


# Superior turbinate management and olfactory outcome after endoscopic endonasal transsphenoidal surgery for pituitary adenoma: a propensity score-matched cohort study

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**Background:** Surgical management of the superior turbinate (ST) is required to access the sella in endoscopic endonasal transsphenoidal surgery (EETS) for pituitary adenoma. Two common ST management techniques include partial resection of the ST (PRST) and intentional lateralization of the ST (ILST). Given the concentrated distribution of the olfactory nerve fibers on the medial surface of the ST, in this study we aimed to ascertain whether PRST worsens the objective olfactory outcome when compared with ILST.

**Methods:** A retrospective, propensity score-matched cohort study was performed at a tertiary referral center. A total of 232 adult patients undergoing EETS for pituitary adenoma were analyzed. The threshold test (STT) and the 12-item identification test (SIT-12) from “Sniffin’ Sticks” were administered for separate nostrils preoperatively and 6 months postoperatively.

**Results:** Of 232 patients, 109 had right-sided PRST and 123 received right-sided ILST. Propensity score matching—controlling for olfactory-related confounding factors, including gender, age, medical comorbidities, surgical technique, and preoperative olfaction—resulted in 74 matched pairs. When comparing the 6-month postoperative olfactory performance of the right nostril, the STT score was significantly lower in the PRST group than the ILST group ( $p = 0.036$ ,  $\eta^2$  for effect size estimate = 0.030), but the SIT-12

scores were similar in the 2 groups ( $p = 0.325$ ). Overall, the olfactory outcomes for the right nostril did not qualitatively differ between the PRST and ILST groups ( $p = 0.401$ ).

**Conclusion:** Despite its association with threshold impairment, PRST in EETS does not seem to carry an additional risk of postoperative olfactory dysfunction. © 2020 The Authors. *International Forum of Allergy & Rhinology* published by Wiley Periodicals, Inc. on behalf of American Academy of Otolaryngic Allergy and American Rhinologic Society.

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**Key Words:**

olfaction; superior turbinate; endoscopic endonasal skull-base surgery; transsphenoidal; pituitary surgery

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Endonasal transsphenoidal surgery (EETS) through 2 nostrils (binostril) for pituitary adenoma is common, but it sometimes contributes to postoperative olfactory dysfunction.<sup>1–3</sup> The frequency and duration of this nasal morbidity vary widely, as seen in the high heterogeneity of previous studies.<sup>4</sup> EETS-related olfactory dysfunction theoretically arises from intraoperative loss of the olfactory nerve fibers (ONFs), and through postoperative obstruction of airflow toward the olfactory cleft due to crust formation and structural changes in the nasal cavity.<sup>5</sup> Nasal crusting resolves as mucociliary clearance is re-established

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after surgery, whereas neural and structural damage has a long-term impact on olfactory outcome. Although generally underreported, impaired olfaction greatly affects daily activities relevant to a patient's quality of life.<sup>6</sup> As such, it is of utmost importance to preserve the ONFs and intranasal structures bilaterally during surgery. In some cases, however, this preservation is hindered by the creation of the surgical corridor.

As an integral part of binostril EETS for pituitary adenoma, the superior turbinates (STs) must be surgically managed to establish endonasal access to the sella. It is common practice for the ST to be either intentionally lateralized or partially resected. Partial resection of the ST (PRST) creates more horizontal room and is thus superior to intentional lateralization of the ST (ILST) in accessing the sella.<sup>7</sup> Given the high density of ONFs on the medial surface of the ST, the inferior one third of the ST is conventionally removed in an attempt to preserve olfaction while gaining access.<sup>1,7-9</sup> This management strategy may be supported by observational data suggesting that binostril EETS with bilateral PRST portends no ill effect on self-reported sense of smell in patients with pituitary adenoma at the 1-year follow-up.<sup>7</sup> Nevertheless, there remains controversy because subjective patient impressions do not always correlate with objective olfaction.<sup>10,11</sup> More importantly, EETS-related olfactory dysfunction is associated with a number of surgical techniques, including middle turbinate resection and nasoseptal flap elevation.<sup>5</sup> In addition, an array of non-EETS factors that impact olfaction (eg, age, gender, obesity, cigarette smoking, alcohol dependence, diabetes mellitus, neurodegenerative disorders, mood disorders, sinonasal inflammatory disease, or anatomic variants) may be present in a given patient undergoing binostril EETS for pituitary adenoma. To ascertain the true effect of PRST on olfaction, there should be a control group matched for these olfactory-related confounding factors.

Considering the lack of compelling evidence for the role of PRST in olfactory preservation, we sought to determine whether differences in management techniques of the ST (ie, PRST vs ILST) lead to different risk profiles for olfactory dysfunction in patients undergoing binostril EETS for pituitary adenoma using a propensity score-matched cohort study design.

