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Complications of Primary and Revision Functional Endoscopic Sinus Surgery for Chronic Rhinosinusitis

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Abstract

Objective—The goal of this study was to determine the incidence of major complications following primary and revision functional endoscopic sinus surgery (FESS). Additionally, this study aimed to determine factors associated with the occurrence of complications including patient and provider characteristics and the use of image guidance system (IGS) technology.

Study Design—Retrospective cohort analysis of California and Florida all-payer databases from 2005–2008.

Methods—The rates of major surgical complications (skull base, orbital, and hemorrhagic) after primary and revision FESS were calculated, and bivariate analyses were performed to investigate relationships of complications with demographic and clinical characteristics. A multivariate model was used to determine risk factors for the occurrence of major complications.

Results—Among 78,944 primary FESS cases, 288 major complications were identified representing a complication rate of 0.36% (95% CI 0.32%–0.40%). The major complication rate following revision cases (n = 19; 0.46%) and primary cases (n = 288; 0.36%) was similar (OR=1.26; 95% CI 0.79–2.00). Multivariate analysis showed that patients who were >40 years old, had a primary payer of Medicaid, had surgery involving the frontal sinus, or had image guidance during surgery were at higher risk for major complications.

Conclusion—The rate of major complications (0.36%) associated with primary FESS is lower than earlier reports. The rate of major complications following revision FESS (0.46%) was found to be similar to primary cases. IGS, insurance status, age, and extent of surgery were found to be associated with an increased risk of major complications following FESS.

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INTRODUCTION

Chronic rhinosinusitis (CRS) is characterized by inflammation of the nasal cavity and one or more of the paranasal sinuses, and is estimated to affect 15% of the adult population.[1] Treatment of rhinosinusitis is highly variable, and frequently involves multi-drug therapy with corticosteroids, antibiotics, saline irrigation, mucolytics, and decongestants. When medical therapy is unsuccessful, functional endoscopic sinus surgery (FESS) may be recommended for symptom improvement. As a result of the large number of people with medically refractory rhinosinusitis, FESS is commonly performed in the United States with more than 500,000 procedures performed annually.[2]

FESS is an effective treatment modality for patients who fail medical therapy, and has been reported to provide both immediate and long-term symptom reduction and improvement in quality of life in 85% of patients.[2,3] Outcomes of FESS have improved due to technologic advances, improved surgical training, and better understanding of the pathophysiology of the disease. However, contemporary rates of complications following FESS have not been well-described.[4] Major complications that have been reported include cerebrospinal fluid (CSF) leak, meningitis, hemorrhage, and orbital injuries.[5] Prior estimates of the frequency of these complications from FESS are variable with reports ranging from 0% to nearly 2%.[6–14] Kennedy et al. in the United States and Cumberworth et al. in the United Kingdom conducted early independent surveys of surgeons performing FESS, and reported major complication rates of 0.4% and 0.2% respectively.[5,15] In a retrospective clinical study of complications by a single surgeon over a 25-year period after the introduction of FESS, Stankiewicz et al. noted a comparatively high complication rate of 3.1%.[16] Finally, in a more recent study examining the rate of complications between 2003 and 2007 from FESS for CRS using the MarketScan® database, Ramakrishnan et al. found that major complications occurred in 1.0% of cases with a rate of major hemorrhage several times higher than prior studies.[17,18]

Despite a high initial success rate, 10–15% of patients who undergo FESS will undergo revision surgery.[19–21] Revision FESS is often considered to have an increased risk of complications due to altered anatomy and scarring.[22] In one retrospective study of 90 patients, revision surgery was found to be a significant risk factor for CSF leak.[6,23] However, King et al. reported that revision FESS carried no more risk for complications than primary FESS among 43 patients who had prior surgery.[24] Furthermore, complications were no more likely in revision FESS cases for nasal polyposis as compared to primary cases.[25] To date, no study has examined the risk of complications in revision FESS for CRS using a large database.

