Title

Modifications to the Endoscopic Approach for Anterior Skull Base Lesions Improve Postoperative Sinonasal Symptoms

Journal
Journal of Neurological Surgery Part B Skull Base, 75(01)

ISSN
1526-8012

Authors
Thompson, Christopher F
Suh, Jeffrey D
Liu, Yuan
et al.

Publication Date
2014-02-01

DOI
10.1055/s-0033-1356492

Peer reviewed

Modifications to the Endoscopic Approach for Anterior Skull Base Lesions Improve Postoperative Sinonasal Symptoms

Christopher F. Thompson[1] Jeffrey D. Suh[1] Yuan Liu[1] Marvin Bergsneider[2] Marilene B. Wang[1]

[1] Department of Head and Neck Surgery, University of California, Los Angeles, California, United States
[2] Department of Neurosurgery, University of California, Los Angeles, California, United States

Address for correspondence Christopher F. Thompson, MD, Department of Head and Neck Surgery, UCLA, 10833 Le Conte Ave, 62-132 CHS, Los Angeles, CA 90095-1624, United States (e-mail: chrthompson@mednet.ucla.edu).

J Neurol Surg B 2014;75:65–72.

Abstract

Background/Objective Our institution previously showed that patients experience significant postoperative sinonasal symptoms for the first few months after endoscopic transnasal transsphenoidal skull base surgery (eTNTS). Since our initial study we have modified our technique, discontinuing routine resection of the middle turbinate, maxillary antrostomies, and nasoseptal flaps. In this study, we analyze whether these technical modifications decrease postoperative sinonasal morbidity after eTNTS.

Methods A retrospective review was performed of 93 consecutive patients who underwent eTNTS at a tertiary academic medical center from August 2011 to August 2012.

Main Outcome Measures Sino-Nasal Outcome Test (SNOT)-20 and SNOT-22 scores preoperatively and after surgery.

Results Compared with our previous study, our new cohort experienced a significant improvement ($p < 0.05$) in SNOT scores for the need to blow nose, runny nose, postnasal discharge, thick nasal discharge, wake up at night, reduced concentration, and frustrated/restless/irritable. Within the new cohort, patients who did not have a nasoseptal flap or middle turbinate resection had less worsening and faster improvement of nasal symptom scores after surgery.

Conclusions Preserving normal sinonasal physiology during eTNTS by limiting middle turbinate resections, avoiding unnecessary maxillary antrostomies, and reducing the use of nasoseptal flaps when feasible results in less sinonasal morbidity and more rapid recovery during the postoperative period.

Keywords
- skull base
- endonasal surgical approach
- endoscopic surgery
- nasoseptal flap

Introduction

Endonasal endoscopic surgery continues to gain acceptance as a minimally invasive and effective approach for benign and malignant pathology of the anterior skull base.[1] The endoscopic approach has been shown to result in shorter hospital stay, faster recovery, and improved cosmetic outcomes while not compromising survival or complication rates compared with open or microscopic approaches.[2–4] Nevertheless, the endonasal approach is not without its own potential morbidity. Previous studies have demonstrated negative effects on quality of life on several outcome measures.[5–7]

Our institution has previously shown that patients experience significant sinonasal symptoms after endoscopic transnasal transsphenoidal skull base surgery (eTNTS).[5] On the Sino-Nasal Outcome Test (SNOT)-20, postoperative scores

received
January 21, 2013
accepted after revision
July 29, 2013
published online
October 10, 2013

DOI http://dx.doi.org/10.1055/s-0033-1356492.
ISSN 2193-6331.

significantly worsened for the need to blow nose, sneezing, runny nose, postnasal discharge, thick nasal secretions, ear fullness, and facial pain and pressure. These complaints were especially worse in the early postoperative period (36–101 days), with most symptoms returning toward baseline by 6 to 9 months. Although the SNOT-20 is primarily used to assess the effectiveness of treatment for sinusitis, it provides valuable and quantifiable data for measuring sinonasal and rhinosinusitis symptoms (►**Table 1**). Since this initial study, we have modified our surgical technique during the endoscopic approach in an attempt to decrease postoperative sinonasal complaints.

At our institution, we currently spare the middle turbinate when possible, avoid maxillary antrostomies, and avoid early harvest of the nasoseptal flap when feasible to minimize the disruption of normal sinonasal physiology. Our objective was to determine if these modifications in technique would result in decreased postoperative sinonasal complaints based on patient responses to the SNOT-20 or SNOT-22 after undergoing eTNTS (►**Table 1**).

