Neurosurgical infection rates and risk factors: a national surgical quality improvement program analysis of 132,000 patients, 2006e-2014

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■ BACKGROUND: **The existing body of literature on postoperative neurosurgical infections lacks large multicenter reports on postoperative neurosurgical infections. This is the largest study to date of postoperative neurosurgical infections rates, time to event, and risk factors.**

■ METHODS: **Demographics, medical history, and postoperative infections were assessed for all adult patients in the large, randomized, multicenter American College of Surgeons–National Surgical Quality Improvement Program (ACS-NSQIP) database undergoing an operation with a surgeon whose primary specialty was neurological surgery from 2006 to 2014.**

■ RESULTS: **Of 3,723,797 cases from 517 institutions in the NSQIP from 2006 to 2014, 132,063 neurosurgery cases were identified. Within these patients, the 30-day rate of postoperative infections was 5.3%. Postoperatively, 1.8% of patients developed surgical site infections (SSI), and 3.9% developed other infections including pneumonia and urinary tract infections. Superficial SSI had a cumulative incidence of 0.8% at a median of 16 (interquartile range [IQR], 11–22) days. Pneumonia had a cumulative incidence of 1.4% at a median of 5 days (IQR, 2–10 days). Systemic inflammatory response syndrome had a cumulative incidence of 1.6% at a median of 3 days (IQR, 8–16 days). Predictors of postoperative infections on multivariable analysis included female sex, older age, obesity, functionally dependent status before surgery, ventilator dependence, preoperative steroid use, bleeding disorders, hyponatremia, lymphocytosis, anemia, thrombocytosis, emergent case status, wound class II–IV, American Society of Anesthesiologists class 3–5, and longer operative times.**

■ CONCLUSION: **The overall ACS-NSQIP reported rate of postoperative infections was 5.3% from 2006 to 2014. Multivariable analysis demonstrated several predictive factors for postoperative infections.**

INTRODUCTION

Postoperative infections lead to increased morbidity, mortality, cost, unplanned readmission, reoperation, and prolonged length of stay after neurological surgery.[1-12] Incidence of neurosurgical infections remains highly variable. Reported rates of surgical site infections, for example, vary from 1%–8% in cranial cases to 0.5%–18% in spine operations.[1,2,5,6,8,10,13-18] Similarly, reports of predictive factors have yet to establish a clear picture of the risks for infection after neurosurgery.[1,6-8,10,15,19-21] The majority of reports regarding infections in neurosurgical patients have assessed complications from single institutions across limited time frames, and few studies have used

Key words
- Complications
- Infection
- Neurosurgery
- NSQIP
- Quality improvement
- Organ space infections
- Surgical site infections
- Urinary tract infections

Abbreviations and Acronyms
ACS: American College of Surgeons
ASA: American Society of Anesthesiologists
BMI: Body mass index
COPD: Chronic obstructive pulmonary disease
INR: international normalized ratio
IQR: Interquartile range
NSQIP: National Surgical Quality Improvement Program
PTT: Partial thromboplastin time
RVU: Relative value unit
SIRS: Systemic inflammatory response syndrome
SSI: Surgical site infections
UTI: Urinary tract infection

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a large, multi-institutional sample to analyze the rates of all infections after neurosurgery.[2,4,6,7,14,21-23]

The purpose of this study was to characterize the incidence of and predictive factors for postoperative neurosurgical infections of any type. The American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) is a large, prospectively collected, nationwide, multicenter database of 30-day postoperative outcomes.[9,11,20,24] The ACS initiated the NSQIP project in 2004, and the database now includes more than 3.7 million patient cases from more than 500 institutions. The database includes objective criteria, internal audits to filter reported data, and more than 130,000 neurosurgical records from 2006 to 2014.[9,11,12,20,24-29] We analyzed the NSQIP database to create predictive models for postoperative infections after neurological surgery.

METHODS

Data Source

The prospective National Surgical Quality Improvement Program (NSQIP) registry was used for the years 2006–2014, and it is maintained by the American College of Surgeons (ACS). Trained surgical reviewers prospectively collect data for NSQIP using a uniform protocol. Hospitals, ranging from small rural community hospitals to large academic centers, included within NSQIP require sufficient financial and institutional resources to maintain high-quality data collection and analysis required by the standards of the database. Patients enrolled in NSQIP are followed for 30 days postoperatively, and all complications (among those collected in the NSQIP algorithm) that occurred during this period are recorded; there is no administrative censoring or loss to follow-up of patients entered. Our institutional review board has exempted the deidentified NSQIP data set from individual review.

