Nasality outcome in unilateral chronic rhinosinusitis following functional endoscopic sinus surgery

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Abstract

Objectives: In this study we aimed to investigate the prevalence of abnormal nasality in patients with unilateral rhinosinusitis and their nasality outcomes following functional endoscopic sinus surgery (FESS). Design, Setting, Participants: A total of 42 patients with unilateral chronic rhinosinusitis who underwent unilateral FESS between April 2016 and November 2017 were enrolled. The patients were divided into two groups, wide opening surgery and limited surgery, according to the severity of the disease. Questionnaires on sinonasal symptoms and nasality were recorded. Main outcome measures: The change in the nasalance score and symptoms were measured preoperatively, 6 months, and 12 months after the operation. Results: Among 42 patients, the subjective reports showed that one-third of unilateral chronic rhinosinusitis (CRS) patients had abnormal nasality preoperatively and significant improvement following FESS. The Lund-Mackay score was significantly negatively correlated with preoperative nasalance of [i] and positively correlated with change of nasalance of [i]. The increase in the value of [i] is statistically significant (p=0.01) following FESS. In the wide opening surgery group, the change in nasalance was significant, but not in the limited surgery group. Conclusion: Although only one side of the nasal airway was involved, one-third of the patients reported abnormal nasality. In patients with more disease severity who underwent wide opening surgery, the nasalance significantly increased 1 year after FESS. The increase in the nasalance score may represent a return to a normal status since the self-reported nasality assessment was significantly improved postoperatively.

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Main outcome measures: The change in the nasalance score and symptoms were measured preoperatively, 6 months, and 12 months after the operation.

Results: Among 42 patients, the subjective reports showed that one-third of unilateral chronic rhinosinusitis (CRS) patients had abnormal nasality preoperatively and significant improvement following FESS. The Lund-Mackay score was significantly negatively correlated with preoperative nasalance of [i] and positively correlated with change of nasalance of [i]. The increase in the value of [i] is statistically significant (p=0.01) following FESS. In the wide opening surgery group, the change in nasalance was significant, but not in the limited surgery group.

Conclusion: Although only one side of the nasal airway was involved, one-third of the patients reported abnormal nasality. In patients with more disease severity who underwent wide opening surgery, the nasalance significantly increased 1 year after FESS. The increase in the nasalance score may represent a return to a normal status since the self-reported nasality assessment was significantly improved postoperatively.

Key Words*:* chronic rhinosinusitis; nasality; sinus surgery; nasalance, voice

Key points:

- One-third of the patients with unilateral rhinosinusitis reported abnormal nasality preoperatively.
- The Lund-Mackay score was significantly positively correlated with change of nasalance of [i].
- In the higher severity group who received more wide opening surgery, the change in nasalance was significantly increase 1 year after FESS.
- The post-operative nasalance score may closed to a normal status since the self-reported nasality assessment was significantly improved postoperatively.

Introduction

Speech and voice are essential parts of communication in daily life. Nasal resonance plays an important role in speech quality. The subjective perception of nasal sounds is defined as nasality, and it may change with the patency of the nasal cavity. A structural alteration of the nasal cavity, related to sinonasal disease or surgery, may cause voice quality changes.[1] According to the different proportion of vocal amplification in the sinonasal cavities, abnormal nasality can classify into hypernasality, hyponasality, and mixed resonance.[2] Hyponasal voice may be related to nasal structural obstructive pathologies, such as rhinosinusitis, nasal polyposis, or nasal septal deviation.[3] On the other hand, the voice of patients with cleft palate or velopharyngeal incompetence usually presents as hypernasality. Traditionally, objective examination of voice quality was subjectively evaluated by speech pathologists using auditory perceptual methods. A nasometer is a portable, noninvasive, and computer-based machine that provides an objective evaluation of nasality called nasalance. The nasometer is widely used to evaluate changes in nasality.[4-6]

