

## ORIGINAL RESEARCH

# Nasal resonance changes after endoscopic endonasal transsphenoidal skull base surgery: Analysis of voice quality

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## Abstract

**Objectives:** To study the effect of endoscopic endonasal transsphenoidal surgery on voice quality in patients with pituitary lesions.

**Methods:** An observational study comparing voice quality before and after surgery was conducted between September 2015 and September 2017 at Srinagarind Hospital, Khon Kaen University, Thailand. Pituitary tumor patients who underwent endoscopic endonasal transsphenoidal surgery were recruited. The nasal corridors were created with a type I (preserving both middle turbinates with a rescue flap) or type II (cutting one middle turbinate with a raised nasoseptal flap) for the binostril with four-hand technique. All patients were evaluated for nasal resonance, acoustic parameters, acoustic perception, and self-assessment of their satisfaction with postoperative voice changes with a visual analog scale (VAS). The patients were evaluated 1 day before surgery and at 1 and 3 months after surgery.

**Results:** Forty-four patients, including 19 males and 25 females with a mean age of  $50.0 \pm 15.6$  years, were enrolled. Mean scores for nasal resonance and all acoustic parameters were not significantly changed after surgery for either nasal corridor type ( $p > .05$ ). Regarding acoustic perception, word and sentence and GIBAS scores showed no significant difference before and after surgery ( $p > .09$ ) in either type of nasal corridor. There was no incidence of hypernasality voice after surgery. Patients' self-satisfaction ratings (i.e., VAS) with voice quality were high and showed no significant change 1 and 3 months postsurgery ( $p > .05$ ).

**Conclusions:** These endoscopic endonasal transsphenoidal approaches are minimally invasive skull base surgery techniques that have minimal effects on postsurgery voice quality.

**Trial Registration:** This trial was registered at ClinicalTrial.gov (NCT02828514).

**Level of Evidence:** 4.

## KEYWORDS

endoscopic, nasal resonance, pituitary, transsphenoidal surgery, voice

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## 1 | INTRODUCTION

Voice, an essential oral communication tool, is produced by air from the lungs passing through the vocal cord in the glottis and is then modified by various aerodigestive tract structures, including the supraglottis, oropharynx, nasopharynx, nose, paranasal sinus, oral cavity, and lips. The nasal cavity and paranasal sinus play the role of resonance organs for voice<sup>1</sup>; therefore, changes in any of the nasal cavity and paranasal sinus structures may affect voice quality.

Endoscopic transsphenoidal surgery has been introduced to manage midline skull base lesions because it is a minimally invasive technique, obviates brain retraction, and allows a short postoperative recovery duration. Prior to the skull base surgery stage, the nasal cavity and paranasal sinus must be created as the corridor to approach the lesion at the skull base. Therefore, the volume and shape of the nasal cavity and paranasal sinus are altered, which may affect nasal resonance and voice quality. Currently, there is a lack of data on voice quality after endoscopic skull base surgery. Kim et al.<sup>2</sup> reported on the endoscopic transsphenoidal approach with a rescue flap. Their results showed that the mean nasalalance, jitter, shimmer, and voice handicap index scores were significantly increased after surgery ( $p < .05$ ), whereas the GRBAS score was not significantly different pre- and postsurgery ( $p > .05$ ).

Recently, various modified minimally invasive techniques have been developed to create nasal corridors that aim to preserve the function of the sinonasal tract and reconstruct skull base defects. Therefore, the aim of the study was to investigate the effect of nasal corridors on voice quality in endoscopic transsphenoidal surgery.