Table 1 Sino-Nasal Outcome Test (SNOT)-20 and SNOT-22 questionnaires

Item no.	SNOT-20	SNOT-22
1	Need to blow nose	Need to blow nose
2	Sneezing	Sneezing
3	Runny nose	Runny nose
4	Cough	Nasal obstruction
5	Postnasal discharge	Loss of smell or taste
6	Thick nasal discharge	Cough
7	Ear fullness	Postnasal discharge
8	Dizziness	Thick nasal discharge
9	Ear pain	Ear fullness
10	Facial pain/pressure	Dizziness
11	Difficulty falling asleep	Ear pain
12	Wake up at night	Facial pain/pressure
13	Lack of a good night's sleep	Difficulty falling asleep
14	Wake up tired	Wake up at night
15	Fatigue	Lack of a good night's sleep
16	Reduced productivity	Wake up tired
17	Reduced concentration	Fatigue
18	Frustrated/ restless/irritable	Reduced productivity
19	Sad	Reduced concentration
20	Embarrassed	Frustrated/ restless/irritable
21		Sad
22		Embarrassed

Methods

Our study was approved by the institutional review board of the University of California, Los Angeles. A total of 93 consecutive patients who underwent eTNTS from August 2011 to August 2012 were included in this study. All surgeries were performed by a dual-surgeon team that included two otolaryngologists (MBW, JDS) and a neurosurgeon (MB). Access to the anterior skull base for tumor resection or encephalocele/ cerebrospinal fluid (CSF) leak repair was via the transnasal transsphenoidal endoscopic approach in all cases. Most cases were pituitary tumors, and a transellar/parasellar approach was used. There was one clival chordoma that required an infrapetrous transclival approach, and there were five esthesioneuroblastomas that used transcribriform approaches. All 93 patients did not have at least one of the following procedures performed during the endoscopic approach: partial middle turbinate resection, nasoseptal flap, or maxillary antrostomy. Postoperative stents were not routinely used. Dissolvable packing was used in most cases, and patients typically began using nasal saline spray 1 to 2 days after surgery. Office-based debridements occurred at 1 to 2 weeks postoperatively, and every 4 to 6 weeks thereafter as needed. Patients were instructed to irrigate their sinuses twice daily with a saline solution for at least 6 to 8 weeks postoperatively.

The main outcome measure was SNOT-22 scores preoperatively and after surgery. The SNOT-22 is a validated and widely used disease-specific health-related quality-of-life measure for rhinosinusitis that consists of 22 items, with each item measured on an ordinal Likert scale from 0 to 5.[8] The SNOT-22 is a modification of the SNOT-20 and includes two additional items: nasal obstruction and loss of taste or smell (►**Table 1**).[8,9] Higher scores indicate worse symptoms. The first 12 items pertain to specific physical sinonasal symptoms including nasal symptoms (numbers 1–8) and ear or pressure symptoms (numbers 9–12). The final 10 items address more systemic and psychological symptoms, with question numbers 13 to 17 pertaining to sleeping difficulty.[8]

Evaluating the Postoperative Symptoms between New and Old Cohorts

In the first part of our analysis, we compared the mean change from baseline SNOT survey scores of our new cohort to the mean SNOT survey scores of our previously published cohort who routinely had a partial middle turbinate resection, nasoseptal flap, and maxillary antrostomy performed during the eTNTS approach.[5] Because our old cohort ($n = 69$) completed the SNOT-20 instead of the SNOT-22, we used SNOT-20 scores for our comparison analysis between these two cohorts.

To control properly for potential differences between cohorts that may be due to unequal timing in survey scores, observations were grouped into finer time intervals than in our previous study.[5] SNOT-20 scores were collected at baseline (preoperative), 30 to 59 days postoperative, 60 to 89 days

Table 2 Summary statistics for number of days follow-up by cohort and time

Time point	Cohort	No. of patients	Mean, d	Median, d	Standard deviation	*p* value
Baseline	Old	31	0	0	0	1.00
	New	56	0	0	0	
30–59 d	Old	6	50	51.5	7.8	0.81
	New	35	48	50	8.0	
60–89 d	Old	25	71	69	6.9	0.29
	New	27	73	75	8.7	
4–6 mo	Old	27	129	132	28.3	0.89
	New	26	130	127	28.9	
7–12 mo	Old	15	234	227	36.2	0.89
	New	18	248	224	62.9	

postoperative, 4 to 6 months postoperative, and 7 to 12 months postoperative (►**Table 2**). Overall, 7 of the 93 patients in our new cohort completed SNOT surveys outside these time periods, and thus they were excluded from this comparison analysis.

The mean changes from baseline in each SNOT-20 item were evaluated between cohorts and within cohorts across time using a nonparametric resampling repeated measures analysis of variance (ANOVA) model. This model does not impose the parametric normality assumption and was therefore appropriate for an ordinal Likert scale outcome, such as SNOT scores. A p value < 0.05 indicates a significant difference in the mean score change between the two cohorts at a specific postoperative time interval, and a p value < 0.1 indicates a trend toward significance.

Evaluating the Postsurgical Symptoms of the Three Surgical Modifications in the New Cohort

In addition to comparing SNOT scores after eTNTS between our new and old cohorts, we also examined how avoiding each of the surgical modifications (nasoseptal flap, partial middle turbinate resection, and maxillary antrostomy) affected postsurgical symptoms within our new cohort ($n = 93$). A nasoseptal flap was performed only if the patient had an intraoperative CSF leak, a partial middle turbinate resection was performed if the surgeon team desired wider access to the skull base, and a maxillary antrostomy was performed only if there was preoperative radiographic evidence of maxillary sinusitis.

