Abstract
Objective: To assess olfactory outcomes as measured by an olfactory-specific quality of life (QOL) questionnaire in patients undergoing EESBS for sellar lesions.
Design: Retrospective case series.
Setting: Tertiary academic medical center.
Participants: In total, 36 patients undergoing EESBS for lesions limited to the sella were evaluated.
Main Outcome Measures: The following were performed before and three months after surgery: 22-Item Sinonasal Outcomes Test (SNOT-22), University of Pennsylvania Smell Identification Test (UPSIT), and the Assessment of Self-reported Olfactory Functioning (ASOF), which has three domains: subjective olfactory capability scale (SOC), smell-related problems (SRP), and olfactory-related quality of life (ORQ).
Results: Median age at surgery was 52.5 years, with a median tumor size of 1.8 cm (range: 0.2 to 3.9 cm). Pre- and postoperative median scores were 35 [34, 36.2] and 34.5 [32, 36] for UPSIT, 21 [7.5, 33.5] and 21.5 [6.8, 35.7] for SNOT-22, 10 [9, 10] and 9 [8, 10] for ASOF-SOC, 5 [4.8, 5] and 4.5 [4, 5] for ASOF-SRP, and 5 [5, 5] and 5 [4.5, 5] for ASOF-ORQ. There was no significant change in the two of the three domains of the ASOF. Correlation between ASOF and UPSIT scores were weak. Older age and larger tumor size were associated with worsened olfaction after surgery.
Conclusions: Patients did not experience significant changes in olfactory-specific QOL three months after EESBS, as measured by two domains of the ASOF. The ASOF may serve as a useful adjunctive tool for assessing olfaction after surgery. The lack of correlation between UPSIT and ASOF suggests the need for more research in subjective olfactory-related quality of life after surgery.

Keywords
endoscopic minimally invasive surgery of the skull base, olfaction, quality of life

Introduction
The advent of endonasal endoscopic skull base surgery (EESBS) has revolutionized the management of difficult to reach lesions of the cranial base. Recent literature has demonstrated higher rates of complete tumor resection and improved visualization, in addition to lower rates of diabetes insipidus, olfactory dysfunction, and septal perforation with EESBS. However, EESBS of the sella typically involves disruption of the sphenoid sinus and posterior septal mucosa, which contains olfactory fibers. Therefore, olfactory dysfunction after EESBS,

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has been recognized as a major complication. Patients with olfactory impairment are susceptible to deleterious or decreased food consumption, neglect of personal hygiene, imperception to environmental hazards, and depression.

The degree to which patients experience olfactory dysfunction and the time course for recovery after EESBS is unclear. Several studies have demonstrated no significant changes at various timepoints after surgery, with a recent meta-analysis showing no significant worsening of olfaction. However, other studies have reported significant worsening. These studies analyzed olfactory outcomes anywhere between one and twelve months after surgery, with three months being the most common postoperative timepoint. A number of surgical factors have been associated with olfactory preservation or dysfunction after EESBS. Preservation of the “olfactory strip,” or the superoposterior nasal mucosa containing olfactory free nerve endings, has been shown to preserve olfaction. At the same time, harvesting of the nasoseptal flap (NSF) as well as use of electrocautery have been associated with worsened olfaction.

Studies investigating olfaction after EESBS have used a variety of subjective and objective instruments. The UPSIT and the Sniffin Sticks test have been the most commonly used objective olfactory tests. As for subjective quality of life testing, only general sinonasal outcomes instruments such as the 20- or 22-Item Sinonasal Outcomes Test (SNOT), the Nasal Symptom Score, the Nasal Obstruction Symptom Evaluation, the Anterior Skull Base Inventory, and the Anterior Sinus Obstruction Symptom Evaluation have been used. However, none of these are olfactory-specific. Therefore, olfactory-specific questionnaires, as utilized for chronic rhinosinusitis, are needed to provide additional insight into olfactory outcomes after EESBS. The purpose of this study was to assess olfactory outcomes as measured by the Assessment of Self-Reported Olfactory Functioning (ASOF) questionnaire, an olfactory-specific quality of life (QOL) questionnaire in patients undergoing EESBS for sellar lesions.

**Methods**

This study was approved by the Institutional Review Board at Duke University Hospital. A retrospective medical record review was conducted on adult patients who underwent EESBS with the Duke Skull Base Center for sellar lesions between January 2017 and December 2019. Patients who underwent an approach beyond the sella, such as transplanar, transpterygoid, or transclival, were excluded. Information related to patient demographics, smoking status, tumor type, tumor size, use of NSF, middle turbinate resection, and postoperative radiation were recorded.