Inclusion and Exclusion Criteria

Patients who were included met the following criteria: 1) age 18 years or older; 2) the attending surgeon was a neurosurgeon. Of 3,723,797 cases in NSQIP from 2006 to 2014, 132,063 neurosurgery cases were identified.

Covariates

Pertinent covariates collected by NSQIP were extracted. Age was examined categorically by quartile. Sex, American Society of Anesthesiology (ASA) physical classification (1–2, 3, 4–5, or missing), and preoperative functional status (dependent versus independent) were assessed. Comorbidities evaluated included: smoking (within the past year), hypertension requiring medication, chronic obstructive pulmonary disease, dyspnea, diabetes mellitus, and a bleeding disorder (defined by NSQIP as vitamin K deficiencies, hemophilia, thrombocytopenia, and long-term anticoagulant usage). Body mass index was determined based on height and weight, with obesity defined using World Health Organization criteria: class I obesity as 30–34.99 kg/m^2 and class II or III is greater than 35 kg/m^2. Disseminated cancer is defined by NSQIP as multiple metastases indicating that the cancer is widespread. Preoperative laboratory values were extracted and stratified (stratification was based on previous neurosurgical studies that have used NSQIP as a data source)[30,31]: hematocrit (by 36%), international normalized ratio (by 1.4), partial thromboplastin time (by 40 seconds), and platelets (by 450,000 per microliter). Preoperative steroid use (within 30 days) was also extracted. An open wound is defined by NSQIP as any incision that directly communicates with air. Preoperative systemic inflammatory response syndrome (SIRS) is indicated in any patient with at least two of the following criteria: body temperature greater than 38°C or less than 36°C, heart rate greater than 90 beats per minute, respiratory rate greater than 20 breaths per minute, leukocytosis or leukopenia (white blood cell [WBC] count greater 12,000 cells/μL and less than 4000 cells/μL, respectively), or anion gap acidosis. Admission type, preoperative intubation (within 48 hours), case urgency (emergent or elective), and operative time (by quartile) were also extracted. Wound classification compared class I (clean) operations to class II (clean-contaminated), III (contaminated), or IV (dirty) designations.

Outcomes

The outcomes evaluated were any infection (superficial surgical site infection, organ/space surgical site infection, deep surgical site infection, wound dehiscence, urinary tract infection, pneumonia, systemic inflammatory response syndrome), surgical site infections (superficial surgical site infection, organ/space surgical site infection, deep surgical site infection, wound dehiscence), and other infections (urinary tract infection, pneumonia, systemic inflammatory response syndrome).

Missing Data

Patients with missing data for demographics were placed in a separate category for that variable, allowing for appropriate use of missing data in logistic regression.

Statistical Analysis

Statistical analyses were conducted with SPSS version 23 (IBM, Armonk, NY). Descriptive statistics were performed on baseline variables, and χ^2 measures assessed their association with the specific outcome evaluated. Multivariable logistic regression models were thereafter constructed using backward selection using the likelihood ratio test. A probability value less than 0.05 was determined to be statistically significant.

RESULTS

Demographics

Of 132,063 neurosurgical patients in the ACS-NSQIP database from 2006 to 2014, the 30-day rate of postoperative infections was 5.3%. Over this period, the 30-day mortality was 1.5%, the median length of total hospital stay was 2 days (interquartile range [IQR], 1–5 days), and the median operative time was 128 minutes (IQR, 82–200 minutes). Postoperatively, 1.8% of patients developed surgical site infections (SSI) and 3.9% developed other infections including pneumonia, urinary tract infections, or systemic inflammatory response syndrome (SIRS). Overall, 48.8% of patients were women and the median age was 58 years (IQR, 47–68 years; Table 1).