All of these patients completed SNOT-22 surveys on one or more occasions before and/or after surgery. Time was divided into six categories including baseline (preoperative), 1 month (0–29 days), 2 months (30–59 days), 3 months (60–89 days), 4 to 6 months, and > 6 months postoperative.

Because the number of outcomes (SNOT items) is large and some of the items may be redundant, we initially performed a principal component/factor analysis to determine if the individual SNOT items could be simplified to a fewer number of variables (factors), to be used in the analysis instead of the individual 22 items (data reduction). A scree plot was created by plotting the eigenvalue (variance explained) versus the SNOT item number. This yielded three underlying factors.

To simplify the factor structure, we then performed an oblique rotation based on a three-factor model and examined the resulting rotated factor loadings. Because factors are likely to be correlated, an oblique rotation allows for correlation among the three factors. Based on our factor loadings, the SNOT-22 can be simplified into factor I, psychological symptoms (item numbers 18–22); factor II, nasal drainage symptoms (item numbers 1–8); and factor III, ear and pressure symptoms (item numbers 9–12). Item numbers 13 to 17 (sleep problems) load strongly on both factors I and III, indicating an association of better sleep with both improved psychological symptoms (factor I) and less ear/pressure symptoms (factor III). After establishing these three factors, summary factor scores were obtained by computing the weighted sums of the normalized SNOT items. Thus a factor score is a weighted summary score of all the SNOT items with the largest weights attributed to items that contribute most strongly to it.

The mean changes of factor scores from baseline across time were then calculated within and between patient groups for each surgical modification using repeated measures ANOVA, after confirming the normality and constant variance assumptions. This model allows for interactions between each of the three surgical modifications with time, but it assumes the effects of the surgical modifications are additive among each other within a specified time interval.

Results

We identified 93 consecutive patients who underwent eTNTS for skull base lesions between August 2011 and August 2012. There were 41 males and 52 females with a mean age of 51 years (range: 10–92). Forty-four patients had a nasoseptal flap for skull base reconstruction, 43 had a partial right middle turbinate resection, and 27 had a maxillary antrostomy. ►**Table 2** shows the number of patients at each time interval. There is no significant difference in the number of postoperative days between cohorts at each time interval.

Table 3 Mean changes in Sino-Nasal Outcome Test item score from baseline between old and new cohorts

SNOT Item	Baseline		Postoperative month 3			Postoperative months 4–6			Postoperative months 7–12		
	Old, mean	New, mean	Old, mean	New, mean	*p* value	Old, mean	New, mean	*p* value	Old, mean	New, mean	*p* value
Q1: Need to blow nose	0.94	1.07	0.96	0.00	0.047	0.34	−0.01	0.472	0.21	−0.36	0.324
Q3: Runny nose	0.67	1.19	0.69	−0.27	0.024	0.30	−0.50	0.054	−0.12	−0.64	0.310
Q5: Postnasal discharge	0.56	1.20	1.43	−0.34	0.000	0.95	−0.43	0.004	0.88	−0.30	0.097
Q6: Thick nasal discharge	0.49	0.51	1.74	0.17	0.000	1.41	0.39	0.022	0.24	0.28	0.950
Q12: Wake up at night	1.23	1.71	0.48	−0.69	0.019	0.10	−0.49	0.253	0.34	0.18	0.788
Q17: Reduced concentration	1.29	1.51	0.51	−0.59	0.024	−0.27	−0.67	0.425	−0.40	−0.38	0.971
Q18: Frustrated restless/irritable	1.03	1.46	0.37	−0.56	0.040	−0.03	−0.39	0.470	−0.12	−0.37	0.723

Abbreviations: Q, question; SNOT, Sino-Nasal Outcome Test.
Note: There were no significant differences across time between cohorts for SNOT-20 items 2, 4, 7 to 11, 13 to 16, 19, and 20. A negative mean change indicates an improvement from baseline; a positive mean change indicates a worsening from baseline.

Outcomes between New and Old Cohorts

Compared with the old cohort, our new cohort demonstrated an improvement or less of a worsening from baseline scores that was significant in 7 of the 20 SNOT items. With respect to nasal symptoms (►**Table 3**), our new cohort had a better mean change for SNOT items 1: need to blow nose (third month postop), 3: runny nose (3–6 months postoperative), 5: postnasal discharge (3–12 months postoperative), and 6: thick nasal discharge (3–6 months postoperative). For psychological and global symptoms (►**Table 3**), significant between-group differences were also observed during the third month after surgery for SNOT items 12: wake up at night, 17: reduced concentration, and 18: frustrated/restless/irritable.

Postoperative Outcomes of the Three Surgical Modifications

In the second part of our analysis, we compared the mean change in factor scores from baseline for psychological symptoms (factor I), nasal symptoms (factor II), and ear and pressure symptoms (factor III) for each of the three surgical modifications. A positive change in mean factor score signifies a worsening of symptoms, whereas a negative change in mean factor score indicates an improvement in symptoms from baseline (►**Figs. 1–3**). Analysis was based on our cohort of 93 patients and a total of 220 observations. For patients who filled out multiple SNOT surveys within the same time interval, the corresponding scores were averaged. A total of 55 subjects had survey scores at baseline, 68 at 1-month follow-up, 37 at 2-month follow-up, 27 at 3-month follow-up, 19 at 4- to 6-month follow-up, and 14 at > 6-month follow-up.