The purpose of this study was to use a large all-payer database to determine the rate of major complications following primary and revision FESS. Complications looked at were skull

base, orbital, and hemorrhagic. Additionally, using multivariate analysis this study aimed to examine factors associated with the occurrence of complications including patient and provider characteristics and the use of image guidance systems (IGS).

METHODS

Study Design

This study is a retrospective analysis of patients who underwent primary or revision FESS for a diagnosis of CRS using large all-payer databases from 2005–2008. The primary outcome was the rate of major surgical complications. The Institutional Review Board of Washington University in St. Louis School of Medicine approved this study.

Data Sources

The Healthcare Cost and Utilization Project (HCUP) State Inpatient Database (SID),[26] State Ambulatory Surgery Database (SASD),[27] and State Emergency Department Database(SEDD)[28] from California and Florida were used to identify a cohort of patients who underwent FESS from 2005–2008. These statewide databases contain information from discharge records on all patients regardless of age or payer (Medicare, Medicaid, private insurance, and no insurance). Discharge records of inpatient hospital visits are provided through SID, records from ambulatory surgery visits at both hospitals and free-standing ambulatory surgical centers are provided through SASD, and records from emergency room visits are provided through SEDD.

Using information from the Agency for Healthcare Research and Quality (AHRQ) revisit files, individual patients can be linked and tracked across all three databases. The AHRQ revisit files link individual patients across the HCUP databases using date of birth, gender, and an encrypted patient identifier. In addition, the revisit files provide information about the time period from one visit to another for each patient while keeping exact dates encrypted to protect patient confidentiality. Taken together, these linked state databases offer access to a population of more than 56 million people wherein more than 90% of community hospitals report de-identified data.[26,29]

Study Population

Patients who underwent FESS from January 2005 through December 2008 were identified in the SASD using Current Procedure and Terminology (CPT) codes for FESS (31254, 31255, 31256, 31267, 31276, 31287, and 31288). All cases were required to have a concurrent diagnosis of CRS (471.3–473.3, 473.8, 473.9) based on International Classification of Diseases Ninth Revision (ICD-9) coding. Primary FESS was defined as the first FESS in the SASD from the years of 2005–2008. Revision FESS was defined as any subsequent FESS in the database. Identified cases in the SASD were then linked to the SID and SEDD to obtain information on complications contained within these databases. Cases that were the fourth or more FESS for the same patient in the database were excluded due the limited clinical applicability of results from these cases. Finally, cases missing an encrypted patient identifier were excluded from the study, as they could not be tracked for future complications.

Measures

Primary Outcome—The primary outcome was the occurrence of a major surgical complication following FESS. Major complications examined included skull base, orbital, and hemorrhagic injury. Complications were identified based on specific ICD-9 and CPT codes (Table 1).

Skull base complications were defined as a CSF leak or dural injury within 180 days, or bacterial meningitis within 30 days, after FESS. In addition, if a CSF leak repair or lumbar drain placement occurred within 180 days after FESS, a skull base complication was considered to have occurred. Orbital complications were defined as diplopia, paralytic strabismus, optic nerve injury, epiphora, orbital hemorrhage, or blindness/visual disturbance within 30 days after FESS. Additionally, a patient was considered to have an orbital complication if a person had canthotomy/canthoplasty, strabismus surgery, or orbital decompression in the same time frame. Finally, hemorrhagic complications were counted if a diagnosis of internal carotid artery injury, epistaxis requiring transfusion, or hemorrhage control procedure occurred within 30 days after surgery. Cases were not considered to have a given complication if they were diagnosed with that complication at any point in the 60 days prior to FESS, or 365 days prior to FESS for orbital complications.

Age, Race, Insurance Status, Sinus Operated On, and Use of Image Guidance —All demographic categories were defined at the time of FESS. Age was collapsed into five categories: ≤12 years, 13–18 years, 19–40 years, 41–65 years, and >65 years. Race was categorized as White, Black, Hispanic, or other. Primary expected payer was divided into three categories: private insurance, Medicare, and Medicaid/other. Cases were stratified into four categories in an effort to determine if complications were more likely as more sinuses were operated on. The four categories chosen were surgery on: maxillary sinus and/or ethmoid sinus, sphenoid sinus plus or minus maxillary or ethmoid sinus, frontal sinus plus or minus maxillary or ethmoid sinus, and all four sinuses. Finally for all FESS cases, coding for IGS was recorded based on a concurrent CPT code (61795) for image guidance.