Table 1. Demographics and Preoperative Comorbidities of 132,000 NSQIP-Reported Neurosurgical Patients with and without Postoperative Infection, 2006–2014

			Any Infection		
Variable	**Definition**	**Total**	**Yes**	**No**	***P* Value**
Sex (%)	Female	48.8	50.9	48.7	0.001
	Male	51.1	49.0	51.3	
	Missing	0.1	0.1	0.1	
Age (years)	<47	24.5	18.0	24.9	<0.001
	47–58	25.4	21.6	25.6	
	58–68	24.5	24.9	24.5	
	>68	25.5	35.3	25.0	
	Missing	0.1	0.2	0.1	
BMI (kg/m^2)	<30	57.6	54.9	57.8	<0.001
	30–35	23.2	2.8	23.3	
	>35	17.7	2.5	17.5	
	Missing	1.5	3.7	1.4	
Disposition	Outpatient	19.8	5.6	2.6	<0.001
	Inpatient	80.2	94.4	79.4	
RVU	<15	21.5	12	22	<0.001
	15–25	42.9	39.9	43.1	
	>25	35.6	48.1	34.9	
Diabetes		9.6	15.2	9.3	<0.001
Current smoker		23.6	22.9	23.6	0.20
Dyspnea		5.3	8.4	5.2	<0.001
Functionally dependent	Independent	94.4	83.1	95.1	<0.001
	Dependent	4.9	15.8	4.3	
	Missing	0.6	1.1	0.6	
Ventilator dependent		1.2	9.0	0.8	<0.001
COPD		4.3	8.0	4.1	<0.001
Hypertension w/medication		47.5	57.4	46.9	<0.001
Disseminated cancer		4.3	8.0	4.0	<0.001
Open wound		1.2	4.8	1.0	<0.001
Preoperative steroid use		5.9	1.5	5.7	<0.001
Bleeding disorders		2.6	6.9	2.3	<0.001
Preoperative SIRS		2.1	1.7	1.6	<0.001
Sodium (mEq/L)	>135	82.0	81.2	82.0	0.06
	<135	18.0	18.8	18.0	

Continues

Table 1. Continued

			Any Infection		
Variable	**Definition**	**Total**	**Yes**	**No**	***P* Value**
Creatinine (mg/dL)	<1.4	95.7	91.9	96	<0.001
	>1.4	4.3	8.1	4.0	
Albumin (g/dL)	<3.5	66.1	65.2	66.1	<0.001
	>3.5	32.6	32.2	32.6	
	Not Obtained	1.3	2.5	1.3	
WBC (cells/μL)	4000–12,000k	86	84.5	86.1	<0.001
	<4000	2.6	2.5	2.6	
	>12,000	2.5	8.5	2.2	
	Not Obtained	8.8	4.5	9.1	
Hematocrit (%)	>36	79	66.3	79.7	<0.001
	<36	21	33.7	2.3	
Platelet (per μL)	<450	98.8	97.1	98.9	<0.001
	>450	1.2	2.9	1.1	
PTT (seconds)	<40	98.9	97.8	99	<0.001
	>40	1.1	2.2	1.0	
INR	<1.4	98.9	96.5	99	<0.001
	>1.4	1.1	3.5	1.0	
Emergent case status		5.3	21	4.4	<0.001
Wound class	I	96.8	9.1	97.2	<0.001
	II–IV	3.2	9.9	2.8	
ASA class	1–2	48.2	22.6	49.7	<0.001
	3	45.1	54.8	44.6	
	4–5	6.4	22.2	5.5	
	Missing	0.3	0.4	0.3	
Total operative time (minutes)	Lower quartile < 82	25.3	15.8	25.9	<0.001
	Second quartile 82–128	24.9	2.6	25.1	
	Third quartile 128–200	25.0	26.5	25.0	
	Upper quartile > 200	24.7	37.2	24.1	

BMI, body mass index; RVU, relative value unit; COPD, chronic obstructive pulmonary disease; SIRS, systemic inflammatory response syndrome; WBC, white blood cell count; PTT, partial thromboplastin time; INR, international normalized ratio; ASA, American Society of Anesthesiologists.