## Patients and methods

### Study design and patient population

This study is a retrospective cohort analysis of adult patients  $\geq 18$  years of age who underwent binostril EETS from June 2014 through May 2019, as performed by 2 different senior surgeons (Q.Z. and Z.W.) at Xuanwu Hospital, Capital Medical University. Potential patients were identified from each surgeon's database in consecutive series. The inclusion criteria were follow-up of  $\geq 6$  months and biopsy-proven pituitary adenoma. The exclusion criteria were prior nasal or skull-base surgery, pre-existing

sinonasal inflammatory disease, preoperative anosmia, obstructive septal deviation, and neurodegenerative disorders (eg, Alzheimer or Parkinson diseases) (Fig. 1). Pituitary adenomas with cavernous sinus invasion were also excluded, because invasive tumors are surgically treated using an endoscopic endonasal transcavernous sinus approach at our institution.<sup>12,13</sup> Based on these criteria, 232 of 328 patients remained for analysis.

This study was approved by the local ethics committee (No. 2020004) and was performed in accordance with the principles of the Declaration of Helsinki. The requirement for informed patient consent was waived due to the retrospective nature of this study.

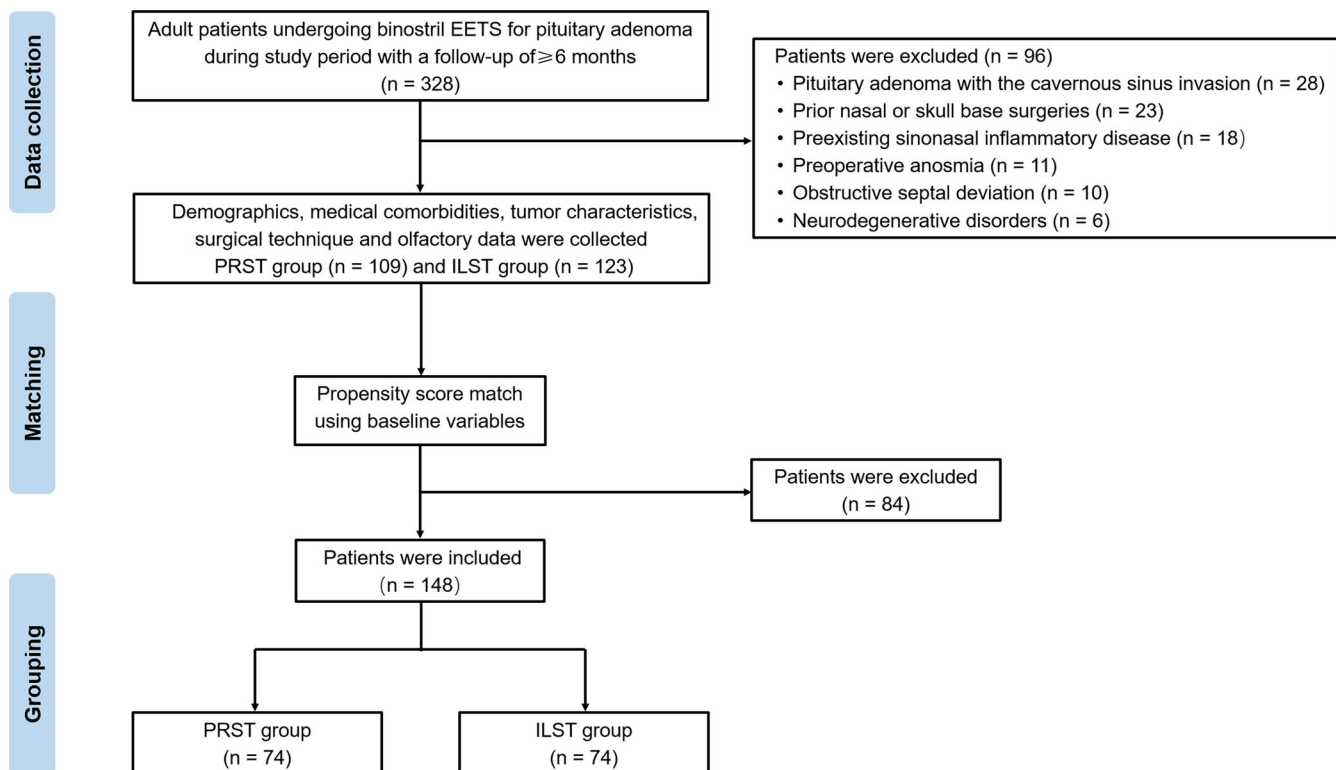
### Surgical techniques

The 2 surgeons performed EETS for pituitary adenoma via the same binostril technique (ie, a primary surgeon manipulated an endoscope and dissecting instruments or a microdrill through the right nostril and an assistant surgeon provided suction through the left nostril). To establish surgical corridors through the 2 nostrils, the inferior and middle turbinates were lateralized bilaterally. The left ST was uniformly lateralized, whereas the right ST was either partially resected (Q.Z.) or intentionally lateralized (Z.W.) (Fig. 2). Regarding PRST, the inferior one third of the ST was surgically removed with straight through-cutting forceps. After limited (usually 1 cm) posterior septectomy, wide sphenoidotomies were performed bilaterally to access the sellar floor. At our surgeons' discretion, a right-sided nasoseptal flap was harvested with cautery cutting at a low-power setting in the standard fashion described by Hadad et al,<sup>14</sup> depending on the perceived skull-base reconstruction needs.

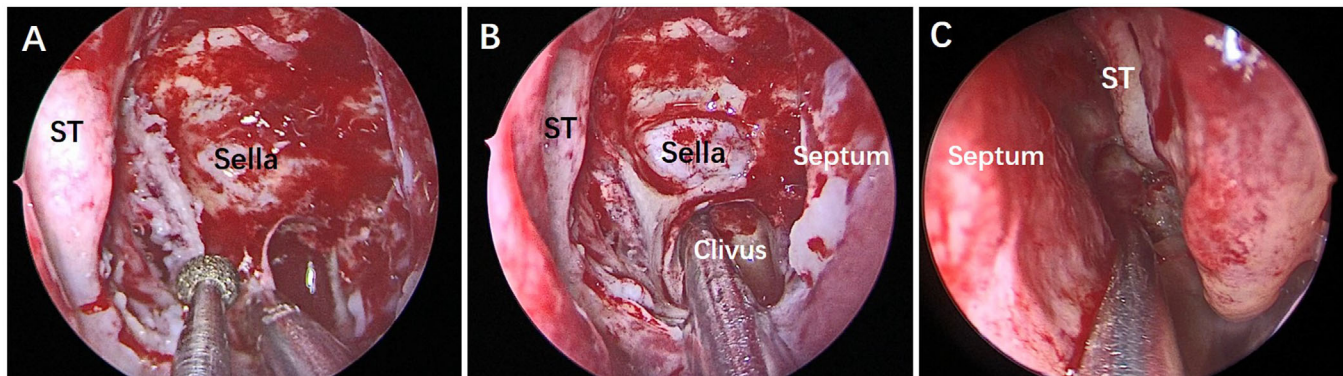