Abnormal nasality is a common complaint; however, not much attention has been paid to nasality in patients with sinonasal disease before. Chronic rhinosinusitis (CRS) is an inflammatory condition of the sinonasal mucosa, which includes the lining of nasal passage and paranasal sinus. The swollen mucosa and congested nasal passage will decrease the resonance of the nasal cavity and cause abnormal nasality.[7] Surgical interventions may change the sinonasal structure and airway passage. Volumetric changes in the nasal cavity will cause alterations in voice quality and resonance[8]. Jiang et al. reported that an increase in nasalance after functional endoscopic sinus surgery (FESS) correlated with an increase in midnasal and postnasal volumes.[9]

Previous studies have presented nasalance change in CRS patients with bilateral high disease burden after FESS.[1,10,9,11]However, nasality change in patients with only one side nasal airway involvement has not been well investigated. Hence, the impact of unilateral sinus surgery on nasality is not well known. Herein, we aimed to investigate the prevalence of abnormal nasality in patients with unilateral CRS. The subjective and objective nasality outcomes after unilateral sinus surgery were measured and analyzed.

Patients and methods

Subjects

Patients diagnosed with unilateral CRS who underwent FESS at Kaohsiung Chang Gung Memorial Hospital between April 2016 and November 2017 were prospectively included. The diagnosis criteria followed the 2015 clinical practice guidelines from the American Academy of Otolaryngology-Head and Neck Surgery Foundation.[12] All patients received adequate medical treatment, including intranasal corticosteroids for at least 2 months and oral steroids or antibiotics (depending on their condition) for 2 to 4 weeks. Patients with a history of palatal disease/surgery, motor speech disorders, immunodeficiency, previous radiotherapy of the head and neck region, previous sinonasal surgery, and tonsillectomy were excluded. Patients with adjunctive inferior turbinate surgery were also excluded. All patients signed informed consent forms before

the operation. Paranasal sinus computed tomography (CT) was performed prior to the operation. The extent of surgery was decided according to the severity of the disease. Limited surgery was defined as maxillary antrostomy with partial anterior ethmoidectomy or sphenoidectomy only. The wide opening surgery was defined as at least 3 sinuses were opened. All patients were regularly followed up at 3-month intervals. After the operation, all patients underwent nasal saline irrigation and received intranasal corticosteroids for at least 1 month according to their condition. Patients with nasal polyps received oral steroids for at least 2 weeks and oral antibiotics for 2 to 4 weeks in cases of acute exacerbation. All patients underwent sinonasal endoscopy and completed the 22-Item Sino-nasal Outcome Test (SNOT-22) before and during the follow-up period.

Clinical assessment

Nasality was subjectively assessed by a Visual Analogue Scale (VAS) filled by the patients, and by questionnaires filled by their partners. The severity of abnormal nasality was reported using a 10-cm VAS. Higher scores reflect worse symptoms of abnormal nasality. A VAS score [?] 3 was considered to indicate significant abnormal nasality. Abnormal nasality was also assessed by the patients' partners using questionnaires. The questionnaire was "Do you think the patient had abnormal nasality in the last 3 months?" The answers included no abnormal nasality, mild abnormal nasality, and noticeable abnormal nasality.

The nasality was objectively assessed using nasalance scores with a nasometer. The Nasometer II system (model 6450, Kay Elemetrics Corp., Lincoln Park, NJ) was used in this study. The ratio of nasal acoustic energy to total (oral and nasal) acoustic energy was displayed with nasalance score as a percentage.[13] The speech material included three vowels [a], [i], [u], and a nasal consonant [m]. Two repetitions, [MaMa] and [MiMi], were also used for evaluation. Two sentences in Chinese were developed for the nasometric evaluation in this study. The hypernasality sentence contained 5 nasal syllables, with 0% nasal consonants and 100% nasal vowels. The hyponasality sentence contained 5 nonnasal syllables, with 100% high-pressure consonants. The tests were evaluated twice, and the average nasalance scores were recorded. These scores, including subjective nasality evaluation and objective nasalance scores, were recorded before surgery. These scores were also evaluated at 6 and 12 months after surgery.

Statistical analyses

Changes in VAS, SNOT-22, and nasalance scores before and after FESS were tested using the Wilcoxon signed rank test. The Mann-Whitney U test was used to compare differences between the limited and wide opening surgery groups. The chi-square test or Fisher's exact test were used for all other between-group comparisons. Percentage changes in subjective abnormal nasality assessment before and after FESS were statistically analyzed using the McNemar-Bowker test. The relationships between the groups were assessed by the spearman correlation analysis. A p-value < 0.05 was considered to indicate statistical significance. All analyses were performed using SPSS version 22 software (IBM Corp., Armonk, NY, USA).