Statistical Analysis

Standard descriptive statistics were used to describe the study population, and the rate of major complications following primary FESS was calculated. For primary FESS cases, associations between available demographic and clinical characteristics, including IGS, and outcomes were evaluated using chi-square tests. Next, the rate of complications following revision FESS was examined. Standard chi-squared tests were done to compare the rate of complications following primary FESS surgeries and revision surgeries. Per HCUP rules, results based on tabulated data of ≤10 individuals were reported as " ≤10" to protect patient confidentiality.

Logistic regression, applied with the PROC SURVEY LOGISTIC command in SAS®, was used to determine risk factors for the occurrence of major complications. Gender, revision status, and all covariates that achieved a level of significance <0.10 on univariate analysis were included in the multivariate model. Diagnostic tests, including tests of multicollinearity, were employed to assure all assumptions of the final model were met.

SAS® 9.2 software (SAS Institute, Cary, NC) was used for all database management and statistical analyses.

RESULTS

Patient Characteristics

Of the 88,444 patients who underwent FESS for CRS, 78,944 patients met the study's inclusion criteria and were included in our analyses (Figure 1). The mean (SD) age of the included population was 47 (17.4) years. The number of cases from California and Florida were similar and slightly more than half of patients were male (n=39,302, 51%). Patients tended to be white (n = 55,176, 80%) and have private insurance (n=59,693, 76%). Approximately 57% (n = 44,614) of primary FESS cases involved only the maxillary and/or ethmoid sinuses. Finally, 9% (n=7,211) of primary FESS cases contained a code for IGS.

Characteristics of major complications following primary FESS

The distribution of characteristics for patients experiencing major complications post-FESS are described in Table 2. A total of 288 major complications from FESS were identified representing a major complication rate of 0.36% (95% CI 0.32–0.40%) per primary FESS case. Among the major complications, 103 skull base complications (complication rate of 0.13%; 95% CI 0.11–0.16%) and 178 orbital complications (complication rate of 0.23%; 95% CI 0.20–0.27%) were identified. In this dataset, <11 major hemorrhagic complications were identified.

On bivariate analysis, patients >65 were more likely to have a major complication (0.67%; OR 3.54; 95% CI 2.43–5.17) as compared to younger adults (0.19%). Patients who had a primary payer of Medicare (0.62%; OR 2.13; 95% CI 1.64–2.77) and Medicaid (0.52%; OR 1.81; 95% CI 1.21–2.70) were more likely to have a complication compared to those with private insurance (0.29%). Additionally, patients who underwent FESS with IGS were significantly more likely to have a major complication (0.65%; OR 1.95; 95% CI 1.42 to 2.66). Finally, cases involving the sphenoid (0.45%; OR 1.58; 95% CI 1.12–2.24), frontal (0.53%; OR 1.88; 95% CI 1.39–2.55) or all sinuses (0.44%; OR 1.56; 95% CI 1.14–2.13) were more likely to have a complication as compared to cases involving only the maxillary and/or ethmoid sinuses.

Risk for individual complications following revision versus primary FESS

The rate of complications was compared between primary and revision FESS (Table 3). Overall the rate of major complications was similar following primary (0.36%) and revision (0.46%) FESS (OR 1.26; 95% CI 0.79–2.00). The rate of skull base complications (OR 1.29; 95% CI 0.60–2.78), orbital complications (OR 1.29; 95% CI 0.71–2.30), and hemorrhagic complications requiring a transfusion were not significantly different between primary and revision FESS.