Psychological Symptoms

Regarding psychological scores (factor I), not using a nasoseptal flap for reconstruction, not performing a partial middle turbinate reduction, but performing a maxillary antrostomy were all associated with a greater improvement from baseline scores (►**Fig. 1A**). This psychological improvement for patients who did not have a nasoseptal flap was significant at 1 ($p < 0.01$), 2 ($p < 0.01$), and 3 ($p < 0.01$) months postoperative, whereas the improvement within the group of patients who had a nasoseptal flap was not significant until 4 months after surgery ($p = 0.04$). Between-group comparison demonstrated a significant difference in improvement for those without a nasoseptal flap 1 month postoperative ($p = 0.02$); otherwise no other significant between-group differences were found at the later postoperative time points.

As shown in ►**Fig. 1B**, patients who did not have a partial middle turbinate resection tended to have a greater mean improvement in psychological symptoms at each postoperative time point, but a between-group analysis failed to find significance at any time point. On within-group analysis, patients who did not have a partial middle turbinectomy showed a significant improvement from baseline at postoperative month 1 through 6 ($p < 0.05$). Patients who did have a partial middle turbinectomy never had a significant change in mean factor scores from baseline in their psychological symptoms.

For patients who had a maxillary antrostomy in the setting of preoperative radiographic evidence of maxillary sinus disease, a significant improvement at each postoperative time point ($p < 0.05$) was found (►**Fig. 1C**). Those who did not have a maxillary antrostomy never had a significant mean factor I score change from baseline. A significant difference between patient groups was noted at postoperative months 2 ($p = 0.05$), 4 to 6 ($p = 0.02$), and > 6 ($p = 0.03$), suggesting those with a maxillary antrostomy have greater improvement in psychological symptoms.

Nasal Symptoms

Regarding nasal symptoms (factor II), not harvesting a nasoseptal flap was associated with less worsening after

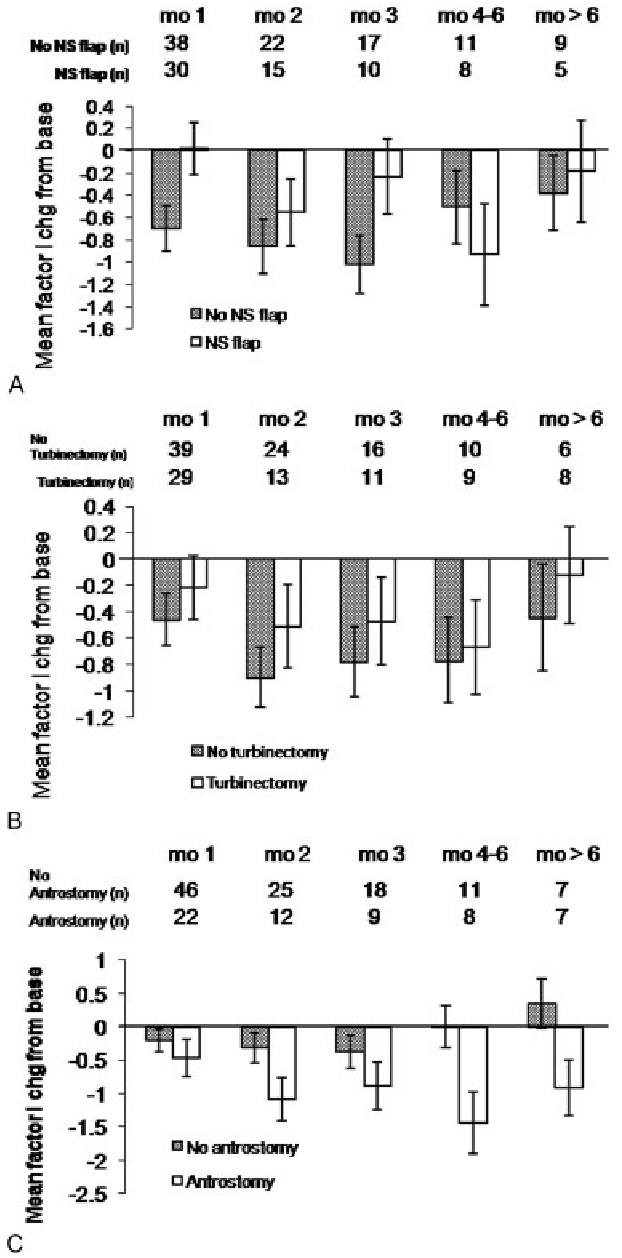

Fig. 1 The mean change in factor score of psychological symptoms for patients who did and did not have (**A**) nasoseptal flap (NP), (**B**) middle turbinate resection, and (**C**) maxillary antrostomy. Abbreviation: mo, month.