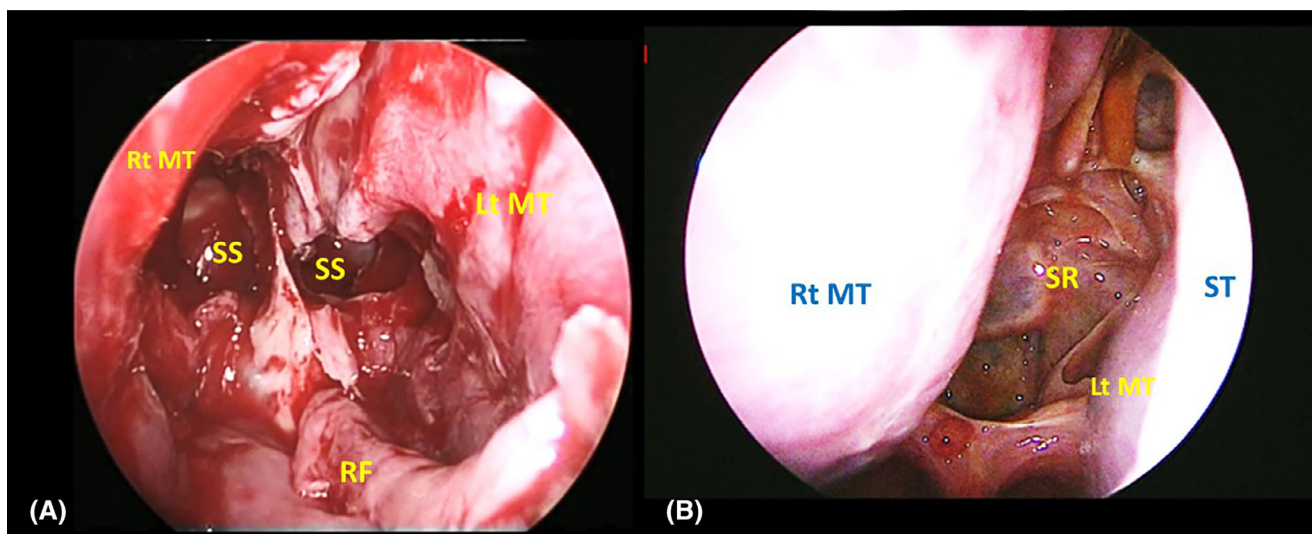
## 2 | MATERIAL AND METHODS

This prospective observational study was performed between September 2015 and September 2017 to compare patient voice

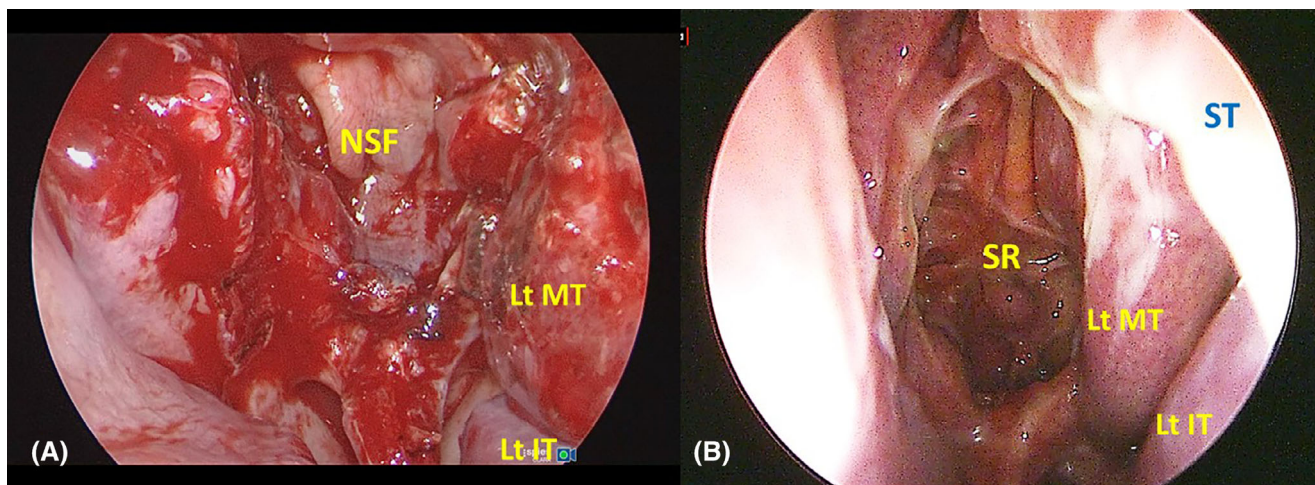
quality pre- and 1 and 3 months after two types of endoscopic transsphenoidal surgery. Patients older than 18 years who presented with pituitary tumors scheduled for endoscopic transsphenoidal surgery were eligible for inclusion. Exclusion criteria included patients with any of the following: a previous history of cleft palate and/or submucosal cleft and those who had undergone endoscopic transsphenoidal surgery with tonsillectomy or uvulopalatopharyngoplasty simultaneously. Four parameters (nasal resonance, acoustic parameters, acoustic perception, and patients' self-satisfaction) of voice quality were measured. Written informed consent was obtained from all participants. One day before surgery, all patients' nasal conditions were evaluated by one rhinologist via nasal endoscopy, and patients' imaging results were assessed by one neurosurgeon to indicate the tumor extension grades (tumor extending through the skull base and tumor seen in the nasal cavity; tumor extending through the skull base but still contained in sphenoid sinus; and tumor contained in intracranial fossa).