Predictors of Complications

Age, gender, insurance status, IGS use, primary versus revision status, and number of sinuses operated on were entered into a logistic regression model. In this model (Table 4),

the rate of major complications was significantly increased in patients 41–65 years (OR 1.88; 95% CI 1.34–2.65) and patients >65 years (OR 2.99; 95% CI 1.77–5.02), as compared with patients 19–40 years. In addition, patients with a primary payer of Medicaid (OR 2.05, 95% CI 1.37–3.06) were more likely to have a complication as compared to those who had private insurance. The odds of a major complication were increased in those who had surgery involving the frontal sinuses (OR 1.70; 95% CI 1.27–2.29). Finally, patients who had surgery that involved IGS were more likely to have a complication (OR 1.55, 95% CI 1.12–2.13).

DISCUSSION

In this study we examined the frequency of major complications following both primary and revision FESS in a cohort of nearly 80,000 patients. In both primary and revision FESS, the risk of major complications was low at 0.36% and 0.46% respectively. In this cohort, patients who were older, had more sinuses operated on, or who had a surgery involving image guidance were more likely to have a major complication.

Early reports on the incidence of complications following FESS were highly variable. Institutional reports from the mid-1990s reported major complication rates up to 2%[6–14] with factors such as increased surgeon experience contributing to a decreased rate of complications.[8] Stankiewicz et al. noted a high complication rate of 3.1%; however, these results reflected a single surgeon's 25-year experience including data from a period soon after the introduction of FESS.[16] As compared to these studies, the rate of complications following primary FESS in this cohort was low with 0.36% of primary FESS cases resulting in major complications. The decreased rate of complications as compared to early studies could be due to increased experience with the procedure over the last several decades as well as improved imaging, technology, instrumentation, and surgical training. Alternatively, the comparatively low rate of complications may be due to study design as the capture of complications in our dataset is based on administrative coding.

In this dataset, the rate of complications varied significantly by age. Prior studies have proposed that the rate of major complications in FESS may be increased in the pediatric population. This supposition is based on the intimate relationship of the paranasal sinuses with anatomic areas that are at risk including the orbit, skull base, and carotid arteries in children.[30,31] However, Ramakrishnan et al. reported that major complications from FESS in the pediatric population did not appear to be more common.[18] In addition, a meta-analysis of outcomes following pediatric FESS found complications to be extremely rare with no CSF leaks or orbital complications in 690 children.[32] Similarly, in our cohort, complications in the pediatric population were rare with no skull base complications in nearly 3,000 pediatric cases.

While complications were uncommon in children, our study showed that patients >65 were three times more likely to have a major complication following FESS as compared to younger adults. In a retrospective study containing 171 patients, patients >65 years experienced a disproportionately large share of complications following FESS.[33] In two other smaller studies of safety and outcomes following FESS in patients >60 years of age,

complications were not more common in older patients; however, these studies only involved a combined total of 143 patients.[10,34] As rhinosinusitis is the sixth most common chronic condition in those ≥65 years,[34] the increased rate of FESS complications in this group is worthy of further exploration.

In our dataset, Medicaid insurance status was a significant predictor of complications following FESS. This finding is similar to other studies, involving a wide-array of surgeries, that have found worse outcomes and increased post-operative complications in patients with a primary payer of Medicaid as compared to those with private coverage.[35–39] To our knowledge no one has investigated how complications following FESS vary by insurance status. Several reasons may explain the association between post-operative complications and Medicaid status in our dataset. First, patients with Medicaid have been shown to have decreased access to outpatient specialty care,[40] which may lead to delayed treatment, presentation with more advanced disease, and presentation with an increased number of co-morbid conditions. Alternatively Medicaid status could be a marker for other factors associated with poor surgical outcomes including lower socioeconomic status, decreased health awareness and literacy, and worse post-operative compliance.[41,42]

In the mid 1990s, image guidance technology was introduced to FESS. To date, no randomized controlled trials have compared outcomes between patients receiving surgery with and without IGS. Among retrospective studies, only one case series showed a statistically significant benefit to IGS in decreasing complications,[43] with four others showing no significant risk reduction.[44–47] In the population-based database study by Ramakrishnan et al.,[18] no conclusions were drawn between the use of IGS and the complication rate associated with FESS. In our multivariate model, patients who had sinus surgery with IGS were nearly 60% more likely to have a major complication. Several possible reasons for the increased rate of complications following FESS with IGS exist. In particular, this technology is more likely to be utilized in cases that are deemed more complex due to the extent of disease or anatomic considerations. Alternatively, another possible explanation is that overconfidence in technology and a false sense of security may actually have a deleterious effect on surgical outcomes. This phenomenon has been observed in the similar safeguard technology of nerve monitoring.[48]

