



Clinical Study

United States neurosurgery annual case type and complication trends between 2006 and 2013: An American College of Surgeons National Surgical Quality Improvement Program analysis



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ABSTRACT

We aimed to identify trends in the neurosurgical practice environment in the United States from 2006 to 2013 using the American College of Surgeons–National Surgical Quality Improvement Program (NSQIP) database, and to determine the complication rate for spinal and cranial procedures and identify risk factors for post-operative complications across this time period. We performed a search of the American College of Surgeons–NSQIP database for all patients undergoing an operation with a surgeon whose primary specialty was neurological surgery from 2006 to 2013. Analysis of patient demographics and pre-operative co-morbidities was performed, and multivariate analysis was used to determine predictors of surgical complications. From 2006 to 2013, the percentage of spinal operations performed by neurosurgeons relative to cranial and peripheral nerve cases increased from 68.0% to 76.8% ($p < 0.001$) according to the NSQIP database. The proportion of cranial cases during the same time period decreased from 29.7% to 21.6% ($p < 0.001$). The overall 30-day complication rate among all 94,621 NSQIP reported patients undergoing operations with a neurosurgeon over this time period was 8.2% (5.6% for spinal operations, 16.1% for cranial operations). The overall rate decreased from 11.0% in 2006 to 7.5% in 2013 ($p < 0.001$). Several predictors of post-operative complication were identified on multivariate analysis.

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1. Introduction

Post-operative complications in neurosurgery can result in significant morbidity and mortality [1,2]. Many relatively common complications, such as surgical site infections and urinary tract infections, are largely considered preventable. As a result, much effort has been expended in recent years on limiting or eliminating these complications in an effort to improve patient outcomes, decrease length of stay, and lower costs. Surgical complications can increase healthcare costs for a variety of reasons, most prominently by lengthening hospital stay and increasing the rate of re-admission and/or re-operation [1–11]. Due to recent reimbursement restrictions by the Center for Medicare and Medicaid Services on key, preventable hospital-acquired conditions, post-operative complications may also begin to impose increased financial burden on the hospital rather than the payer [12–16].

The identification of risk factors for developing post-operative complications can help discern which patients may be at elevated

risk for developing complications and result in incorporation of this knowledge into improved treatment plans. In 2004, the American College of Surgeons (ACS) established the National Surgical Quality Improvement Program (NSQIP) database to collect and report 30-day outcomes in order to determine and improve post-operative complication rates [17–23]. The database is a large, randomized, nationwide, multi-center database and has previously been used by a wide array of surgical specialties to generate predictive models and identify risk factors associated with post-operative complications [17,18,20,24–35].

Few papers have been published in the neurosurgical literature using the NSQIP database [24,36–57]. Those that have been published generally focus on complications following individual operation types [24,36,37,39,41,46,51,52,57] or on a single complication type [37–39,43,47,48,56]. The purpose of this study was two-fold. First, we aimed to determine the overall post-neurosurgery complication rates between 2006 and 2013, for both cranial and spinal procedures, using the ACS–NSQIP database. Based on these results, we aimed to categorize clinical risk factors that predict post-operative complications for neurosurgical procedures by multivariate analysis.

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The second aim of the study was to examine possible changes in proportions of cranial versus spinal neurosurgery over the time period in question. It has been hypothesized previously that changes in reimbursement patterns and residency training may affect case load among practicing neurosurgeons [58–60]. We aimed to compare the relative proportions of spine and cranial cases performed by neurosurgeons from 2006 to 2013, as reported in the NSQIP database, in order to identify possible trends in the overall practice environment of United States (U.S.) neurosurgery.

2. Methods

After Institutional Review Board approval, all existing NSQIP records from 2006 to 2013 were collected and compiled. From these, only those patients who underwent an operation with a surgeon whose primary reported surgical specialty was neurosurgery were extracted. 94,621 patients were identified. These cases were then analyzed to identify trends in case type and complication rate, using one-way ANOVA with Scheffé's *post hoc* analysis. Bivariate comparisons were performed using chi-squared statistics, and multivariate regression was used to identify risk factors for 30-day post-operative complications. All data analysis was performed with IBM Statistical Package for the Social Sciences (SPSS) version 23 (2014) (IBM Corporation, Armonk, NY, USA). For all tests, $p < 0.05$ was considered significant.

3. Results

Of 94,621 patients in the NSQIP database who underwent neurosurgical operations from 2006 to 2013, 50.9% were male (Table 1). The mean age of all neurosurgery patients was 56.74 years (SD = 14.90 years), and 81.8% underwent inpatient

procedures. During the 30-day post-operative period, 8.2% of patients experienced complications (5.6% for spinal patients, 16.1% for cranial patients). The average age of patients who developed complications was 60.7 years (SD = 14.93 years). Pre-operative clinical features among patients who developed complications included coma greater than 24 hours (6.2%), ventilator dependence (11.4%), impaired sensorium (18.0%), cerebrovascular accident (CVA)/stroke with neurological deficit (16.9%), myocardial infarction within six months of operation (1.1%), acute renal failure (0.6%), congestive heart failure (1.5%), current dialysis (1.5%), quadriplegia (2.5%), open wound/wound infection (4.3%), and dependent health status prior to surgery (18.5%).