### 2.1 | Voice analysis

Nasal resonance was analyzed with a Nasometer II: model 6450 (KayPENTAX, Lincoln Park, NJ). The nasometer devices included a headset, sound filter, and computer. After calibration, the nasometer headset was placed on the patient's head with a baffle plate that fits around the upper lip and cheek to separate the nasal and oral cavities. The two microphones were positioned on the superior and inferior surfaces of the baffle plate to detect acoustic output from nasal and oral cavities separately during speech. The test comprised three speech stimuli that included a nasal sentence (Winter passage) designed to assess the full range of nasal consonants, an oral sentence (Laying Hen passage) designed to be devoid of nasal consonants, and a final sentence (My House passage) designed to assess a mixture of oral and nasal



**FIGURE 1** Nasal corridor type I was created with a rescue flap. Both middle turbinates were preserved. The posterosuperior portion of the bony septum was resected, whereas the septal mucosa was preserved and displaced inferiorly (A). The nasal endoscopic findings showed mucosal recovery following surgery at 3 months (B). Abbreviations: Lt, left; MT, middle turbinate; RF, rescue flap; Rt, right; SR, sellar region; SS, sphenoid sinus



**FIGURE 2** Nasal corridor type II was created with a nasoseptal flap. The middle turbinate was cut, and the nasoseptal flap was raised for reconstruction at the surgical defect. Posterior septectomy was performed to create the common cavity (A). The nasal endoscopic findings showed mucosal recovery and nasoseptal healing after surgery at 3 months (B). Abbreviations: IT, inferior turbinate; Lt, left; MT, middle turbinate; NSF, nasoseptal flap; NSF, nasoseptal flap; SR, sellar region

consonants. However, these three speech stimuli are based on English passages that Thai speakers may find difficult to speak correctly. Thus, Prathanee et al.<sup>3</sup> developed a standardized Thai speech version for nasometry testing in Thailand, and this version was used in this study.

Acoustic parameters were assessed with the Computerized Speech Lab (CSL) model 4500 (KayPENTAX, Lincoln Park, NJ).

Patients were positioned at a fixed distance of 10 cm from a microphone in a quiet room. The patient was asked to vocalize and sustain vowel sound for 3 s to assess the four acoustic parameters: jitter, noise to harmonic ratio (NHR), F0, and shimmer.

Acoustic perceptual tests were also used for subjective voice quality measurement. Patients were asked to read the words and