As part of our clinical routine, patients underwent an outpatient follow-up with a rhinologist (P.L.) for nasal debridement. Olfactory assessment was performed postoperatively if nasal crusting was absent, as determined by endoscopic inspection. At our institution, olfactory reassessment is uniformly conducted at 6 months postoperation.

### Olfactory assessment

Objective olfactory testing was performed for separate nostrils (monorhinal testing) using the threshold test and the 12-item identification test from "Sniffin' Sticks" (Burghart, Wedel, Germany). These 2 tests were selected to investigate olfactory function at both the threshold and suprathreshold levels in our clinical practice. Other suprathreshold olfactory tests, such as odor discrimination, were not included to shorten the testing time without sacrificing measurement accuracy. To minimize the negative impact of iver impact on the testing results, each test was randomly performed on 1 side and then repeated on the other side. During each odor presentation for a given nostril, subjects closed the other nostril with the thumb. Monorhinal testing started with the Sniffin' Sticks threshold test (STT; score range, 1-16). Subjects had to distinguish the pen with



**FIGURE 1.** Flow diagram outlining the patient inclusion grouping. EETS = endoscopic endonasal transsphenoidal surgery; PRST = partial resection of the superior turbinate; ILST = intentional lateralization of the superior turbinate.



**FIGURE 2.** Endoscopic view of the binostril technique (A) and the sellar region with preservation of the right ST (B) and the left ST (C). ST = superior turbinate.

increasing concentrations of 2-phenylethanol from the other 2 odorless pens. The Sniffin' Sticks 12-item identification test (SIT-12; score range, 1-12) was conducted with 12 pens with different odors and a list of 4 descriptors for reference, in which subjects had to choose an answer from the list. All 12 odors in the SIT-12 have been validated for their cross-cultural application to Asian subjects (correct identification rate  $>75\%$ ) after replacement of some of the original odor descriptors with equivalents that are common in Asia and that indicate the same or similar odors.<sup>15</sup> We consider a SIT-12 score  $\geq 10$  as normosmia, 7 to 9 as hyposmia and  $\leq 6$  as functional anosmia.<sup>16</sup> In this study, olfactory deterioration was defined by the worsening of the

preoperative olfactory categorization of the SIT-12 score at 6 months postoperation.