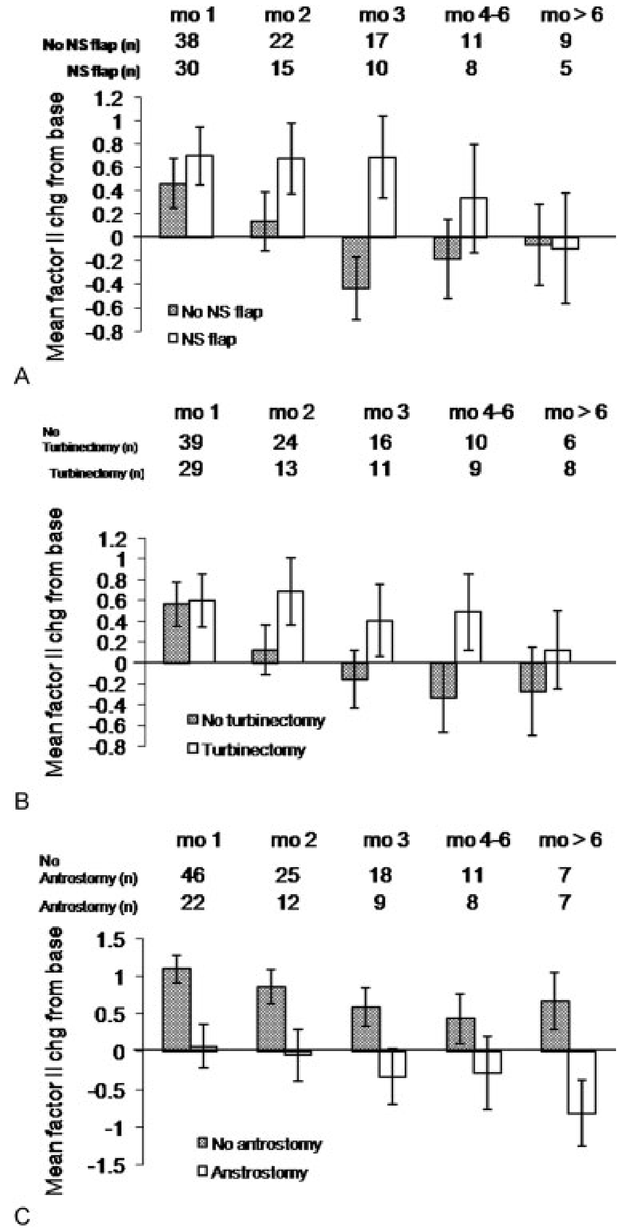

Fig. 2 The mean change in factor score of nasal symptoms for patients who did and did not have (**A**) nasoseptal flap (NP, (**B**) middle turbinate resection, and (**C**) maxillary antrostomy. Abbreviation: mo, month.

surgery, as shown in ►**Fig. 2A**. Within the group of patients that did not have a nasoseptal flap, this worsening in nasal symptoms was only significant during the first month postoperative ($p = 0.03$), after which patients' nasal symptoms improved. Patients who did have a nasoseptal flap showed significant worsening in symptoms at postoperative month 1 ($p = 0.01$),2 ($p = 0.03$), and 3 ($p = 0.05$). Comparing the mean change in factor scores of nasal symptoms between groups found a significant difference at 3 months postoperative ($p = 0.01$). In fact, 3 months after surgery, patients with a nasoseptal flap still had a worsening of symptoms from baseline; whereas patients who did not have a nasoseptal flap tended to have an improvement compared with baseline nasal symptoms.

Patient groups who had a partial middle turbinectomy and those who did not both demonstrated a significant worsening in nasal symptoms at 1 month postoperative ($p = 0.01$ and $p = 0.02$, respectively) (►**Fig. 2B**). This worsening above baseline was persistent in the middle turbinectomy group across all time points, with significance continuing to postoperative month 2 ($p = 0.04$). The mean change from base difference in nasal symptoms between groups trended toward significance at 4 to 6 months postoperative ($p = 0.09$) because patients without a middle turbinate resection tended to have an improved change in mean factor score compared with baseline.

Not having a maxillary antrostomy was significantly associated with a greater worsening of nasal symptom scores,