Results

Characteristics of the sample

A total of 56 consecutive patients with unilateral CRS who underwent FESS on the affected side were enrolled. Patients with recurrent disease (n=2) or loss of follow-up (n=12) were excluded. Finally, the 42 patients who completed the 1-year follow-up were enrolled. There were 21 men (50%) and 21 women (50%) with a mean age of 49.9±15.8 years. The preoperative Lund–Mackay CT score and Lund-Kennedy endoscopic score were 4.3±2.3 and 2.6±1.5, respectively. Of these 42 patients, 33 (78.6 %) were diagnosed with CRS without nasal polyps (CRSsNP). According to the disease severity, 21 (50%) received limited surgery and 21 (50 %) received wide opening surgery. The patients who underwent wide opening surgery had significantly higher disease severity as evaluated by CT and sinonasal endoscopy. The demographic and clinicopathological data are shown in Table 1.

Correlation between nasalance, subjective questionnaires, and disease severity

The Lund-Mackay scores had a significant negative correlation with preoperative nasalance of [i] and [m] ([i] R= -0.342, P = 0.026; [m] R= -0.356, P = 021) and a significant positive correlation with the change of nasalance of [i] and [m] ([i] R= 0.486, P = 0.001; [m] R= 0.418, P = 0.006). The VAS scores of nasality were not correlated with nasalance. The SNOT-22 nasal domain had a significant negative correlation with preoperative nasalance of [i] (R= -0.307, P = 0.048) and a significant positive correlation with the change in nasalance of [m] (R= 0.365, P = 0.017). Regarding nasal obstruction of SNOT-22, there was a significant negative correlation with the preoperative nasalance of [a], [i], and [u] ([a] R= -0.460, P = 0.002; [i] R= -0.408, P = 0.007; [u] R= -0.318, P = 0.040) and a significant positive correlation with the change of nasalance of [m] (R= 0.312, P = 0.044; Table 2).

Changes in nasalance following FESS

The median preoperative nasalance scores of [a], [i], and [u] were 31.0 (IQR 16.0-44.0), 28.0 (IQR 18.8-54), and 9.5 (IQR 6.0-22.3), respectively. The 6-month postoperative values of [a], [i], and [u] were 30.0 (IQR 16.0-40), 36.0 (IQR 28.5-52.0), and 12.0 (IQR 7.5-20.0). The nasalance scores increased one year postoperatively to 34.5 (18.8-48.3) for [a], 38.0 (29.0-60.3) for [i] and 13.0 (8.3-23.7) for [u]. However, only the change in the nasalance score of [i] was statistically significant (p=0.012; Figure 1) 1 year after FESS. The patients were divided into two groups by surgical extension of FESS. Nasalance scores showed no difference in patients who received limited surgery 1 year after FESS (Table 3). However, the nasalance scores of [i], [m], and [MiMi] significantly increased in patients who received wide opening surgery 1 year after FESS. (Table 4).

Change in subjective nasality outcome following FESS

There was a significant decrease in self-rating VAS scores for abnormal nasality after FESS in both groups. The total pre-operative VAS of abnormal nasality was 2.6 $\pm$ 2.8, and it significantly decreased to 0.8 $\pm$ 1.3 ($p < 0.001$) and 0.4 $\pm$ 0.7 ($p < 0.001$) at 6 and 12 months post-operatively, respectively. The percentage of patients that had significant abnormal nasality (VAS[?]3) decreased to 9.5% ($p = 0.021$) and 0% ($p < 0.001$) at 6 and 12 months post-operatively, respectively. The percentage of noticeable abnormal nasality evaluated by patients' partners significantly decreased (47.6% to 7.1%, $p < 0.001$), and no abnormal nasality significantly increased (33.3% to 85.8%, $p < 0.001$) 1 year after FESS. The SNOT-22 and Lund-Kennedy endoscopic scores significantly improved after surgery as well (Table 5).