**TABLE 1** Demographic data

Characteristic	Number	Percentage
Gender		
Male	19	43.2
Female	25	56.8
Age (mean ± SD)	50.0 ± 15.6	
Underlying disease		
None	32	72.7
Diabetes mellitus	4	9.0
Hypertension	4	9.0
Other	7	15.9
Diagnosis		
Non-functioning pituitary tumor		
Microadenoma	1	2.3
Macroadenoma	29	65.9
Functioning pituitary tumor		
Acromegaly	7	15.9
Cushing disease	2	4.5
Prolactinoma	3	6.8
Other	4	9.1
Extension of tumor		
Only intracranial extension	31	70.5
Extend downward to sinus	13	29.5
Nasal corridor		
Type I	21	47.7
Type II	23	52.3

sentences in the set that was created and standardized by Phrataneet al.<sup>4</sup> for evaluation of normal or hypo/hypernasality. The GIRBAS scale (grading, instability, roughness, breathiness, asthenia, and strain) was also used as a perception test to rate each patient on counting numbers after taking a deep breath. This is a popular and reliable perceptual scale<sup>5,6</sup> with a scoring range of 0–3 (0 = normal; 1 = slight disturbance; 2 = moderate disturbance; 3 = severe disturbance).<sup>7</sup> Both perceptual analysis tests were administered by an experienced speech therapist who was unaware of nasometer and CSL results and patients' disease details.

All voice analysis tests were performed with each patient 1 day before surgery and 1 and 3 months after surgery. Finally, at 1 and 3 months postsurgery, each patient completed a self-assessment of their satisfaction with postoperative voice changes via a visual analog scale (VAS) with a rating range of 0 (unsatisfactory) to 10 (extreme satisfaction).

## 2.2 | Surgical procedure

After standard protocol induction of general anesthesia, endoscopic endonasal transsphenoidal surgery was performed to create the nasal corridor. Several modified nasal corridors are used for transsphenoidal surgery. For this study, nasal corridors were classified into two types. In type I, we preserved the middle turbinate and displaced the septal mucosa inferiorly as the rescue flap.<sup>8</sup> Afterwards, the posterosuperior bony septum was removed for combined bilateral nostrils with the four-hand dissection technique (Figure 1A). We used this type for small pituitary tumors with no anticipated cerebrospinal fluid leakage. Nasal corridor type II was created to repair anticipated cerebrospinal fluid leakage. We cut one side of the middle turbinate and raised the septal mucosa as a nasoseptal flap.<sup>9</sup> Subsequently, the posterior bony septum was resected to allow the four-hand dissection technique via bilateral nostrils (Figure 2A).

## 2.3 | Statistical analysis

The patients were classified into two groups. A sample size of 20 patients per group was deemed appropriate considering 95% confidence intervals and a power of 90%. The mean difference in nasalance score between pre- and postsurgery was estimated to be 6, which was approximately the mean difference in nasalance score in oronasal passage of Kim et al.<sup>2</sup> The SD of nasalance score differences between pre- and postsurgery was accepted of 8.25. Furthermore, 10% loss to follow-up was expected; therefore, 22 patients per group were enrolled.

Descriptive data are presented as percentages and means  $\pm$  SD. The paired *t* test was used to compare pre- and postoperative mean scores for acoustic parameters and nasometry analysis. McNemar's exact test was used to compare proportional nasality events pre- and postoperation. The nasal endoscopic findings at 1 and 3 months after surgery were compared with Fisher's exact test. A value of *p* < .05 was considered statistically significant. All data were analyzed using STATA (v 10.1: Stata Corp. 2015, TX).