### Statistics

With regard to the sample-size calculation, Kim et al<sup>17,18</sup> have reported that ILST-induced intranasal volume changes do not correlate with objective olfactory changes after binostril EETS, suggesting that the overall impact of ILST on olfaction is minimal. In an earlier study of endoscopic sinus surgery (ESS), the incidence of objective olfactory decline after PRST was 12% in patients with chronic rhinosinusitis.<sup>19</sup> As such, we assumed that there could

potentially be, at a minimum, a 12% difference in the incidence of olfactory dysfunction to ensure that any difference present was detected. Using a 2-sided test, an  $\alpha$  of 0.05, and a power of 0.8, a 122-subject sample was calculated as necessary for this study, with 61 subjects per group.

Categorical variables are presented as number and percent. Chi-square test or Fisher's exact test (when cell count was  $<5$ ) was used to determine differences in categorical variables between the 2 groups. Continuous variables were initially tested for normality using the Shapiro-Wilk test. For data with a normal distribution, they are presented as mean  $\pm$  standard deviation, and parametric tests were subsequently used; otherwise, data are presented as median and interquartile range and then applied with appropriate nonparametric alternatives. Thus, we used either the independent samples *t* test or the Mann-Whitney *U* test to compare continuous variables between groups and the Wilcoxon signed-rank test to compare continuous variables within groups. To be concise in reporting,  $\eta^2$  was calculated for effect-size estimates of the nonparametric data in this study. The range for  $\eta^2$  is from 0 to 1, with a larger value indicating a greater difference.  $\phi$  was calculated for effect-size estimates of the categorical data in this study, with a larger value indicating a greater difference.

Propensity score matching was performed using logistic regression analysis to create a propensity score for the PRST and ILST groups with a logistic regression model. The following variables were entered into the propensity model: age, gender, body mass index (BMI), diabetes mellitus, depression, anxiety, smoking status, drinking status, maximum size of tumor, nasoseptal flap elevation, preoperative STT and SIT-12 scores for the right nostril. One-to-one matching without replacement was performed with a 0.011 caliper width, and the resulting score-matched pairs were used in subsequent analyses.

All statistical tests were 2-sided, and  $p < 0.05$  was considered statistically significant. All statistical analyses were completed using SPSS version 24.0 (IBM Corp, Armonk, NY).

## Results

During the study period, 232 patients were included in this study. Just over half of the overall study cohort was female (50.4%), and the mean age of patients at the time of operation was  $45.9 \pm 9.2$  years. One hundred nine (47.0%) patients underwent right-sided PRST and left-sided ILST, and 123 patients (53%) received bilateral ILST intraoperatively. Patients' demographics, medical comorbidities, tumor characteristics, and surgical techniques known to impact olfaction are indicated in Table 1. There was no significant difference between groups with regard to age, depression, anxiety, smoking, or drinking status. Compared with the ILST group, however, the PRST group had a significantly greater proportion of male patients and higher BMI and incidence of diabetes mellitus. In addition, the right-sided nasoseptal flap for skull-base reconstruction was

more frequently harvested in the PRST group than in the ILST group.

To decrease the potential effect of olfactory-related confounding factors, patients' preoperative backgrounds were adjusted by using 1:1 propensity score-matched analysis (Fig. 1). A total of 74 pairs were matched without significant differences in these confounding factors, as shown in Table 2. The preoperative and 6-month postoperative olfactory performances between the right and left nostrils were compared within groups (Table 3). In both the PRST and ILST groups, the STT and SIT-12 scores were comparable between the 2 nostrils at preoperation but were significantly lower for the right nostril than for the left nostril at 6 months postoperation.

The preoperative and 6-month postoperative olfactory performance for the right nostril was compared across the 2 groups (Table 4). The preoperative STT and SIT-12 scores were similar between the PRST and ILST groups after adjustment ( $p = 0.510$  and  $p = 0.932$ , respectively). However, the 6-month postoperative STT score was significantly lower in the PRST group than in the ILST group ( $p = 0.036$ ). By contrast, the 6-month postoperative SIT-12 scores were still similar in the PRST and ILST groups ( $p = 0.325$ ). When examining categorically, no significant difference was identified between the PRST and ILST groups in terms of the overall pre- or postoperative categorization of the SIT-12 score ( $p = 0.742$  and  $p = 0.628$ , respectively). Of patients with preoperative normosmia, 15 (39.5%) in the PRST group and 10 (25.0%) in the ILST group developed postoperative hyposmia. No normosmic patients in either group had postoperative anosmia. Of patients with preoperative hyposmia, 1 (2.8%) in the PRST group and 2 (5.9%) in the ILST group developed postoperative anosmia; meanwhile, 9 (25.0%) patients in the PRST group and 6 (17.6%) in the ILST group had postoperative normosmia, none of whom had received nasoseptal flap elevation intraoperatively. A total of 16 patients (21.6%) in the PRST group and 12 patients (16.2%) in the ILST group had olfactory deterioration after surgery, with no significant difference between the 2 groups ( $p = 0.401$ ).