Discussion

CRS may cause abnormal nasality and adverse effects on quality of life.[14] However, only a few studies have investigated nasality changes in CRS patients. Hong et al. demonstrated that the nasalance of patients with bilateral nasal polyposis was significantly lower than that of healthy controls before operation and increased to the level of the healthy controls 3 weeks after FESS.[7]Two studies had investigated the impact of FESS on nasalance change in patients with high disease burden CRS with nasal polyps, and found that the nasalance returned to nearly preoperative level 3 to 6 months following FESS.[11,15] To the best of our knowledge, this is the first study to discuss nasality in patients with unilateral CRS. These patients had only one side nasal airway involvement and had relatively less disease burden with favorable surgical outcomes.[16] In the subjective evaluation, we found that 33.3% of unilateral CRS patients had abnormal nasality by self-scoring VAS and that 47.6% had noticeable abnormal nasality as evaluated by their partners. In addition, a negative correlation was found between the Lund-Mackay score and nasalance in patients with unilateral CRS.

Hyponasality is present in patients with sinonasal disease with obstruction of nasal airways.[7] Sinonasal surgery alters the structure and patency of the nasal cavity, and the acoustic characteristics of the vocal tract change with it. Behrman et al. reported that decreased nasal mucosal surface area and widened nasal passages after sinonasal surgery will result in a decrease in acoustic damping and an increase in acoustic coupling with the paranasal sinuses. Therefore, sinonasal surgery may result in increased nasalance.[17] Renata Soneghet et al. reported that the mean nasalance values of [i] increased significantly from 27.2% preoperatively to 39.8% 1 month after FESS.[1] Kim et al. reported an initial increase in nasalance following FESS which eventually returned to near pre-operative values 6 months later.[18] However, a trend toward increase of nasalance in [a], [i], [u] was still found after surgery, although the increase did not reach clinical significance

(all *P-values*between 0.05 and 0.1). Otherwise, the postoperative sinonasal condition was not mentioned, and recurrent nasal polyps or edematous mucosa may also cause a decrease in nasalance postoperatively.

In our study, all patients underwent endoscopy, and the sinonasal mucosal status was nearly normal postoperatively. We found a significant increase in nasalance 1 year after FESS, particularly in patients who received wide opening FESS. The nasalance of [i], [m], and [MiMi] were significantly increased. The Lund-Mackay CT score was negatively correlated with preoperative nasalance ([i] and [m]) and positively correlated with postoperative nasalance change ([i] and [m]) with clinical significance. A higher nasalance change in patients who underwent wide opening FESS may be due to a relatively lower nasalance level preoperatively and a wider open sinonasal cavity postoperatively. The significantly increased nasalance following FESS was accompanied by a significant improvement in the subjective nasality assessments (in both patient-reported VAS scores and questionnaires reported by patients' partners). These results imply that an increase in nasalance corresponded to a nasalance return to a relative normal value.

The nasalance did not correlate with the subjective VAS of abnormal nasality, but a significant negative correlation was found between preoperative nasalance ([a], [i], [u]) and the severity of nasal obstruction. A previous study revealed a correlation between the increase in the volume of the nasal cavity and the increase in the nasalance score in patients who underwent FESS due to CRS.[9,19] These results imply that the patency of the nasal airway has a significant impact on nasalance change. The healing and regeneration of the sinonasal mucosa happens usually within 6 months, and mucosal vibration may normalize subsequently.[20] Platt et al. found that the bony structure continued to change in average 14.3 months after wide opening ethmoidectomy.[21] This alteration in the bony framework of the paranasal sinuses after operation may be another reason for the nasalance change after operation. In our study, a more significant change in nasalance was found in patients who underwent wide opening surgeries.

There are still some limitations in this study, and the first is the limited sample size included in research. Some patients can't complete the entire post-op follow up and they were excluded from the study. Another limitation of this study is the lack of normal controls for comparison. However, the nasalance value is variable between individuals and may be influenced by age, race, sex, geographic regions, and habitual language.[4,22,23] Therefore, a large sample size is needed to establish normative values. In our study, we compared pre- and post-operative nasalance to eliminate the possible bias of individual differences. Furthermore, our post-operative nasalance was close to the value of Mandarin speakers reported in the normal papulation.[22]

Conclusion

A negative correlation was found between the nasalance score and the severity of rhinosinusitis in our cohort. Although unilateral CRS had a relatively lower disease burden, abnormal nasality was still reported in one-third of the patients preoperatively. The nasalance score significantly increased 1 year after FESS, particularly in patients with higher disease severity who received wide opening surgery. The increase in the nasalance score may represent a return to a normal status since the self-reported nasality assessment was significantly improved postoperatively.