The ASOF, UPSIT, and SNOT-22 instruments were administered at the preoperative visit, which was typically one or two weeks prior to surgery, and at three months postoperatively. For patients who missed their three-month postoperative visit, assessments were performed at the next visit up to but no later than six months postoperatively. Only patients with pre- and postoperative UPSIT and ASOF data were included in the analysis. The ASOF is a validated quality of life psychometric questionnaire specifically for olfaction disorders. It consists of three subdomains which include the Subjective Olfactory Capability Scale (SOC), which rates overall olfactory ability from a scale of 0 to 10, the Smell-Related Problems Scale (SRP), and the Olfactory-related Quality of Life Scale (ORQ). (Figure 1)

**Operative Technique**

All cases included in this analysis were collaborative procedures performed by rhinology and neurosurgery. In general, bilateral sphenoidotomy, rescue flap harvest, and removal of the rostrum and intersinus septum were performed. Ethmoidectomy with middle or superior turbinate resection was left to the discretion of the rhinologist. Middle turbinate resection was partial and unilateral, with the exception of one case in which it was partial and bilateral. Electrocautery was used judiciously for rescue flap harvest and for NSF harvest when required. The superior incision of the NSF and the rescue flap was made at the level of the sphenoid natural os, at least 1 cm below the cribiform plate, below the olfactory fibers. The size of the posterior septectomy was also at the discretion of the surgeons, but was approximately 1 to 1.5 cm in length.

The reconstructive method was based on presence and flow rate of cerebrospinal fluid (CSF) leak, size of defect, and surgeon preference. When no leak was present, the sphenoid sinus was simply lined with Gelfoam (Pfizer, New York, NY) with or without a free mucosal graft from the middle turbinate. Absorbable packing material (Nasopore [Polyganics, Groningen, the Netherlands] or PosiSep [Hemostasis, St. Paul, MN]) was placed in the nasal cavity. For low-flow CSF leaks, an abdominal fat graft supported by non-absorbable packing was used. Packing was removed after five to seven days. For high-flow CSF leaks with a visible dural defect, a NSF with or without abdominal fat was used for reconstruction. Packing was removed after five to seven days, but bilateral Doyle splints (Medtronic, Jacksonville, FL) were left in place for three to six weeks to promote re-epithelialization of the septum donor site. Endoscopic debridement was performed at minimum one month and three months after surgery.

**Statistical Analysis**

Study data were collected and managed using Research Electronic Data Capture (REDCap). Medians [Q1 = 25th percentile, Q3 = 75th percentile] were presented for continuous variables while frequencies (%) were presented for categorical variables. The baseline and follow-up olfactory scores were compared using Wilcoxon signed rank tests with Bonferroni correction when appropriate.
correlation was calculated for the changes in UPSIT score compared to the changes in the ASOF scores to assess the monotonic relationship between these scores. Furthermore, we defined worsening UPSIT or ASOF as a binary outcome indicating a negative change score. In order to identify factors associated with these outcomes, univariate analyses were performed for each patient’s characteristic. Tumor pathology was dichotomized into whether the patient had pituitary adenoma or not. Continuous variables were compared between worsening and not worsening groups using Wilcoxon rank sum tests while categorical variables were compared using Fisher’s exact tests. If an incomplete SNOT-22 questionnaire had at least 50% of items completed, item-level missingness was imputed using mean of the completed items. The imputation method was utilized by Hopkins et al. when missing data was encountered in their study to validate the SNOT-22 questionnaire, and is consistent with studies utilizing other patient-based outcomes measures. All analyses were performed in R 3.5.3 (R Core Team, 2019).

**Figure 1.** Assessment of self-reported olfactory functioning and olfaction related quality of life (ASOF). Adapted from Pusswald G, Auff E, Lehrner J. Development of a Brief Self-Report Inventory to Measure Olfactory Dysfunction and Quality of Life in Patients with Problems with the Sense of Smell. Chemosensory Perception. 2012;5(3-4):292 to 299. The ASOF can be obtained from http://www.psimistri.com.
Results

A total of 36 patients met inclusion criteria, completing both the ASOF and the UPSIT before and after surgery. Complete SNOT-22 data were available for 31 patients. 11 patients (30.6%) were male. Median age was 52.5 [35, 60.8] years (range: 20 to 73 years). 4 (11.1%) of patients were active smokers. 5 patients (13.9%) underwent NSF reconstruction. 16 patients (44.4%) underwent middle turbinate resection. 2 patients (5.6%) underwent postoperative stereotactic radiation. Median tumor size was 1.8 [1.2, 2.2] cm (range: 0.2 to 3.9 cm). Information related to tumor size and pathology are found in Table 1.