## Discussion

Given the increasing concern for patients' quality of life, olfaction has been a primary consideration in binostril EETS for pituitary adenoma. However, the concept of olfactory preservation remains somewhat controversial with regard to intraoperative management of the ST. Previous studies in cadavers and living subjects have confirmed that the ONFs are concentratedly distributed on the medial aspect of the ST.<sup>20,21</sup> Thus, most skull-base surgeons argue that PRST serves an alternative in cases of compromised access to the sella with ILST, citing the purported risk to the ONFs and thereby olfactory function.<sup>1,8,9,22</sup> However, Fujimoto et al<sup>7</sup> asserted that bilateral PRST does not worsen subjective olfactory outcome in patients undergoing binostril EETS for



**TABLE 1.** Patient demographics, medical comorbidities, tumor characteristics, and surgical technique before propensity score matching\*

	Total (n = 232)	PRST (n = 109)	ILST (n = 123)	t/Z/ $\chi^2$	p	$\eta^2$	$\phi$
<b>Demographics</b>							
Gender, n (%)				4.397	<b>0.036<sup>a</sup></b>	–	0.138
Female	117 (50.4)	47 (43.1)	70 (56.9)				
Male	115 (49.6)	62 (56.9)	53 (43.1)				
Age (years), mean $\pm$ SD	45.9 $\pm$ 9.2	46.2 $\pm$ 8.6	45.7 $\pm$ 9.8	0.410	0.683 <sup>b</sup>	–	–
<b>Medical comorbidities</b>							
Body mass index (kg/m <sup>2</sup> ), median (IQR)	22.0 (20.6–24.0)	22.8 (20.8–24.6)	22.0 (20.6–23.4)	–2.218	<b>0.027<sup>c</sup></b>	0.021	–
Diabetes mellitus, n (%)	32 (13.8)	21 (19.3)	11 (8.9)	5.179	<b>0.023<sup>a</sup></b>	–	0.149
Depression (history/self-reported), n (%)	45 (19.4)	20 (20.3)	25 (18.3)	0.144	0.704 <sup>a</sup>	–	–
Anxiety (history/self-reported), n (%)	45 (19.4)	18 (16.5)	27 (22.0)	1.093	0.296 <sup>a</sup>	–	–
Smoking history, n (%)				3.750	0.153 <sup>a</sup>	–	–
None	145 (62.5)	61 (56.0)	84 (68.3)				
Past	60 (25.9)	33 (30.3)	27 (22.0)				
Current	27 (11.6)	15 (13.8)	12 (9.8)				
Alcohol history n (%)				3.343	0.188 <sup>a</sup>	–	–
None	143 (61.6)	62 (56.9)	81 (65.9)				
Past	67 (28.9)	33 (30.3)	34 (27.6)				
Current	22 (9.5)	14 (12.8)	8 (6.5)				
<b>Tumor data</b>							
Maximum size of tumor (mm), median (IQR)	16.9 (11.7–20.8)	18.0 (12.5–21.0)	15.9 (11.2–19.0)	–0.203	0.839 <sup>c</sup>	–	–
Functional classification, n (%)				2.517	0.113 <sup>a</sup>	–	–
Functional	134 (57.8)	57 (52.3)	77 (62.6)				
Nonfunctional	98 (42.2)	52 (47.7)	46 (37.4)				
<b>Surgical technique</b>							
Nasoseptal flap elevation, n (%)	54 (23.3)	33 (30.3)	21 (17.1)	5.227	<b>0.018<sup>a</sup></b>	–	0.150

\*Bold indicates significance.

<sup>a</sup>Chi-square test.<sup>b</sup>Independent samples t test.<sup>c</sup>Mann-Whitney U test.

ILST = intentional lateralization of the superior turbinate; IQR = interquartile range; PRST = partial resection of the superior turbinate; SD = standard deviation.

pituitary adenoma. Although these data suggest that PRST provides the benefit of improved access, which outweighs the risk of impaired olfaction, the lack of an objective olfactory measurement and a control group with ILST limited the ability of the Fujimoto and colleagues to draw strong conclusions. In the present study, through the use of alidated objective olfactory instruments and a matched control population we were unable to identify any clinically significant difference between PRST and ILST in objective olfactory outcomes at 6 months after binostril EETS for pituitary adenoma. We also demonstrated that PRST for surgical access to the sella carries no additional risk of postoperative olfactory dysfunction.