TABLE 2 Objective measurement of voice quality

Acoustic parameters	1 month after surgery (n = 44)						3 months after surgery (n = 40)					
	Nasal corridor type I (n = 21)			Nasal corridor type II (n = 23)			Nasal corridor type I (n = 20)			Nasal corridor type II (n = 20)		
	Preoperative (Mean $\pm$ SD)	Postoperative (Mean $\pm$ SD)	<i>p</i> value	Preoperative (Mean $\pm$ SD)	Postoperative (Mean $\pm$ SD)	<i>p</i> value	Preoperative (Mean $\pm$ SD)	Postoperative (Mean $\pm$ SD)	<i>p</i> value	Preoperative (Mean $\pm$ SD)	Postoperative (Mean $\pm$ SD)	<i>p</i> value
Jitter	1.2 $\pm$ 0.8	1.3 $\pm$ 1.0	.72	1.2 $\pm$ 0.8	1.3 $\pm$ 1.0	.71	1.3 $\pm$ 0.8	1.1 $\pm$ 0.7	.41	1.2 $\pm$ 0.7	1.1 $\pm$ 0.7	.65
NHR	0.2 $\pm$ 0.04	0.2 $\pm$ 0.2	1.00	0.16 $\pm$ 0.04	0.2 $\pm$ 0.2	.32	0.2 $\pm$ 0.04	0.2 $\pm$ 0.04	1.00	0.2 $\pm$ 0.04	0.2 $\pm$ 0.04	1.00
F0	172.7 $\pm$ 49.1	176.5 $\pm$ 41.5	.79	172.4 $\pm$ 48.7	177.6 $\pm$ 41.6	.70	173.7 $\pm$ 49.2	180.8 $\pm$ 47.3	.64	170.4 $\pm$ 48.6	180.1 $\pm$ 46.2	.52
Shimmer	4.9 $\pm$ 2.4	5.0 $\pm$ 2.6	.90	4.9 $\pm$ 2.4	5.0 $\pm$ 2.6	.89	4.9 $\pm$ 2.4	4.5 $\pm$ 2.4	.53	4.8 $\pm$ 2.5	4.5 $\pm$ 2.4	.70
Nasometry												
My house	42.8 $\pm$ 7.6	44.8 $\pm$ 8.2	.42	41.6 $\pm$ 7.5	44.8 $\pm$ 7.9	.15	42.8 $\pm$ 7.6	44.9 $\pm$ 8.1	.40	43.0 $\pm$ 7.4	45.1 $\pm$ 8.0	.39
Winter	56.3 $\pm$ 9.1	61.1 $\pm$ 6.7	.06	54.5 $\pm$ 9.0	61.1 $\pm$ 6.7	.09	56.2 $\pm$ 9.2	59.0 $\pm$ 9.2	.72	56.1 $\pm$ 8.9	59.1 $\pm$ 9.2	.30
Laying hen	22.5 $\pm$ 11.8	23.0 $\pm$ 8.5	.88	22.2 $\pm$ 11.6	22.9 $\pm$ 8.4	.33	22.4 $\pm$ 11.9	23.1 $\pm$ 9.0	.84	22.5 $\pm$ 11.1	23.2 $\pm$ 8.9	.83

TABLE 3 Subjective measurement of voice quality

Acoustic perceptual analysis	1 month after surgery (n = 44)				3 months after surgery (n = 40)				p value	
	Nasal corridor type I (n = 21)		Nasal corridor type II (n = 23)		Nasal corridor type I (n = 20)		Nasal corridor type II (n = 20)			
	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative		
<b>*word</b>										
-1 = Hyponasality	2	0	1	0	2	1	0	0	>.99	>.99
0 = Normal	19	21	22	23	18	19	20	20		
1 = Hypernasality	0	0	0	0	0	0	0	0		
<b>*sentence</b>										
-1 = Hyponasality	2	0	1	0	2	1	0	0	>.99	>.99
0 = Normal	19	21	22	23	18	19	20	20		
1 = Hypernasality	0	0	0	0	0	0	0	0		
<b>*grading</b>										
0 = Normal	21	20	20	20	20	19	19	19	>.99	>.99
1 = Mild	0	1	3	3	0	1	1	1		
2 = Moderate	0	0	0	0	0	0	0	0		
3 = Severe	0	0	0	0	0	0	0	0		
<b>*instability</b>										
0 = Normal	21	20	20	20	20	19	19	19	>.99	>.99
1 = Mild	0	1	3	3	0	1	1	1		
2 = Moderate	0	0	0	0	0	0	0	0		
3 = Severe	0	0	0	0	0	0	0	0		
<b>*rough</b>										
0 = Normal	21	20	20	20	20	19	19	19	>.99	>.99
1 = Mild	0	1	3	3	0	1	1	1		
2 = Moderate	0	0	0	0	0	0	0	0		
3 = Severe	0	0	0	0	0	0	0	0		
<b>*breathiness</b>										
0 = Normal	21	20	21	21	20	20	19	19	>.99	>.99
1 = Mild	0	1	2	2	0	0	1	1		
2 = Moderate	0	0	0	0	0	0	0	0		
3 = Severe	0	0	0	0	0	0	0	0		