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Table 1. Clinical characteristics of the study cohort

Clinical characteristics	All patients	Limited surgery (n = 21)	Wide opening surgery (n = 21)	p-value
Female, n (%)	21 (50%)	11 (52.4%)	10 (47.6%)	0.76
Mean age (years)	49.9 ± 15.8	51.6 ± 14.8	48.2 ± 16.9	0.44

Asthma*	3 (7.1%)	0 (0 %)	3 (14.3%)	0.07
Allergic rhinitis	10 (23.8%)	4 (19.0%)	6 (28.6%)	0.47
Smoking	11 (26.2%)	4 (19.0%)	7 (33.3%)	0.57
Disease severity				
Lund-Mackay score	4.3 ± 2.3	2.6 ± 1.5	6.1 ± 1.8	< 0.001
Lund-Kennedy score	2.6 ± 1.5	1.8 ± 1.1	3.5 ± 1.3	< 0.001
CRS types, n (%)				
CRSsNP	33 (78.6%)	16 (76.2%)	17 (81.0%)	0.71
CRSwNP	9(21.4%)	5 (23.8%)	4 (19.0%)	
Side of disease, n (%)				
Right	19 (45.2%)	7 (33.3%)	12 (57.1%)	0.12
Left	23 (54.8%)	14 (66.7.0%)	9 (42.9%)	
Data are presented as mean or as number (%). Mann-Whitney U test (2-tailed) was used for continuous variables. Chi-square test and or Fisher's exact test were used for categorical variables. (* Fisher's exact test.) p < 0.05 indicates significant difference between 2 groups. CRSsNP = Chronic rhinosinusitis without nasal polyps; CRSwNP = Chronic rhinosinusitis with nasal polyps ; CT = Computer tomography.	Data are presented as mean or as number (%). Mann-Whitney U test (2-tailed) was used for continuous variables. Chi-square test and or Fisher's exact test were used for categorical variables. (* Fisher's exact test.) p < 0.05 indicates significant difference between 2 groups. CRSsNP = Chronic rhinosinusitis without nasal polyps; CRSwNP = Chronic rhinosinusitis with nasal polyps ; CT = Computer tomography.	Data are presented as mean or as number (%). Mann-Whitney U test (2-tailed) was used for continuous variables. Chi-square test and or Fisher's exact test were used for categorical variables. (* Fisher's exact test.) p < 0.05 indicates significant difference between 2 groups. CRSsNP = Chronic rhinosinusitis without nasal polyps; CRSwNP = Chronic rhinosinusitis with nasal polyps ; CT = Computer tomography.	Data are presented as mean or as number (%). Mann-Whitney U test (2-tailed) was used for continuous variables. Chi-square test and or Fisher's exact test were used for categorical variables. (* Fisher's exact test.) p < 0.05 indicates significant difference between 2 groups. CRSsNP = Chronic rhinosinusitis without nasal polyps; CRSwNP = Chronic rhinosinusitis with nasal polyps ; CT = Computer tomography.	Data are presented as mean or as number (%). Mann-Whitney U test (2-tailed) was used for continuous variables. Chi-square test and or Fisher's exact test were used for categorical variables. (* Fisher's exact test.) p < 0.05 indicates significant difference between 2 groups. CRSsNP = Chronic rhinosinusitis without nasal polyps; CRSwNP = Chronic rhinosinusitis with nasal polyps ; CT = Computer tomography.