In terms of the overall patient cohort, the right ST was either partially resected or intentionally lateralized, whereas the left ST was uniformly lateralized. This management strategy for the STs is tailored to our binostril technique, which is characterized by surgical manipulation, primarily through the right nostril. It is well-established that the nostril with better sensitivity determines the joint sensitivity of both nostrils in individuals.<sup>23–25</sup> To prevent iatrogenic impairment of gross olfaction, meticulous attention is placed on minimizing olfactory damage to the left nostril intraoperatively. To accomplish this, suction was only surgically manipulated through the left nostril, considering its much lower space requirement and potential for surgical trauma

**TABLE 2.** Patients' demographics, medical comorbidities, tumor characteristics, and surgical technique after propensity score matching

	Total (n = 148)	PRST (n = 74)	ILST (n = 74)	t/Z/ $\chi^2$	p
<b>Demographics</b>					
Sex, n (%)				0.108	0.742 <sup>a</sup>
Women	76 (51.4)	37 (50.0)	39 (52.7)		
Men	72 (48.6)	37 (50.0)	35 (47.3)		
Age (years), mean $\pm$ SD	46.0 $\pm$ 9.3	45.8 $\pm$ 8.3	46.1 $\pm$ 10.2	-0.194	0.846 <sup>b</sup>
<b>Medical comorbidities</b>					
Body mass index (kg/m <sup>2</sup> ), median (IQR)	22.0 (20.6–23.9)	22.0 (20.6–24.0)	22.1 (21.0–23.9)	-0.261	0.794 <sup>c</sup>
Diabetes mellitus, n (%)	26 (17.6)	14 (18.9)	12 (16.2)	1.287	0.666 <sup>a</sup>
Depression (history/self-reported), n (%)	30 (20.3)	15 (20.3)	15 (20.3)	0.000	1.000 <sup>a</sup>
Anxiety (history/self-reported), n (%)	33 (22.3)	15 (20.3)	18 (24.3)	0.351	0.554 <sup>a</sup>
Smoking history, n (%)				0.453	0.797 <sup>a</sup>
None	89 (60.1)	44 (59.5)	45 (60.8)		
Past	41 (27.7)	22 (29.7)	19 (25.7)		
Current	18 (12.2)	8 (10.8)	10 (13.5)		
Alcohol history n (%)				0.157	0.925 <sup>a</sup>
None	92 (62.2)	45 (60.8)	47 (63.5)		
Past	45 (30.4)	23 (31.1)	22 (29.7)		
Current	11 (7.4)	6 (8.1)	5 (6.8)		
<b>Tumor data</b>					
Maximum size of tumor (mm), median (IQR)	14.4 (10.8–19.3)	14.4 (10.1–19.7)	14.4 (11.1–19.1)	-0.140	0.889 <sup>c</sup>
Functional classification, n (%)				-	0.957 <sup>d</sup>
PRL-secreting	77 (52.0)	38 (51.4)	39 (52.7)		
GH-secreting	5 (3.4)	2 (2.7)	3 (4.1)		
ACTH-secreting	2 (1.4)	1 (1.4)	1 (1.4)		
Nonfunctional	64 (43.2)	33 (44.6)	31 (41.9)		
<b>Surgical technique</b>					
Nasoseptal flap elevation, n (%)	29 (19.6)	13 (17.6)	16 (21.6)	0.386	0.534 <sup>a</sup>

<sup>a</sup> Chi-square test.<sup>b</sup> Independent samples t test.<sup>c</sup> Mann-Whitney U test.<sup>d</sup> Fisher's exact test.

ACTH = adrenocorticotropic hormone; GH = growth hormone; ILST = intentional lateralization of the superior turbinate; IQR = interquartile range; PRL = prolactin; PRST = partial resection of the superior turbinate; SD = standard deviation.

compared with other instruments (eg, dissection tools, or a drill). In addition to PRST, the nasoseptal flap elevation with the potential to damage the ONFs was intentionally avoided in the left nasal cavity for olfactory preservation. This surgical strategy was supported in a recent study by Soyka et al,<sup>26</sup> who reported that harvesting of the nasoseptal flap for skull-base reconstruction leads to impairment in objective measures of olfaction on the donor side. Considering that our binostril approach may very well produce

distinct olfactory outcomes between the right and left nostrils, monorhinal testing was specifically performed in this patient cohort. A combination of the STT and SIT-12 was employed to evaluate the olfactory threshold and identification for each nostril. We found that the STT and SIT-12 scores were similar between the nostrils preoperatively but were significantly lower for the right nostril than for the left nostril at 6 months after surgery in both the PRST and ILST groups. On the whole, this result is in keeping with