For scores on outcomes measures, there was no significant worsening of the SNOT-22 or two domains of the ASOF (SOC, SRP). In contrast, there was statistically significant worsening of the UPSIT and ASOF-ORQ. (Table 2). Spearman’s correlation was estimated to assess for monotonic relationship. No strong correlation between the change in UPSIT and ASOF measures was found (lr, ≤ 0.15). (Table 3)

On univariate analysis, male sex, smoking status, tumor size, nasoseptal flap, middle turbinate resection, radiation, and adenoma on histology were not associated with worsening UPSIT. Age, however, was associated with worsening UPSIT. Specifically, the median age in the worsening UPSIT group was 58 [35, 66.2] compared to 40 [34.8, 54] (p = 0.034). (Table 4) A larger tumor size was associated with worsening ASOF-SOC on univariate analysis (2 [1.6, 2.8] vs. 1.5 [0.9, 2]; p = 0.017). (Table 5)

Table 1. Characteristics of Patients Undergoing Transsellar EESBS.

| Characteristics                  | Total (n = 36) |
|----------------------------------|---------------|
| Male                             | 11 (30.6%)    |
| Age at surgery (years), median   | 52.5 [35, 60.8] |
| Smoker                           | 4 (11.1%)     |
| Tumor size (cm), median          | 1.8 [1.2, 2.2] |
| Pathology                        |               |
| Pituitary Adenoma Non-secreting  | 16 (44.4%)    |
| Pituitary Adenoma ACTH           | 5 (13.9%)     |
| Pituitary Adenoma GH             | 2 (5.6%)      |
| Pituitary Adenoma Prolactin      | 8 (22.2%)     |
| Craniohypophygioma               | 1 (2.8%)      |
| Chordoma                         | 1 (2.8%)      |
| Meningioma                       | 1 (2.8%)      |
| Fibro-osseous                    | 1 (2.8%)      |
| Rathke Cleft Cyst                | 1 (2.8%)      |
| Nasoseptal flap                  | 5 (13.9%)     |
| Middle turbinate resection       |               |
| None                             | 20 (55.6%)    |
| Unilateral                       | 15 (41.7%)    |
| Bilateral                        | 1 (2.8%)      |
| Radiation                        | 2 (5.6%)      |

Q1 – 25th percentile; Q3 – 75th percentile.

Table 2. Olfactory Assessments at Baseline and Postoperative Status.

| Outcomes                  | Baseline | Postoperative | Change | P-value |
|---------------------------|----------|---------------|--------|---------|
| UPSIT (n = 36)            | 35 [34, 36.2] | 34.5 [32, 36] | −1 [−3, 0.2] | 0.008* |
| SNOT-22 (n = 31)          | 21 [7.5, 31]  | 21.5 [6.8, 35.7] | −3 [−6.6, 6] | 0.537  |
| ASOF SOC (n = 34)         | 10 [9, 10]   | 9 [8, 10]     | 0 [−2, 0] | 0.033  |
| ASOF SRP (n = 36)         | 5 [4.8, 5]   | 4.5 [4, 5]    | 0 [−0.8, 0.1] | 0.030  |
| ASOF ORQ (n = 34)         | 5 [5, 5]     | 5 [4.5, 5]    | 0 [−0.5, 0] | 0.013* |

Abbreviations: ASOF: Assessment of Self-reported Olfactory Functioning; ORQ: olfactory-related quality of life; SNOT-22: 22-Item Sinonasal Outcome Questionnaire; SOC: subjective olfactory capability scale; SRP: smell-related problems; UPSIT: University of Pennsylvania Smell Identification Test.

Table 3. Correlation Between ASOF Domains and UPSIT.

| Outcomes          | n. | Spearman’s correlation with UPSIT |
|-------------------|----|----------------------------------|
| ASOF-SOC.         | 34. | −0.10.                            |
| ASOF-SRP.         | 36. | −0.11.                            |
| ASOF-ORQ.         | 34. | 0.14.                             |

Abbreviations: ASOF: Assessment of Self-reported Olfactory Functioning; ORQ: olfactory-related quality of life; SOC: subjective olfactory capability scale; SRP: smell-related problems; UPSIT: University of Pennsylvania Smell Identification Test.

Table 4. Univariate Analysis for Worsening UPSIT Score.

| Characteristics | No (n = 16) | Yes (n = 20) | P-value |
|-----------------|------------|-------------|---------|
| Age at surgery  | 40 [34.8, 54] | 58 [35, 66.2] | 0.034* |
| Smoker          | 7 (43.8%)  | 4 (20.0%)   | 0.159   |
| Tumor size      | 1.7 [1.2, 2.2] | 1.8 [1.4, 2.4] | 0.599   |
| Nasoseptal flap | 3 (18.8%)  | 2 (10.0%)   | 0.637   |
| Middle turbinate resection | 7 (43.8%)  | 9 (45%)     | 1.000   |
| Radiation       | 0 (0.0%)   | 2 (10.0%)   | 0.489   |
| Adenoma on histology | 14 (87.5%) | 17 (85.0%) | 1.000   |

Abbreviation: UPSIT: University of Pennsylvania Smell Identification Test.