Cumulative Incidence and Time to Event

Superficial SSI had a cumulative incidence of 0.8% at a median of 16 days (IQR, 11–22 days; Table 2). Deep SSI had a cumulative incidence of 0.6% at a median of 15 days (range, 11–21 days). Organ space SSI had a cumulative incidence of 0.5% at a

Table 2. Cumulative Incidence and Time to Event of Postoperative Neurosurgery Infections

Variable	Cumulative Incidence (%)	Time to Event (days)	
		Median	IQR
Superficial SSI	0.8	16	(11—22)
Deep SSI	0.6	15	(11—21)
Organ/space SSI	0.5	14	(6—21)
Wound dehiscence	0.3	17	(11—23)
Pneumonia	1.4	5	(2—10)
UTI	1.8	9	(5—16)
SIRS	1.6	3	(8—16)

SSI, surgical site infections; UTI, urinary tract infection; SIRS, systemic inflammatory response syndrome.

median of 14 days (range, 6—21 days). Wound dehiscence had a cumulative incidence of 0.3% at a median of 17 days (range, 11—23 days). Pneumonia had a cumulative incidence of 1.4% at a median of 5 days (range, 2—10 days). Urinary tract infections (UTIs) had a cumulative incidence of 1.8% at a median of 9 days (5—16 days). SIRS had a cumulative incidence of 1.6% at a median of 3 days (IQR, 8—16 days).

Multivariate Models

On multivariable logistic regression, predictors of any neurosurgery infection were female sex, age greater than 68 years, body mass index (BMI) greater than 35 kg/m², inpatient disposition, relative value unit (RVU) greater than 15 units, diabetes, functional dependence before surgery, ventilator dependence, history of severe chronic obstructive pulmonary disease (COPD), open wound, preoperative steroid use, bleeding disorders, preoperative SIRS, hyponatremia (sodium < 135 mEq/L), lymphocytosis (WBC count > 12,000 cells/mL), anemia (hematocrit < 36%), thrombocytosis (platelets > 450,000/mL), emergent case status, wound class II—IV, ASA class 3—5, and total operative time longer than 82 minutes (Table 3).

Predictors of surgical site infections were age greater than 47 years, BMI > 30 kg/m², inpatient disposition, RVU > 25 units, diabetes, current smoking status, missing functional status, open wound, preoperative steroid use, WBC counts not obtained preoperatively, anemia, emergent case status, wound classification II—IV, ASA class 3—5, and total operative time longer than 82 minutes.

Predictors of other infections (pneumonia, UTI, SIRS) were female sex, age greater than 58 years, inpatient disposition, RVU greater than 15 units, diabetes, functional status, ventilator dependence, history of COPD, open wound, preoperative steroid use, bleeding disorders, hyponatremia, lymphocytosis (WBC count > 12,000 cells/mL), WBC labs not obtained preoperatively, anemia, emergent case status, wound classification II—IV, ASA class 3—5, and total operative time longer than 128 minutes.

DISCUSSION

The existing body of literature on postoperative neurosurgical infections generally lacks robust multicenter reports on postoperative neurosurgical infections. As a result, trends and predictive factors for postoperative infections are highly variable from one study to the next.[6,10,15,18] The NSQIP program originated in the Veterans Health Administration as a risk-adjusted effort to improve quality, reduce morbidity and mortality, and lower healthcare costs through detailed analysis of postoperative, 30-day complication rates.[16,20,24,28,29] Widespread adoption of the database occurred in part because of successful reduction of complications and quality improvement by participating institutions.[32] The analysis reported here was undertaken to fill the existing gap in the neurosurgical literature on overall trends in postoperative infections by using the nationally validated, risk-adjusted ACS-NSQIP database.

The overall incidence of postoperative infections in this analysis (5.3%) is similar to that reported in single-center reports of outcomes including and beyond the 30-day postoperative period.[15,18] Hamdeh et al.[1] reviewed 448 neurosurgical patients treated at a single center and found a surgical site infection incidence of 4.3%. Zhan et al.[18] retrospectively reviewed 1470 patient records and found an overall infection rate of 7.4%. Cassir et al.[15] conducted a prospective study over 24 months of 949 patients and found an SSI incidence of 4.5%.

In the ACS NSQIP database, the most common surgical site infections were superficial SSIs (0.8%) followed by deep SSIs (0.6%). Ordered from most common to least, UTI, postoperative SIRS, pneumonia, superficial SSIs, deep incisional SSIs, organ space infections, and wound dehiscence accounted for postoperative neurosurgical infections in this report.