There are several limitations to this study that are worthy of consideration. First, all information in this study was collected retrospectively from an administrative dataset. In any administrative dataset, complications, particularly minor ones, may be systematically undercoded. In addition, all data contained in this study is collected and linked at the state level. Thus, if a patient has a surgery in one state and receives subsequent care for a complication in another state, his or her complication will be missed. Since no specific CPT coding for balloon sinus dilatation existed at the time, some cases of balloon dilatation may be contained in this dataset. However, balloon dilatation was generally coded as unlisted 31299, which was not included in our dataset. The possibility also exists that complications were only temporally related to FESS and were not truly a complication from surgery. We tried to mitigate this possibility by reviewing patient records prior to surgery in an effort to ensure preexisting conditions were not wrongly considered complications of surgery. Finally, it is possible that a patient had a FESS prior to the beginning of the dataset, thus

falsely increasing the number of primary FESS cases and decreasing the number of revision cases in our cohort. This would likely result in an overestimation of complications in the primary group and an underestimation in the revision group.

CONCLUSIONS

This study suggests that the overall major complication rate following primary FESS is low with a major complication rate of 0.36%. In addition, the overall major complication rate following revision FESS is similar to primary FESS. We found that advanced age, insurance status, extent of surgery, and utilization of IGS were associated with an increased risk of major complications. These areas are worthy of further investigation.

Acknowledgments

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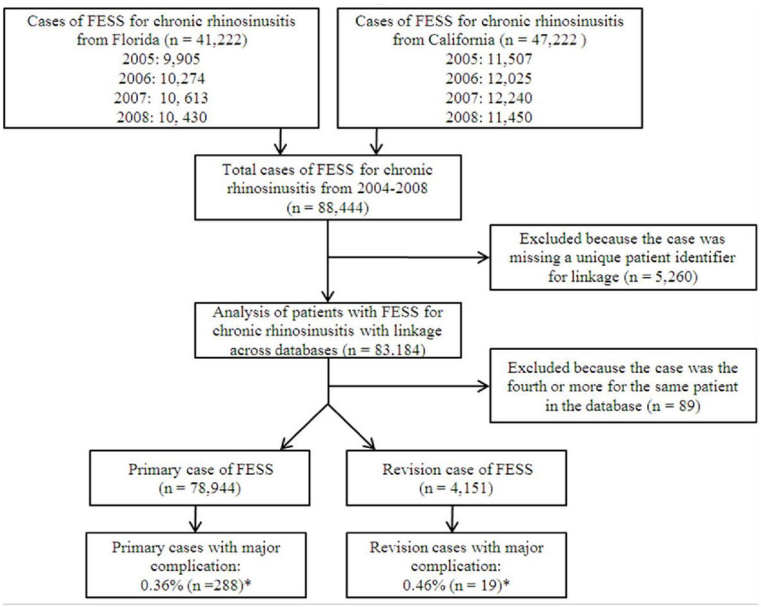

Figure 1.

Study flow diagram

*Participants were considered to have a major complication if they had a diagnostic or procedural code for skull base injury, orbital injury, ICA injury, or other hemorrhagic injury that resulted in a blood transfusion.