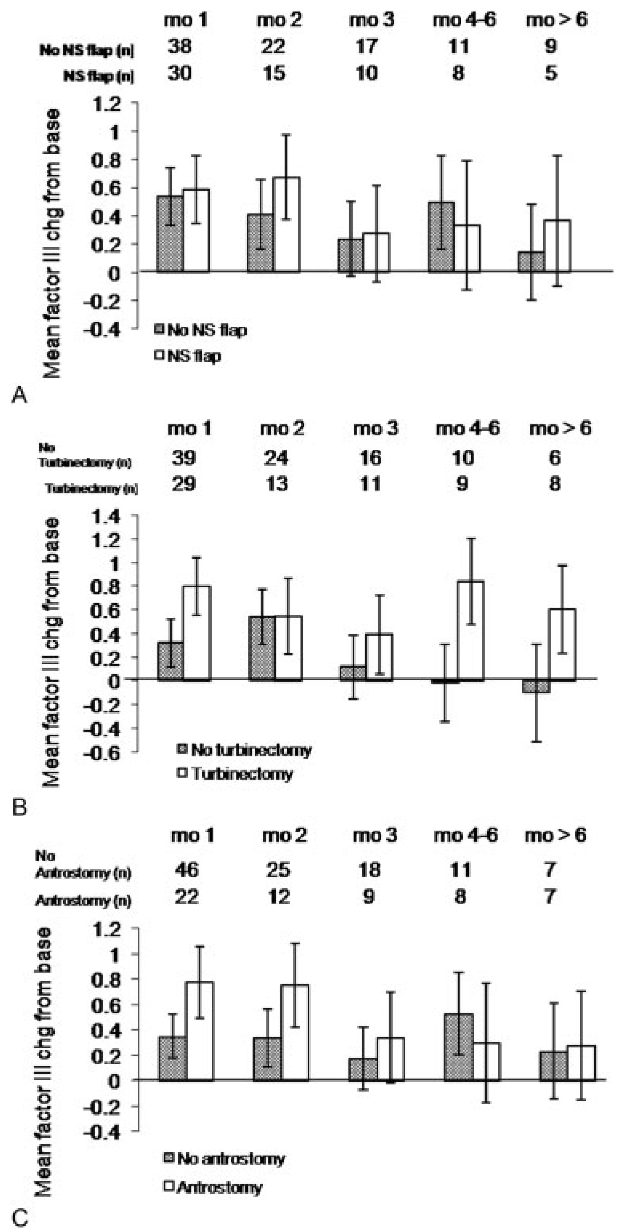

Fig. 3 The mean change in factor score of ear and pressure symptoms for patients who did and did not have (**A**) nasoseptal flap (NP), (**B**) middle turbinate resection, and (**C**) maxillary antrostomy. Abbreviation: mo, month.

compared with patients who did have a maxillary antrostomy at postoperative months 1 ($p < 0.01$), 2 ($p = 0.03$), 3 ($p = 0.04$), and > 6 ($p = 0.01$). This difference between groups can be visualized in ►**Fig. 2C.** Patients who had a maxillary antrostomy actually demonstrated an improvement in mean nasal symptom scores after 2 months.

Ear and Pressure Symptoms

Regarding ear and pressure symptoms, the mean change in factor score for those patients who had a nasoseptal flap and/or a partial middle turbinectomy and/or a maxillary antrostomy appear to demonstrate a greater worsening from baseline (►**Fig. 3**). However, between-group analysis failed to find any significant differences in the changes of mean factor scores between patient groups. The only difference that trended toward significance occurred at postoperative month 4, with the absence of middle turbinectomy associated with less worsening in ear and pressure symptoms ($p = 0.07$) (►**Fig. 3B**). At this 4-month postoperative period, the middle turbinectomy group had a significant worsening in symptoms ($p = 0.02$) compared with no change in patients without a partial middle turbinate resection (p > 0.1).

Rate of Postoperative Cerebrospinal Fluid Leak

There was no significant difference in postoperative CSF leak between patients who did and did not have a nasoseptal flap for skull base reconstruction. Only 2 of the 44 patients (4.5%) with a nasoseptal flap developed a postoperative CSF leak. None of the 49 patients (0%) without a nasoseptal flap had a postoperative CSF leak.

Discussion

Due to the nature of the endonasal endoscopic approach, some nasal morbidity after eTNTS is expected.[5–7] When we began performing eTNTS, we routinely resected the inferior half of the right middle turbinate to improve access and visualization, harvested a nasoseptal flap, and performed a maxillary antrostomy for storage of the flap during surgery. More recently, we have modified our approach technique, in the hopes of reducing postoperative sinonasal morbidity. The results from our current study suggest that using surgical techniques that minimize the disruption of normal sinonasal physiology, when possible, results in significantly less worsening of symptoms. More specifically, our study suggests that patients who did not have routine partial middle turbinectomies, nasoseptal flaps, and unnecessary maxillary antrostomies improve faster after surgery based on responses to the SNOT-20 questionnaire (►**Table 3**).

In our comparison of the old and new cohorts (►**Table 3**), there was not a significant difference in symptoms over the first 2 postoperative months. However, by postoperative month 3, our new cohort had a significant improvement, as evidenced by the mean SNOT score changes in items 1, need to blow nose; 3, runny nose; 5, postnasal discharge; and 6, thick nasal discharge. This difference, or improvement of physical sinonasal complaints, continued into the 4- to 6-month postoperative period for SNOT items 5, postnasal discharge, and 6, thick nasal discharge. In fact, the greater improvement in postoperative postnasal discharge in our new cohort compared with the old cohort also trended toward significance 7 to 12 months after surgery ($p < 0.1$). In addition to the improvement in these physical symptoms, our new cohort also had a quicker improvement in several psychological and global symptoms during the third month after surgery for SNOT items 12, wake up at night; 17, reduced concentration; and 18, frustrated/restless/irritated.