**TABLE 3.** Olfactory comparison between the right and left nostrils within groups\*

	PRST (n = 74)			ILST (n = 74)			p <sup>a</sup>	Z	η <sup>2</sup>
	Right nostril	Left nostril	Z	Right nostril	Left nostril	Z			
SIT score, median (IQR)									
Preoperation	10.0 (9.8–11.0)	10.0 (10.0–11.0)	-0.442	10.0 (10.0–11.0)	10.0 (10.0–11.0)	-0.583	0.560	-	-
Postoperation: 6 months	9.0 (8.0–10.3)	10.0 (9.0–11.0)	-3.695	10.0 (9.0–10.0)	10.0 (10.0–11.0)	-4.284	<0.001	0.244	0.244
SIT-12 score, median (IQR)									
Preoperation	10.0 (9.0–11.0)	9.5 (9.0–11.0)	-0.955	10.0 (9.0–10.0)	10.0 (9.0–10.0)	-0.887	0.375	-	-
Postoperation: 6 months	9.0 (8.0–10.0)	10.0 (9.5–10.0)	-2.648	9.0 (8.0–10.0)	10.0 (9.0–11.0)	-3.324	<b>0.001</b>	0.149	0.149

\*Bold indicates significance.  
<sup>a</sup>Wilcoxon signed-rank test.  
 ILST = intentional lateralization of the superior turbinate; IQR = interquartile range; PRST = partial resection of the superior turbinate; SIT-12 = Sniffin' Sticks 12-item identification test; STT = Sniffin' Sticks threshold test.

our expectation of a worse objective olfactory outcome for the right nostril than for the left nostril. It should be noted that typical olfactory testing for 2 nostrils together (birhinal testing) was not performed in this study in an effort to limit bias from the patient's memory or distractions. In light of our binostril technique, it stands to reason that birhinal testing for gross olfaction would not have specifically recognized or reflected the actual impact of right-sided PRST on postoperative olfaction.

When comparing the olfactory outcomes for the right nostril between the 2 groups, the STT score, but not the SIT-12 score, was significantly lower in the PRST group than in the ILST group. In theory, threshold detection is most often attributed to peripheral olfactory function, whereas identification of suprathreshold stimuli may better reflect central olfactory processing. Compared with the SIT-12, the STT would certainly be more sensitive to olfactory changes due to PRST. Prior studies of ESS have histologically confirmed that PRST leads to loss of ONFs.<sup>19,27</sup> Thus, one may consider the threshold impairment in the PRST group as sensorineural. Of additional interest, Say et al<sup>19</sup> did not detect the presence of ONFs in the inferior one third of the ST from patients with objective olfactory decline after ESS for chronic rhinosinusitis. This absence of ONFs in the ST specimens is likely to be associated with direct inflammatory damage in the setting of chronic rhinosinusitis.<sup>28</sup> On the other hand, this finding by Say et al<sup>19</sup> indicates that PRST-induced olfactory impairment is multifactorial, with significant contributions from factors other than the ONFs. An important point to consider is the changed airflow to the olfactory cleft after surgery, although this remains an area in need of further study. Computational fluid dynamics technology has been applied to EETS to assess the effect of structural changes (eg, middle turbinate resection) on airflow allocation in the nasal cavity.<sup>29</sup> Perioperative evaluation of nasal airflow in patients undergoing EETS with PRST will be critical for developing this mechanistic understanding.

Perhaps most interestingly, PRST patients appeared to have an olfactory identification ability similar to ILST patients in spite of their impaired threshold detection. Mechanistically, it is possible that the remaining ONFs in the right nasal cavity retain relatively normal identification as suprathreshold stimuli are delivered. Not surprisingly, the perioperative changes in olfactory status as defined by the SIT-12 scores were comparable between the 2 groups, supporting that PRST and ILST have similar effects on objective olfactory outcomes from a clinical perspective. Furthermore, our assessment of the outcome data revealed no significant difference in the incidence of olfactory deterioration between the PRST and ILST groups. In addition, some patients with preoperative hyposmia in both groups became normosmic (25.0% vs 17.6%) after surgery. Although its precise mechanisms are unknown, it is worth noting that none of the patients with olfactory improvement in our cohort had nasoseptal flap elevation intraoperatively, highlighting the importance of preserving the septal ONFs.