Table 1

ICD-9 diagnosis codes and CPT codes for included complications of FESS

Complication or Procedure	ICD-9 Code(s)	CPT code(s)
Skull base		
CSF rhinorrhea	349.81	61618, 61619, 31290, 31291, 62272
Bacterial meningitis	320.x	
Dural tear	349.3, 349.31, 349.39	
Orbital		
Diplopia	368.2	
Paralytic stabismus	378.5x	67311–67318
Optic nerve injury	950	
Blindness	369.x	
Epiphora	375.2	
Orbital Hemorrhage	376.32, 376.89	
Canthotomy/Canthoplasty		67715, 67950
Orbital Decompression		31292–31294
Hemorrhagic		
Epistaxis/nasal hemorrhage	784.7	30901, 30903, 30905, 30906
Injury to the ICA	900.03	
Blood transfusion		36340

“x” denotes any numerical value; ICA: Internal Carotid Artery; ICD: International Classification of Diseases; CPT: Current Procedural Terminology

Table 2

Demographics and clinical characteristics of complications after primary FESS

Characteristic	Patients	Patients with skull base complications, n (%)	Unadjusted OR (95% CI)	Patients with orbital complications, n (%)	Unadjusted OR (95% CI)	Patients with major complications, n (%)	Unadjusted OR (95% CI)
Total State	78,944	103 (0.13)	--	178 (0.23)	--	288 (0.36)‡	--
California	41,155	43 (0.10)	Ref	103 (0.25)	Ref	151 (0.37)	Ref
Florida	37,789	60 (0.16)	1.52 (1.03–2.25)*	75 (0.20)	0.79 (0.59–1.07)	137 (0.36)	0.99 (0.78–1.25)
Age at FESS (yrs)							
≤12†	2,834	≤10 (<0.36)†	--	≤10 (<0.36)†	--	≤10 (<0.36)†	--
13–18	2,263	≤10 (<0.58)†	--	≤10 (<0.58)†	--	≤10 (<0.58)†	--
19–40	21,621	12 (0.06)	Ref	28 (0.13)	Ref	41 (0.19)	Ref
41–65	39,943	69 (0.17)	3.17 (1.69–5.75)*	90 (0.23)	1.74 (1.14–2.66)*	161 (0.40)	2.13 (1.51–3.00)*
>65	11,823	21 (0.18)	3.20 (1.58–6.52)*	54 (0.46)	3.54 (2.24–5.59)*	79 (0.67)	3.54 (2.43–5.17)*
Gender							
Female	37,152	45 (0.12)	Ref	81 (0.22)	Ref	130 (0.35)	Ref
Male	39,302	57 (0.15)	1.20 (0.81–1.77)	96 (0.24)	1.12 (0.83–1.51)	156 (0.40)	1.14 (0.90–1.43)
Race							
White	55,176	75 (0.14)	Ref	117 (0.21)	Ref	197 (0.36)	Ref
Black	2,878	≤10 (<0.35)†	--	≤10 (<0.35)†	--	16 (0.56)	1.56 (0.94–2.60)
Hispanic	6,811	≤10 (<0.15)†	--	20 (0.30)	1.39 (0.86–2.23)	27 (0.40)	1.11 (0.74–1.66)
Other	4,407	≤10 (<0.23)†	--	13 (0.29)	1.39 (0.78–2.47)	18 (0.41)	1.15 (0.71–1.86)
Insurance Status							
Private insurance	59,693	≥65 (>0.10)†	Ref	98 (0.16)	Ref	173 (0.29)	Ref
Medicare	13,804	28 (0.20)	--	52 (0.38)	2.30 (1.64–3.22)*	85 (0.62)	2.13 (1.64–2.77)*
Medicaid	5,344	≤10 (<0.19)†	--	26 (0.49)	2.97 (1.93–4.59)*	28 (0.52)	1.81 (1.21–2.70)*
Image Guidance							
No	71,733	91 (0.13)	Ref	144 (0.20)	Ref	241 (0.33)	Ref
Yes	7,211	12 (0.17)	1.31 (0.72–2.40)	34 (0.47)	2.36 (1.62–3.43)*	47 (0.65)	1.95 (1.42–2.66)*