Because our new cohort improved faster after surgery, the second part of our analysis sought to determine how each specific surgical modification affected postoperative symptoms. Partial or total resection of the middle turbinate has been described for improved visualization and surgical access to the transsphenoidal skull base.[10] However, healthy middle turbinates play critical roles in the normal nasal physiological cycle and maintenance of laminar airflow. Middle turbinates protect the maxillary and ethmoid sinuses from inhaled air and the resultant drying effects on sinus mucociliary clearance.[11] Partial resection of the middle turbinate can also lead to exposed bony edges and increased crusting, as well as synechiae formation and lateralization of the remaining turbinate, resulting in frontal sinusitis.[12] Although most of the published literature focusing on the importance of the middle turbinate has been done in patients with inflammatory sinus disease, Nyquist et al[13] published a study in 2010 looking at middle turbinate preservation during endonasal endoscopic surgery for skull base lesions. In their study, the middle turbinate was preserved in 160 of 163 cases. A total of 120 of these patients had postoperative magnetic resonance imaging studies performed at a mean postoperative interval of 16 months (range: 2–46 months), and there were no patients with radiologic evidence of frontal sinusitis.[13]

In the present study, patients who did not have partial middle turbinate resections appear to have a resolution of their nasal symptoms more quickly (►**Fig. 2B**). At 1 month postoperative, patients who did or did not have turbinate resections both complained of worsening nasal symptoms and there was a significant increase in the mean factor score from baseline for both groups. However, a significant worsening in nasal symptoms, which includes items 1 to 8 on the SNOT-22 (►**Table 1**), only persisted into postoperative month 2 in patients who did have a partial middle turbinectomy. Those without turbinate resections had a much less worsening in nasal symptoms during month 2 compared with the first month after surgery, and then they actually had an improvement in nasal symptoms, as evidenced by a negative mean factor II change (►**Fig. 2B**). This improvement trended toward significance compared with patients who did have a middle turbinate resection during postoperative months 4 to 6 ($p = 0.09$). Additionally, patients with a middle turbinate resection appear to have prolonged ear and pressure symptoms. Significant worsening from baseline within these patients occurred during the 4- to 6-month postoperative period ($p = 0.02$). This worsening trended toward significance when compared with those without a turbinate resection ($p = 0.07$) (►**Fig. 3B**). A difference in psychological symptoms associated with a partial middle turbinectomy is less drastic; both groups demonstrated improvement after eTNTS removal of their skull base tumor (►**Fig. 1B**).

In addition to routine partial middle turbinate resections, our initial technique involved raising a nasoseptal flap for skull base reconstruction.[5] Use of a nasoseptal flap is a reliable technique for reconstructing the anterior skull base.[10,14] However, harvest of a nasoseptal flap leaves a large area of exposed septal cartilage and/or bone, leading to significant crusting and adversely affecting normal sinonasal function. This exposed cartilage requires repeated debridements until remucosalization of the nasal septum occurs, which can take up to 3 months for complete healing.[7,10] Now we only use a nasoseptal flap if a CSF leak is noted intraoperatively or if a patient has risk factors for the development of a postoperative CSF leak including obesity, benign intracranial hypertension, prior radiation therapy, large tumors, advanced age, or diabetes. The results of this present study suggest a faster improvement in nasal symptoms when a nasoseptal flap is not used. Also, none of the patients in this series without a nasoseptal flap developed a postoperative CSF leak, suggesting that routine use of the flap is unnecessary.

In our new cohort, patients who had a nasoseptal flap had a significant worsening in nasal symptoms, as measured by factor II (►**Fig. 2A**), through 3 months after surgery. Those without a nasoseptal flap only demonstrated a significant worsening from baseline at 1 month postoperative. The significant difference found between these two groups at 3 months postoperative ($p = 0.01$) is likely due to the fact that exposed septal cartilage takes up to 3 months to fully remucosalize, thus prolonging the restoration of normal sinonasal function.[7,10]

Less of a distinction can be made in psychological or ear and pressure scores, but those patients who did not have a nasoseptal flap appear to do marginally better in both categories. Within-group analysis revealed a significant improvement in psychological scores during the first 3 months postoperative in patients who did not have a nasoseptal flap that was not found in patients who did have a nasoseptal flap (►**Fig. 1A**). However, between-group analysis only revealed significance at 1 month postoperative (0.02). Patients without a nasoseptal flap also no longer had a significant worsening in ear and pressure symptoms by postoperative month 2, which was noted in patients with a nasoseptal flap ($p = 0.03$) (►**Fig. 3A**). However, no significance between groups was found at any postoperative time point.

After harvest of the nasoseptal flap, maxillary antrostomies were used to store and protect the flap during surgery.[10] However, creation of a maxillary antrostomy to store the nasoseptal flap temporarily in a patient without preoperative evidence of maxillary sinus disease could potentially exacerbate sinonasal symptoms by two putative mechanisms. First, failure to include the natural maxillary sinus ostium in the surgical antrostomy can result in mucus recirculation and impaired clearance. Second, placement of the nasoseptal flap in the maxillary sinus may result in mucosal trauma and ciliary dysfunction. Currently, in cases where the probability of an intraoperative CSF leak is high, we perform a "rescue" flap, to preserve the vascular pedicle in case a nasoseptal flap is needed for reconstruction as described by Rivera-Serrano et al.[15] This flap is not elevated from the septal cartilage unless the flap is used, avoiding large areas of exposed cartilage. In those cases where a nasoseptal flap is required, such as for large skull base defects, the flap is elevated and placed in the nasopharynx, obviating the need for a maxillary antrostomy and potentially decreasing the risk of sinus dysfunction.