Several preoperative comorbidities, including obesity, inpatient disposition, higher RVU indicating more complicated procedures, diabetes, functional dependence status before surgery, preoperative mechanical ventilation, history of severe COPD, preoperative open wound, preoperative steroid use, preoperative SIRS, preoperative lymphocytosis, emergent case status, contaminated, dirty, or infected wound class, and higher ASA classification of 3—5 (patients with severe systemic disease, patients with life-threatening severe systemic disease, and moribund patient with survival dependent on the procedure) have been identified as predictors of postoperative infections in previous single center studies.[3,5,13,15]

Our study found several points of overlap with a recent publication by Lieber et al.[33] on preoperative predictors of spinal infection, including the predictive factors of female sex, inpatient status, diabetes, preoperative steroid use, BMI > 30 kg/m², ASA class and operative duration. Another study by Lieber et al.[34] also demonstrated that preoperative corticosteroid use was an independent predictor of organ-space SSI but not superficial or deep-incisional SSI. For patients with glioblastoma multiforme, Chaichana et al.[35] reported factors that were significantly associated with postoperative infection, including prior surgery, diabetes mellitus, and increased duration of hospital stay.

Gupta et al.[36] reviewed 22,576 cases in the NSQIP database in which the patient had COPD and reported that COPD is associated with increased risk for postoperative pneumonia,

Table 3. Predictors of Neurosurgery Infections by Multivariable Logistic Regression

		Any Infection			Surgical Site Infections			Other Infections		
Variable	Definition	Odds Ratio	95% CI	*P* Value	Odds Ratio	95% CI	*P* Value	Odds Ratio	95% CI	*P* Value
Sex (%)	Female	—	—	Ref.	—	—	—	—	—	Ref.
	Male	0.903	0.855–0.953	<0.001	—	—	—	0.884	0.829–0.942	<0.001
	Missing	0.944	0.325–2.743	0.92	—	—	—	1.293	0.431–3.879	0.64
Age (years)	<47	—	—	Ref.	—	—	—	—	—	Ref.
	47–58	0.943	0.866–1.026	0.17	—	—	—	1.077	0.968–1.199	0.17
	58–68	1.015	0.931–1.106	0.74	—	—	—	1.258	1.131–1.399	0
	>68	1.314	1.206–1.433	<0.001	—	—	—	1.881	1.694–2.089	0
	Missing	1.174	0.625–2.202	0.62	—	—	—	1.738	0.891–3.389	0.11
BMI	<30	—	—	Ref.	—	—	Ref.	—	—	Ref.
	30–35	0.995	0.929–1.067	0.90	1.198	1.075–1.335	0.001	0.909	0.837–0.987	0.02
	>35	1.195	1.11–1.286	<0.001	1.805	1.625–2.003	<0.001	1.01	0.923–1.104	0.83
	Missing	1.11	0.948–1.3	0.19	1.233	0.919–1.653	0.163	1.033	0.869–1.228	0.71
Disposition	Outpatient	—	—	Ref.	—	—	Ref.	—	—	Ref.
	Inpatient	1.991	1.768–2.242	<0.001	1.486	1.276–1.731	<0.001	2.624	2.213–3.112	<0.001
RVU	<15	—	—	Ref.	—	—	—	—	—	Ref.
	15–25	1.12	1.022–1.227	0.02	—	—	—	1.24	1.1–1.397	<0.001
	>25	1.117	1.017–1.226	0.02	—	—	—	1.523	1.351–1.717	<0.001
Diabetes		1.139	1.051–1.234	0.002	1.167	1.029–1.324	0.02	1.15	1.049–1.261	0.003
Current smoker		—	—	—	1.261	1.147–1.387	0	—	—	—
Functionally dependent	Independent	—	—	Ref.	—	—	Ref.	—	—	Ref.
	Dependent	1.669	1.532–1.818	<0.001	1.131	0.959–1.334	0.14	1.78	1.622–1.954	<0.001
	Missing	1.633	1.244–2.143	<0.001	2.124	1.454–3.103	<0.001	1.464	1.061–2.02	0.02
Ventilator Dependent		2.312	2.016–2.653	<0.001	—	—	—	2.511	2.178–2.895	<0.001
COPD		1.374	1.239–1.524	<0.001	—	—	—	1.488	1.327–1.668	<0.001
Hypertension with medication		1.059	0.996–1.126	0.07	—	—	—	1.072	0.998–1.152	0.06
Open wound		1.781	1.523–2.082	<0.001	1.919	1.509–2.441	<0.001	1.595	1.335–1.904	<0.001
Preoperative steroid use		1.371	1.253–1.5	<0.001	1.506	1.305–1.736	<0.001	1.334	1.204–1.478	<0.001
Bleeding disorders		1.183	1.048–1.335	0.006	—	—	—	1.224	1.075–1.394	0.002
Preoperative SIRS		1.961	1.751–2.196	<0.001	—	—	—	2.247	1.994–2.533	<0.001
Sodium (mEq/L)	>135	—	—	Ref.	—	—	—	—	—	Ref.
	<135	1.118	1.036–1.206	0.004	—	—	—	1.126	1.032–1.228	0.007
Albumin (g/dL)	<3.5	—	—	Ref.	—	—	Ref.	—	—	—
	>3.5	0.953	0.899–1.011	0.11	0.919	0.838–1.008	0.07	—	—	—
	Not obtained	1.199	1.003–1.434	0.05	1.249	0.927–1.683	0.14	—	—	—