The rate of post-neurosurgery complications decreased from 11.0% in 2006 to 7.5% in 2013 ($p < 0.001$) based on the NSQIP database (Table 2, Fig. 1). There was also a significant decrease in re-operations from 2009 to 2013, from 5.5% to 3.5% ($p < 0.001$), but no significant change from 2006 to 2013. Whereas the spinal complication rate was the same (5.4%) in 2006 and 2013, the cranial complication rate decreased from 23.2% in 2006 to 14.6% in 2013 ($p < 0.001$).

The percentage of spine cases performed by neurosurgeons relative to cranial cases increased from 68.0% in 2006 to 76.8% in 2013 ($p < 0.001$). (Table 3) The relative proportion of cranial cases decreased over the same time period, from 29.7% in 2006 to 21.6% in 2013 ($p < 0.001$). Overall, there was an 8.8% increase in spinal cases relative to total cases and an 8.1% decrease in cranial cases relative to total cases between 2006 and 2013. The number of peripheral nerve and non-neurosurgery operations reportedly performed by neurosurgeons was relatively small and remained relatively constant across the years included in this study.

On multivariate analysis, predictors of post-operative complication were sex ($p = 0.039$, odds ratio [OR] = 0.916), age ($p < 0.001$,

Table 1
National Surgical Quality Improvement Program (NSQIP) neurosurgery patient demographics and prior medical history

	Total (n = 94621)	No Complication (n = 86837)	Complication (n = 7784)	p-value
Mean age, years $\pm$ SD	56.74 $\pm$ 14.90	56.39 $\pm$ 14.84	60.70 $\pm$ 14.93	<0.001
Male sex, number (%)	48107 (50.9)	44164 (50.9)	3943 (50.7)	0.748
Inpatient	77386 (81.8)	69935 (80.5)	7451 (95.7)	<0.001
Pre-Operative Comorbidities, number (%)				
Diabetes mellitus with oral agents or insulin	5886 (6.8)	5063 (6.4)	823 (11.8)	<0.001
Current smoker within one year	22802 (24.1)	21065 (24.3)	1737 (22.3)	<0.001
Dyspnea	4948 (5.2)	4413 (5.1)	535 (6.9)	<0.001
Recent alcohol use	1344 (3.8)	1178 (3.7)	166 (5)	<0.001
Do not resuscitate status	142 (0.4)	114 (0.4)	28 (0.8)	<0.001
Diminished functional health status	5432 (5.8)	4009 (4.6)	1423 (18.5)	<0.001
Ventilator dependent	1245 (1.3)	359 (0.4)	886 (11.4)	<0.001
History of severe COPD	4059 (4.3)	3491 (4)	568 (7.3)	<0.001
Congestive heart failure within 30 days pre-op	368 (0.4)	248 (0.3)	120 (1.5)	<0.001
Myocardial infarction within 6 months pre-op	94 (0.3)	58 (0.2)	36 (1.1)	<0.001
Hypertension requiring medication	44718 (47.3)	40216 (46.3)	4502 (57.8)	<0.001
Acute renal failure	127 (0.1)	83 (0.1)	44 (0.6)	<0.001
On dialysis pre-op	371 (0.4)	254 (0.3)	117 (1.5)	<0.001
Impaired sensorium	1297 (3.7)	703 (2.2)	594 (18)	<0.001
Coma greater than 24 hours	281 (0.8)	75 (0.2)	206 (6.2)	<0.001
History of transient ischemic attacks	854 (2.4)	724 (2.3)	130 (3.9)	<0.001
CVA/Stroke with neurological deficit	1427 (4)	870 (2.7)	557 (16.9)	<0.001
CVA/Stroke without neurological deficit	681 (1.9)	546 (1.7)	135 (4.1)	<0.001
Paraplegia	1277 (3.6)	1052 (3.3)	225 (6.8)	<0.001
Quadriplegia	277 (0.8)	196 (0.6)	81 (2.5)	<0.001
Disseminated cancer	3993 (4.2)	3375 (3.9)	618 (7.9)	<0.001
Open wound/wound infection	1224 (1.3)	887 (1)	337 (4.3)	<0.001
Steroid use for chronic condition	5702 (6)	4882 (5.6)	820 (10.5)	<0.001
Bleeding disorders	2494 (2.6)	1879 (2.2)	615 (7.9)	<0.001
Recent blood transfusion	344 (0.4)	223 (0.3)	121 (1.6)	<0.001
Recent chemotherapy	413 (1.2)	332 (1)	81 (2.5)	<0.001
Recent radiotherapy	225 (0.6)	170 (0.5)	55 (1.7)	<0.001
Recent operation	982 (2.8)	748 (2.3)	234 (7.1)	<0.001

COPD = chronic obstructive pulmonary disease, CVA = cerebrovascular accident, Pre-op = pre-operative, SD = standard deviation.

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