are intrinsic constraints of the ACS NSQIP® database. First, our data assess only 30-day complications, and although the majority of CVAs in patients having noncardiac surgery occur in this interval, some CVAs undoubtedly occur later, therefore it is likely that CVA rates are somewhat higher than those we report [19]. Additionally, the ACS NSQIP® database does not differentiate between ischemic and hemorrhagic stroke, and although studies [6, 23, 34] have shown that the majority of perioperative strokes is ischemic, we are unable to comment on the specific proportions in our study. Moreover, although the ACS NSQIP® database contains a comprehensive list of preoperative and operative variables, certain predictors of CVA (such as atrial fibrillation and carotid stenosis) are not included, which may be potential confounders in our results [9, 12]. Additionally, although our study captures a large national sample size, the ACS NSQIP® database does not contain information regarding institution type (community versus academic), surgical volume, institution-specific postoperative protocols, surgeon experience, geographic location, use of chemical thromboprophylaxis, prevention of perioperative bleeding using chemoprophylaxis (such as tranexamic acid), and type of fixation in TKA and in THA (cemented versus uncemented), all of which may play a role in CVA rates. Finally, the treatment for CVA (tissue plasminogen activator versus other pharmacologic treatment) was not recorded in the ACS NSQIP® database.

Our results show that of patients undergoing elective orthopaedic surgery, 0.08% to 0.70% of them experience a 30-day CVA, depending on the procedure. Similar proportions were seen in previous reports of CVA in joint arthroplasty but our findings show a higher percentage than in reports of CVA after posterior lumbar arthrodesis [22–24]. A potential explanation for this discrepancy may be the differences in the source of data between the studies, as the National (Nationwide) Inpatient Sample (NIS) captures only predischarge events unlike the ACS NSQIP®,

therefore leading to lower proportions of postoperative CVA (0.15%) [5]. In addition, our study expands on previously known literature owing to a larger, national cohort of patients. The majority (62%) of postoperative strokes occurred within 2 days after surgery with a peak incidence on postoperative Day 1, but more than ¼ of these adverse events appear after hospital discharge. Mortazavi et al. [29] reported that patients experienced a postoperative CVA primarily on postoperative Day 1, with 25 of 36 patients (69%) experiencing a CVA within the first 2 days after TKA or THA. Our study expands on their data through a larger number of patients, and with the inclusion of nonarthroplasty cases which follow a similar temporal pattern. This information regarding timing of CVAs is important for postoperative in-house monitoring of high-risk patients and appropriate followup timing succeeding hospital discharge.

Although our study identified several important patient- and procedure-related risk factors for postoperative CVA that previously have been associated with CVA in orthopaedic surgery, others such as insulin-dependent diabetes mellitus, hypertension, chronic obstructive pulmonary disease, and long operative times were not formerly identified. Similar to the results in our study, a previous report in the orthopaedic literature identified increased age as a risk factor for CVA [24]. A higher comorbidity burden appears with advanced age, and rates of perioperative CVA are significantly increased in the elderly [2, 20]. Diabetes, hypertension, chronic obstructive pulmonary disease, and increased operative time, however, were reported not to be independently associated with CVA after elective orthopaedic surgery [24, 29].However, this may be attributable to insulin-dependent diabetes mellitus not being separated from noninsulin-dependent diabetes mellitus, there were smaller patient cohorts, and/or the exclusion of postdischarge CVAs with the NIS, which may have contributed to these discrepancies. Insulin-dependent diabetes mellitus has been linked to advanced atherosclerosis and ischemic stroke, whereas uncontrolled hypertension is associated with ischemic and hemorrhagic CVA in the general population [13, 35]. Moreover, chronic obstructive pulmonary disease recently was shown to be associated with carotid artery wall thickening, placing patients at greater danger for ischemic events [21]. Furthermore, advanced operative time has been linked to numerous postoperative adverse events after orthopaedic surgery, potentially owing to the effect of anesthesia time or to a more complicated procedure [3, 36]. An important difference in the results of our study with those of Mortazavi et al. [29] is that general anesthesia was not independently associated with CVA. Once again, this may have stemmed from differences in patient characteristics between the two studies and the larger number of patients in our study, along with different preoperative variable inclusions. Although our results show that a history of transient ischemic attack is a predictor of CVA, paradoxically, history of CVA was not independently associated with 30-day CVA rates [10]. An explanation for this incongruity may be that patients with previous CVA may have been receiving anticoagulants before surgery thereby preventing perioperative strokes, whereas patients with only a history of transient ischemic attack may not have had this previous prophylaxis. Additionally, previous CVA may have been embolic—for example, from mural thrombi in patients with a history of atrial fibrillation or patent foramen ovale—which may have been controlled and treated before surgery. On the basis of these findings, we recommend that patients older than 75 years, those who have undergone a procedure longer than 3 hours, or with insulin-dependent diabetes mellitus, hypertension, history of transient ischemic attack, dyspnea, or chronic obstructive pulmonary disease should be managed and followed more stringently in the immediate postoperative period after orthopaedic surgery by those involved their postoperative care. These patients may be targets for preoperative pharmacologic prophylaxis in the future [7, 25].

We present an analysis of 30-day CVAs after elective orthopaedic surgery in a large, national sample. Orthopaedic surgeons should be aware that the majority of postoperative CVAs occur by postoperative Day 2, and patients at high risk should be monitored more closely during this time. Although many associated patient comorbidities are not modifiable, physicians should be aware of these patients for preoperative counseling and risk stratification, while limiting operative time to reduce the risk of perioperative CVAs. Future studies should examine the association of other patient comorbidities such as noncoronary heart disease and atrial fibrillation on CVA in the orthopaedic population for more definitive recommendations.

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