Discussion

Disruption of the olfactory epithelium during EESBS raises the concern for postoperative olfactory dysfunction. Therefore, investigating the factors influencing olfactory dysfunction after EESBS is critical. Numerous studies have
investigated olfactory outcomes after EESBS. Several studies have demonstrated no significant changes anywhere from one to twelve months after EESBS, with three-month outcomes being the most commonly reported. In contrast, Tam et al. demonstrated worsened UPSIT scores six months after EESBS. Similarly, Hong et al. found that use of electrocautery was associated with subjective olfactory loss at three months, and Cingoz et al. demonstrated worsening olfactory recognition on the Sniff Sticks test at eight weeks. Consistent with these studies, we also found a statistically significant decrease in postoperative UPSIT scores at three to six months following EESBS of the sphenoid sinus. However, it should be noted that the median difference in UPSIT scores in our cohort (−1) is likely not clinically significant. This is supported by the fact that there was no significant difference in olfactory-specific QOL scores as measured by the ASOF. Based on these findings, we conclude that EESBS of the sella does not seem to result in olfactory changes that significantly impact a patient’s QOL. At the same time, we should point out that 10 out of 36 patients (27.8%) in our cohort experienced a clinically significant drop in UPSIT (defined as 3 points or more) at three months. This is important for pre-operative counseling.

Our results also point to the utility of an olfactory-specific quality of life instrument to assess olfaction after EESBS. Olfactory-specific quality of life questionnaires have not been widely used in otolaryngology and skull base surgery. Soler et al. reported use of a modified version of the Questionnaire of Olfactory Disorders to assess olfactory outcomes after surgery for chronic rhinosinusitis. This study is the first to utilize a validated olfactory-specific quality of life questionnaire after endoscopic skull base surgery.

This study also investigated whether certain clinical factors were associated with worsening olfactory outcomes after EESBS. We found that while tumor size, turbinate resection, radiation, smoking status, or NSF use were not associated with worsening on the UPSIT, older patients had worsening after surgery. Similarly, Kim et al. demonstrated worse outcomes with older age. This suggests that older patients may have less olfactory “reserve”. We also found that larger tumor size was associated with worsening of the ASOF-SOC. This is consistent with a study by Kim et al., who demonstrated worsening smell identification scores with large tumors, presumably due to greater disruption of sinonasal anatomy. Although our sample size was too small to perform a multivariate analysis, it is worthwhile as a future endeavor to examine whether age and tumor size are risk factors for worsened olfactory outcomes. With the change in UPSIT ranging from −7 to +5 in our patient cohort, there are clearly certain patients who have much poorer olfactory outcomes.

Our study raises the question of the best tools for assessing olfaction after EESBS. For objective testing, most studies have utilized self-administered smell identification tests such as the UPSIT or the Brief Smell Identification Test. Although such smell identification testing is convenient, it is unclear if this type of suprathreshold testing is appropriate in this setting. Kim et al. utilized the Connecticut Chemosensory Clinical Research Center Test, which has an olfactory threshold testing component, to show worsened outcomes after EESBS. Similarly, the Sniffin Sticks test, which has a threshold component, has been used to show worsened scores after EESBS. For subjective testing, studies have mainly focused general sinonasal outcomes instruments, such as the SNOT-22, which have an olfactory-related item. However, an olfactory-specific QOL questionnaire such as the ASOF can provide additional insight into the patient’s everyday experience as it relates to olfaction.

Limitations of this study pertain to attrition bias and recall bias associated with patient questionnaires due to the retrospective nature of the study. The majority of patients who underwent EESBS during the study period were not included due to lack of follow-up and incomplete data, leading to a small sample size. We also did not utilize olfactory threshold testing, which may shed useful insight into optimal testing. Finally, we did not follow patients beyond three months, even though further changes in olfaction can occur beyond that.
Conclusion

Patients did not experience significant changes in olfactory-specific QOL three months after EESBS, as measured by two domains of the ASOF. The ASOF may serve as a useful adjunctive tool for assessing olfaction after surgery. The lack of correlation between UPSIT and ASOF suggests the need for more research in subjective olfactory-related quality of life after surgery.

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Author Contributions

Declaration of Conflicting Interests

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Ethical Approval

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Trial Registration

Not applicable, because this article does not contain any clinical trials.

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