Continues

Table 3. Continued

		Any Infection			Surgical Site Infections			Other Infections		
Variable	Definition	Odds Ratio	95% CI	*P* Value	Odds Ratio	95% CI	*P* Value	Odds Ratio	95% CI	*P* Value
WBC (cells/μL)	4000–12,000	—	—	Ref.	—	—	—	—	—	Ref.
	<4000	0.898	0.759–1.063	0.21	—	—	—	0.863	0.707–1.052	0.15
	>12,000	1.459	1.296–1.643	<0.001	—	—	—	1.585	1.395–1.799	<0.001
	Not obtained	0.568	0.494–0.653	<0.001	—	—	—	0.529	0.446–0.628	<0.001
Hematocrit (%)	>36	—	—	Ref.	—	—	Ref.	—	—	Ref.
	<36	1.44	1.347–1.539	<0.001	1.172	1.06–1.296	0.002	1.532	1.422–1.651	<0.001
Platelet count (per μL)	<450	—	—	Ref.	—	—	Ref.	—	—	—
	>450	1.215	1.01–1.462	0.04	1.449	1.092–1.922	0.01	—	—	—
Emergent case status		2.196	2.007–2.402	<0.001	1.66	1.421–1.94	<0.001	2.267	2.053–2.504	<0.001
Wound class	I	—	—	Ref.	—	—	Ref.	—	—	Ref.
	II–IV	1.838	1.647–2.051	<0.001	3.083	2.66–3.574	<0.001	1.438	1.259–1.642	<0.001
ASA class	1–2	—	—	Ref.	—	—	Ref.	—	—	Ref.
	3	1.745	1.629–1.869	<0.001	1.407	1.278–1.548	<0.001	1.911	1.754–2.082	<0.001
	4–5	2.465	2.225–2.731	<0.001	1.248	1.049–1.485	0.012	2.849	2.533–3.205	<0.001
	Missing	2.125	1.409–3.203	<0.001	1.877	0.992–3.551	0.053	2.48	1.572–3.912	<0.001
Total operative time (minutes)	Lower quartile < 82	—	—	Ref.	—	—	Ref.	—	—	Ref.
	Second quartile 82–128	1.14	1.04–1.249	0.005	1.262	1.095–1.454	0.001	1.084	0.971–1.21	0.15
	Third quartile 128–200	1.403	1.284–1.534	<0.001	1.444	1.255–1.661	<0.001	1.401	1.261–1.556	<0.001
	Upper quartile > 200	2.063	1.891–2.25	<0.001	2.035	1.777–2.33	<0.001	2.105	1.901–2.331	<0.001

CI, confidence interval; BMI, body mass index; RVU, relative value unit; COPD, chronic obstructive pulmonary disease; SIRS, systemic inflammatory response syndrome; WBC, white blood cell count; ASA, American Society of Anesthesiologists.

sepsis, and increased morbidity, mortality, and length of stay. In 2013, based on the Global Initiative for Chronic Obstructive Lung Disease spirometric criteria for the stages of COPD, Savas et al.[37] published a study that postoperative outcomes were improved, including pulmonary infections, if pretreatment was given to both moderate and severe-stage COPD before undergoing CABG surgery. With further investigation, this finding could be translated to neurosurgical practice to decrease the effect that COPD has on postoperative neurosurgical infection rate.