Table 2. Correlation coefficients between nasalance score, objective evaluation and VAS

	Pre-FESS nasalance score [a]	Pre-FESS nasalance score [i]	Pre-FESS nasalance score [u]	Pre-FESS nasalance score [m]	Change of nasalance score post-FESS 12M [a]	Change of nasalance score post-FESS 12M [i]	Change of nasalance score post-FESS 12M [u]	Change of nasalan score post-FESS 12M [m]
Lund-Mackay score	0.001	-0.342*	-0.033	-0.356*	-0.131	0.486*	0.199	0.418*
Lund-Kennedy score	0.164	-0.118	0.096	-0.182	-0.046	0.250	0.179	0.246
VAS of nasality	-0.055	0.049	0.163	-0.208	-0.099	-0.164	-0.052	0.176
SNOT-22 nasal domain	-0.281	-0.307*	-0.143	-0.249	0.160	0.218	0.139	0.365*
SNOT-22 nasal obstruction	-0.460*	-0.408*	-0.318*	-0.207	0.173	0.251	0.085	0.312*

Spearman correlation analysis were performed to evaluate the association between groups. * $p<$ 0.05; SNOT-22 = the 22-Item Sinonasal Outcome Test; VAS = Visual Analogue Scale; FESS = functional endoscopic sinus surgery.	Spearman correlation analysis were performed to evaluate the association between groups. * $p<$ 0.05; SNOT-22 = the 22-Item Sinonasal Outcome Test; VAS = Visual Analogue Scale; FESS = functional endoscopic sinus surgery.	Spearman correlation analysis were performed to evaluate the association between groups. * $p<$ 0.05; SNOT-22 = the 22-Item Sinonasal Outcome Test; VAS = Visual Analogue Scale; FESS = functional endoscopic sinus surgery.	Spearman correlation analysis were performed to evaluate the association between groups. * $p<$ 0.05; SNOT-22 = the 22-Item Sinonasal Outcome Test; VAS = Visual Analogue Scale; FESS = functional endoscopic sinus surgery.	Spearman correlation analysis were performed to evaluate the association between groups. * $p<$ 0.05; SNOT-22 = the 22-Item Sinonasal Outcome Test; VAS = Visual Analogue Scale; FESS = functional endoscopic sinus surgery.	Spearman correlation analysis were performed to evaluate the association between groups. * $p<$ 0.05; SNOT-22 = the 22-Item Sinonasal Outcome Test; VAS = Visual Analogue Scale; FESS = functional endoscopic sinus surgery.	Spearman correlation analysis were performed to evaluate the association between groups. * $p<$ 0.05; SNOT-22 = the 22-Item Sinonasal Outcome Test; VAS = Visual Analogue Scale; FESS = functional endoscopic sinus surgery.	Spearman correlation analysis were performed to evaluate the association between groups. * $p<$ 0.05; SNOT-22 = the 22-Item Sinonasal Outcome Test; VAS = Visual Analogue Scale; FESS = functional endoscopic sinus surgery.	Spearm correlation analysis were performed to evaluat the association betweer groups. * $p<$ 0.05; SNOT-22 = th 22-Item Sinonasal Outcome Test; VAS = Visual Analogue Scale; FESS = functional endoscopic sinus surgery.

Table 3. Nasalance change in limited functional endoscopic sinus surgery group

[a]
[i]
[u]
[m]
[MaMa]
[MiMi]
[Oral sentence]
[Nasal sentence]
Data are presented as median and interquartile range. Wilcoxon signed rank test was used to assess significant intergroup v

Table 4. Nasalance change in wide opening functional endoscopic sinus surgery group

[a]	
[i]	
[u]	
[m]	
[MaMa]	
[MiMi]	
[Oral sentence]	
[Nasal sentence]	

Data are presented as median and interquartile range. Wilcoxon signed rank test was used to assess significant intergroup v

Table 5. The changes of SNOT-22, subjective nasality outcome and objective endoscopic score following FESS

SNOT-22	
Lund-Kennedy score	
Abnormal nasality resported by patients	
VAS(Total)	
VAS [?] 3, n (%)	
Abnormal nasality resported by parters	
No abnormal nasality	
Mild abnormal nasality	
Noticeable abnormal nasality	

Data are presented as mean or as number (%). Mann-Whitney U test (2-tailed) was used for continuous variables and McN

Figure Legends

FIGURE 1. Nasalance change after endoscopic sinus surgery. Nasalance of [i] significantly increased at 12-month post-surgery**.**