Characteristic	Patients	Patients with skull base complications, n (%)	Unadjusted OR (95% CI)	Patients with orbital complications, n (%)	Unadjusted OR (95% CI)	Patients with major complications, n (%)	Unadjusted OR (95% CI)
Sinus Operated On							
Maxillary and/or ethmoid	44,614	38 (0.09)	Ref	85 (0.19)	Ref	126 (0.28)	Ref
Sphenoid ± maxillary/ethmoid	9,627	17 (0.18)	2.08 (1.17–3.68)*	24 (0.25)	1.31 (0.83–2.06)	43 (0.45)	1.58 (1.12–2.24)*
Frontal ± maxillary/ethmoid	11,714	24 (0.20)	2.41 (1.44–4.02)*	37 (0.32)	1.66 (1.13–2.44)*	62 (0.53)	1.88 (1.39–2.55)*
All four sinuses	12,989	24 (0.18)	2.17 (1.30–3.62)*	32 (0.25)	1.29 (0.86–1.94)	57 (0.44)	1.56 (1.14–2.13)*

OR: odds ratio; CI: confidence interval;

*$p < .05$;

†Exact numbers not reported in accordance with the HCUP data user agreement that prohibits reporting of cells with ≤10 observations;

‡Major complications category includes ≤10 cases with hemorrhagic complications in addition to cases with skull base and orbital complications.

Table 3

Complications after primary and revision FESS

	Primary Cases (n=78,944)	Revision Cases (n=4,151)		
Complication	**Patients, n (%)**	**Patients, n (%)**	**Unadjusted OR (95% CI)**	**P value**
All major complications*	**288 (0.36)**	**19 (0.46)**	**1.26 (0.79 to 2.00)**	**0.34**
Skull base complications	103 (0.13)	≤10 (<0.25)†	--	0.51
Orbital complications	178 (0.23)	12 (0.29)	1.29 (0.71 to 2.30)	0.40

OR: odds ratio; CI: confidence interval;

*Major complications category includes ≤10 cases with hemorrhagic complications;

†Exact numbers not reported in accordance with HCUP data user agreement that prohibits reporting of ≤10 observations.

Table 4

Multivariate analysis of characteristics associated with major complications following FESS

	Skull Base Complications	Orbital Complications	All Major Complications
Characteristic	**Adjusted OR (95% CI)**	**Adjusted OR (95% CI)**	**Adjusted OR (95% CI)**
Age at FESS (yrs)			
≤12†	---	0.21 (0.03–1.57)	0.16 (0.02–1.23)
13–18	0.82 (0.11–6.03)	1.57 (0.58–4.27)	1.39 (0.57–3.38)
19–40	Ref	Ref	Ref
41–65	2.73 (1.51–4.93)*	1.55 (1.01–2.37)*	1.88 (1.34–2.65)*
>65	2.23 (0.96–5.19)	3.66 (1.92–6.98)*	2.99 (1.77–5.02)*
Gender			
Female	Ref	Ref	Ref
Male	1.16 (0.80–1.70)	1.10 (0.82–1.49)	1.10 (0.87–1.39)
Insurance Status			
Private insurance	Ref	Ref	Ref
Medicare	1.42 (0.77–2.62)	1.01 (0.58–1.77)	1.21 (0.79–1.86)
Medicaid	0.35 (0.09–1.37)	3.29 (2.11–5.11)*	2.05 (1.37–3.06)*
Image Guidance			
No	Ref	Ref	Ref
Yes	0.83 (0.44–1.56)	2.10 (1.44–3.06)*	1.55 (1.12–2.13)*
Sinus operated on			
Maxillary and/or ethmoid	Ref	Ref	Ref
Sphenoid ± maxillary/ethmoid	1.61 (0.90–2.89)	1.05 (0.66–1.67)	1.25 (0.88–1.78)
Frontal ± maxillary/ethmoid	2.14 (1.31–3.50)*	1.53 (1.05–2.24)*	1.70 (1.27–2.29)*
All four sinuses	1.99 (1.21–3.26)*	0.98 (0.65–1.48)	1.25 (0.91–1.71)
Procedure			
Primary	Ref	Ref	Ref
First revision	1.15 (0.51–2.64)	1.20 (0.67–2.17)	1.15 (0.71–1.87)
Second revision	1.69 (0.24–12.13)	0.92 (0.13–6.68)	1.16 (0.29–4.71)

OR: odds ratio; CI: confidence interval;

*$p < 0.05$;

†Age category ≤12 years was excluded from the model predicting skull base complications as no skull base complications were found in this group.