**TABLE 4.** Olfactory comparison for the right nostrils between groups\*

	PRST (n = 74)	ILST (n = 74)	Z/ $\chi^2$	p	$\eta^2$
STT score, median (IQR)					
Preoperation	10.0 (9.8–11.0)	10.0 (10.0–11.0)	–0.659	0.510 <sup>b</sup>	–
Postoperation: 6 months	9.0 (8.0–10.3)	10.0 (9.0–10.0)	–2.096	<b>0.036<sup>a</sup></b>	0.030
SIT-12 score, median (IQR)					
Preoperation	10.0 (9.0–11.0)	10.0 (9.0–10.0)	–0.086	0.932 <sup>b</sup>	–
Postoperation: 6 months	9.0 (8.0–10.0)	9.0 (8.0–10.0)	–0.985	0.325 <sup>a</sup>	–
Identification classification, n (%)					
Preoperation			0.108	0.742 <sup>b</sup>	–
Normosmia	38 (51.4)	40 (54.1)			
Hyposmia	36 (48.6)	34 (45.9)			
Postoperation: 6 months			–	0.628 <sup>c</sup>	–
Normosmia	32 (43.2)	36 (48.6)			
Hyposmia	41 (55.4)	36 (48.6)			
Anosmia	1 (1.4)	2 (2.7)			
Olfactory deterioration, n (%)	16 (21.6)	12 (16.2)	0.705	0.401 <sup>b</sup>	–

\*Bold indicates significance.

<sup>a</sup>Mann-Whitney *U* test.

<sup>b</sup>Chi-square test.

<sup>c</sup>Fisher's exact test.

ILST = intentional lateralization of the superior turbinate; IQR = interquartile range; PRST = partial resection of the superior turbinate; SIT-12 = Sniffin' Sticks 12-item identification test; STT = "Sniffin' Sticks" threshold test.

A similar finding was reported by Griffiths et al,<sup>30</sup> who observed a postoperative olfactory improvement rate of 47% in their EETS cohort with intraoperative preservation of the superior olfactory strip in the nasal septum. Most recently, Kuwata et al<sup>31</sup> retrospectively reviewed 26 patients undergoing binostril EETS for pituitary adenoma and concluded there was no difference in objective olfactory outcome between ST preservation and PRST at 6 months postoperation via birhinal testing. Of note, however, patient data regarding demographics, medical comorbidities, and preoperative olfactory status that bias testing results were not presented in their study. In addition, their PRST cohort included patients who had unilateral and bilateral PRST.<sup>31</sup> As discussed, birhinal testing cannot recognize unilateral olfactory impairment related to surgical procedures given its essential reflection of the nostril with better sensitivity. For patients who received unilateral PRST, birhinal testing could have introduced a potential source of bias.

By comparison, the strengths of our study primarily include its sample size calculation and comprehensive olfactory assessment for separate nostrils. However, there are also a few weaknesses in our investigation. First, it was a retrospective study performed at a single institution with a potential selection bias. Second, the propensity score-matched analysis only controlled for a set of observed confounding factors. Other unobserved confounding factors with the potential to impact results could not be incorpo-

rated. Third,  $\approx 50\%$  of patients in both groups had hyposmia preoperatively. These hyposmic patients may have had a pre-existing decline in the population or function of the ONFs prior to binostril EETS. Fourth, the minimal clinically important difference for the SIT-12 used in this study has yet to be determined, limiting our interpretation of the clinical relevance of objective olfaction data. Fifth, posterior septectomy theoretically leads to the shunting of odor-containing airflow across the septal defect, with a resultant disturbance to postoperative monorhinal testing. Although possible in theory, the presumed interference between the 2 nostrils seemed to not substantially affect our testing results, considering the observed significant difference in odor threshold between the 2 nostrils in either group. One explanation for this discrepancy may be the limited nature of posterior septectomy, although this needs to be further verified with computational fluid dynamics technology. Finally, the follow-up of patients in this study was only 6 months. However, Little et al<sup>32</sup> reported that the absence of nasal crusting after EETS takes a mean time of  $16.3 \pm 2.1$  weeks. In our study, the 6-month period gives ample time for debridement and allows the nasal mucosa to return to a baseline. Thus, it can be argued that olfactory outcome could have reached a steady state by 6 months postoperation.<sup>4</sup> Accordingly, a multi-institutional, prospective trial of normosmic patients with a longer olfactory follow-up is necessary to more accurately compare these 2 ST management techniques.



## Conclusion

This retrospective cohort study has demonstrated that PRST patients have an objective olfactory outcome simi-

lar to matched ILST patients with the exception of an impaired threshold. As such, PRST can be safely considered at the time of EETS when undertaken for improving access to the sella. 🌐

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