(Continues)





TABLE 4 Patients' satisfaction

Patients' satisfaction of voice changing	VAS (mean $\pm$ SD)		*p value
	1 month after surgery	3 months after surgery	
Nasal corridor type I	8.52 $\pm$ 1.19	8.81 $\pm$ 1.2	.44
Nasal corridor type II	8.45 $\pm$ 1.24	8.73 $\pm$ 1.3	.48

defined as follows. Fundamental frequency (F0) is the number of times a sound wave produced by the vocal cord repeats during a given time. Therefore, F0 refers to the number of cycles of opening or closure of the glottis.<sup>11</sup> Jitter is the frequency variation from cycle to cycle, and shimmer is the amplitude variation of the sound wave.<sup>12</sup> The last acoustic parameter, NHR, is the ratio between periodic and nonperiodic components comprising a segment of voice speech.<sup>13</sup> Therefore, all acoustic parameters can be mainly affected by glottis pathology. Given that our patients underwent sinonasal cavity and skull base surgery that did not disturb the glottis, our acoustic parameters showed no significant changes after surgery. Similarly, Majidi et al.<sup>14</sup> showed no significant acoustic voice parameter changes after endoscopic sinus surgery. They reported nonsignificantly decreased mean scores for shimmer and F0 ( $p > .05$ ) but no changes for NHR. For jitter, the researchers reported a decreased mean score for some vowels and increases for some other vowels; however, neither change was statistically significant ( $p > .05$ ). Therefore, endoscopic sinus surgery seemed to have only minor effects on acoustic parameters.

We found nonsignificantly increased nasalance mean scores on all three test reading passages postsurgery ( $p > .05$ ). This result is in contrast to Kim et al.,<sup>2</sup> who found significantly increased nasalance scores after surgery ( $p < .05$ ). This difference may be due to the use of different techniques for the creation of a nasal corridor. For our technique, we cut one middle turbinate and raised a nasoseptal flap for nasal corridor type I. We tried to preserve both middle turbinates and septal mucosa as a rescue flap for nasal corridor type II. In both techniques, we cut the posterior part of the nasal septum and removed the posterior ethmoid cell as necessary for available dissection of the pituitary tumor. A comparison with the study by Kim et al.<sup>2</sup> is limited given that their modified technique for creating the nasal corridor was not described. We found no change in subjective acoustic perception. Word and sentences as well as GIBAS score did not change in most of our patients after surgery ( $p > .09$ ), which is similar to Kim et al.'s<sup>2</sup> GRBAS findings.

Our patients self-rated their satisfaction with postsurgery voice changes. The ratings were high with no statistically significant differences in self-satisfaction ratings 1 and 3 months postsurgery from both types of nasal corridors. Although our patients showed satisfaction with postsurgery voice quality, Kim et al.'s<sup>2</sup> patients had a significantly higher voice handicap index (VHI) 6 months after surgery, indicating increased perception of voice quality disability. This difference in results may be due to the longer follow-up period in the Kim et al. study.<sup>2</sup>

A strength of our study is that all surgeries were performed by one rhinologist and one neurosurgeon who used the same surgical techniques. The acoustic perception test was also performed by one

experienced speech therapist masked to other test results and surgery details. This approach reduced possible confounding from inter-operator differences. However, limitations, including small sample size and a short follow-up time, should be addressed in further studies.

## 5 | CONCLUSION

This study showed that both of these endoscopic endonasal transsphenoidal approaches to pituitary surgery slightly increased nasalance scores postsurgery. Endoscopic endonasal transsphenoidal surgery had minimal effects on acoustic perception and patients' voice quality at 1 or 3 months postsurgery, further supporting this minimally invasive technique's role in preserving patients' voice quality.

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## CONFLICT OF INTEREST

All authors have no personal financial or institutional interest in any of the materials and devices described in this article. The authors have no conflicts of interest to declare.

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