Through addressing many preoperative predictors of postoperative infection, the rate of postoperative infection after neurosurgery is trending downward in the literature. In 1992, Patir et al.[38] reported the rate of postoperative infection at 17% and wound infection at 5% in a single institutional study. However, the difficulty in addressing many of these predictive factors is evident in stasis of their involvement in preoperative predictive models. In the same article, Patir et al.[38] also reported risk factors for postoperative infections include some similar to this present study, including emergency surgery, duration more than 4 hours, altered sensorium, and ventilatory support. Many of the factors that our model predicted cannot be modified upon patient presentation, including sex, age, BMI, inpatient disposition, history of COPD, emergent case status, and bleeding disorders. Other factors might be intervened upon, including preoperative wound care, preoperative steroid use, hyponatremia, anemia, and operative time. To decrease the rate of postoperative infections further, the modifiable risk factors should be addressed in the initial patient visit and preoperative period and the more static risk factors should be addressed on a longer continuum.

While this study is the first to analyze overall rate of infections after neurosurgery in a nationwide, multicenter database of more than 3.7 million patients from 517 institutions, limitations of NSQIP analyses include sampling bias relative to inclusion and exclusion criteria.[9,16,20,32,39] Retrieval and deidentified reporting of patient records is subject to errors that are partially mitigated by required training for clinical reviewers. Interrater reliability audits of the NSQIP database demonstrate a 1.96% interobserver disagreement.[20,29] The NSQIP database also lacks neurosurgery-specific clinical factors that could be highly relevant to postoperative infection rates, such as incidence of cerebrospinal fluid leaks. Further limitations of NSQIP analyses include the lack of procedure-specific data and imaging and pathology data that would provide further insight for studies seeking a high level of granularity into specific neurosurgical pathologies. This study was limited to cases in NSQIP performed by an attending surgeon with a primary specialty of neurosurgery; many of the procedures performed by neurosurgeons are also performed by other specialties. As such, the overall risks may differ, and this can be further studied in future studies that investigate neurosurgical pathologies in NSQIP. Future studies that seek to provide clinically relevant information for predicting specific risk adjusted rates based on clinical characteristics must investigate risk factors for infection by each type of operation performed by neurosurgeons and included in NSQIP. The annually growing volume of data harbored in the NSQIP database will allow future studies to answer question that are more specific about the rates and predictive factors for postoperative infections of various types after neurosurgery.

The study presented here is the largest report on postoperative neurosurgical infections known to us in the literature. While it has been established in the literature that postoperative infections increase the risk for readmission, we aimed to understand what factors might contribute to the development of the complications that then are indicated in increased readmission, morbidity, and mortality.[6,9,40] Through the assessment of postoperative neurosurgical infections from a large, national, multi-institutional database, characterization of cumulative incidence and time to event for common postoperative infections, and creation of predictive models for postoperative infections, this study provides a benchmark of reference for the neurosurgical community when looking to modify predictive factors to reduce postoperative infection rates. Future studies can further build on the findings of this study to characterize the postoperative infections further for specific patient populations within the 132,000 included in this study. Future studies can also evaluate postoperative infections in neurosurgery by comparing the neurosurgical cases in NSQIP with non-neurosurgery cases. Furthermore, future studies can investigate whether factors such as specialty of attending (neurosurgery or orthopedic surgery), after controlling for complexity and length of cases, influence the postoperative infection rates after spine surgery.

CONCLUSION

The overall ACS-NSQIP reported rate of postoperative infections was 5.3% from 2006 to 2014. Within infections, 1.8% of patients developed surgical site infections and 3.9% developed other infections including pneumonia, UTIs, or SIRS. SSIs were late complications relative to pneumonia, UTIs, and SIRS. Multivariable analysis demonstrated several predictive factors for postoperative infections, SSIs, pneumonia, UTI, or SIRS.

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