In our recent cohort, patients only had a maxillary antrostomy if preoperative imaging revealed evidence of maxillary sinusitis. Therefore, the improvement in nasal symptoms demonstrated in the maxillary antrostomy group is expected (►**Fig. 2C**). This finding supports performing a maxillary antrostomy in the setting of maxillary sinusitis during the approach in eTNTS for skull base tumors.

The present study has several shortcomings. The study design is a retrospective case series, which holds many inherent biases, such as potential selection bias. However, the potential selection bias was limited in our comparison analysis between our new and old cohorts because we used consecutive eTNTS cases. Although the current report is based on a longitudinal sample, most patients have incomplete data across time, which may have introduced some amount of bias in the results. The findings that our new cohort, in general, had improved scores in 7 of the 20 SNOT items suggests that if less manipulation is done along the nasal corridor during the endoscopic skull base approach, patients' postoperative symptoms may improve sooner. Looking specifically at each surgical modification in the new cohort, controlling for the other surgical variables, not performing a nasoseptal flap and not resecting the middle turbinate appear to have the largest roles in decreasing postoperative sinonasal morbidity. Therefore, when adequate access to the skull base can be obtained without resecting the middle turbinate, and when a nasoseptal flap may not be needed for skull base reconstruction, such as in the absence of an intraoperative CSF leak, our results suggest patients may recover faster. Randomized controlled studies are needed to confirm our study's findings.

Conclusion

Preserving normal sinonasal physiology during transnasal transsphenoidal endoscopic surgery by limiting middle turbinate resections, avoiding maxillary antrostomies when there is no preoperative radiographic evidence of sinusitis, and reducing the use of nasoseptal flaps result in less sinonasal morbidity and more rapid recovery during the postoperative period.

Acknowledgments
Daniella Markovic, MS, of the UCLA Department of Biostatistics contributed to the review of the statistical analysis and presentation of the data.

Note
We were awarded the "Best Clinical Paper by a Resident" at the 23rd Annual Meeting for the North American Skull Base Society; February 15–17, 2013; Miami, FL.

Conflict of interest
The authors have nothing to disclose. No financial funding or support was received.

References

1 Liu JK, Das K, Weiss MH, Laws ER Jr, Couldwell WT. The history and evolution of transsphenoidal surgery. J Neurosurg 2001;95(6):1083–1096
2 Eloy JA, Vivero RJ, Hoang K, et al. Comparison of transnasal endoscopic and open craniofacial resection for malignant tumors of the anterior skull base. Laryngoscope 2009;119(5):834–840
3 Tabaee A, Anand VK, Barrón Y, et al. Endoscopic pituitary surgery: a systematic review and meta-analysis. J Neurosurg 2009;111(3):545–554
4 Cappabianca P, Cavallo LM, Colao A, et al. Endoscopic endonasal transsphenoidal approach: outcome analysis of 100 consecutive procedures. Minim Invasive Neurosurg 2002;45(4):193–200
5 Balaker AE, Bergsneider M, Martin NA, Wang MB. Evolution of sinonasal symptoms following endoscopic anterior skull base surgery. Skull Base 2010;20(4):245–251
6 McCoul ED, Anand VK, Bedrosian JC, Schwartz TH. Endoscopic skull base surgery and its impact on sinonasal-related quality of life. Int Forum Allergy Rhinol 2012;2(2):174–181
7 de Almeida JR, Snyderman CH, Gardner PA, Carrau RL, Vescan AD. Nasal morbidity following endoscopic skull base surgery: a prospective cohort study. Head Neck 2011;33(4):547–551
8 Morley AD, Sharp HR. A review of sinonasal outcome scoring systems—which is best? Clin Otolaryngol 2006;31(2):103–109
9 Piccirillo JF, Merritt MG Jr, Richards ML. Psychometric and clinimetric validity of the 20-Item Sino-Nasal Outcome Test (SNOT-20). Otolaryngol Head Neck Surg 2002;126(1):41–47
10 Kassam A, Snyderman CH, Mintz A, Gardner P, Carrau RL. Expanded endonasal approach: the rostrocaudal axis. Part I. Crista galli to the sella turcica. Neurosurg Focus 2005;19(1):E3
11 Kennedy DW. Middle turbinate resection: evaluating the issues—should we resect normal middle turbinates? Arch Otolaryngol Head Neck Surg 1998;124(1):107
12 Swanson PB, Lanza DC, Vining EM, Kennedy DW. The effect of middle turbinate resection upon the frontal sinus. Am J Rhinol 1995;9(4):191–197
13 Nyquist GG, Anand VK, Brown S, Singh A, Tabaee A, Schwartz TH. Middle turbinate preservation in endoscopic transsphenoidal surgery of the anterior skull base. Skull Base 2010;20(5):343–347
14 Hadad G, Bassagasteguy L, Carrau RL, et al. A novel reconstructive technique after endoscopic expanded endonasal approaches: vascular pedicle nasoseptal flap. Laryngoscope 2006;116(10):1882–1886
15 Rivera-Serrano CM, Snyderman CH, Gardner P, et al. Nasoseptal "rescue" flap: a novel modification of the nasoseptal flap technique for pituitary surgery. Laryngoscope 2011;121(5):990–993