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Original Article

High-Intensity Focused Ultrasound Therapy Versus Coblation for the Treatment of Inferior Turbinate Hypertrophy: A Clinical Trial

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Objectives. To compare the efficacy and safety of high-intensity focused ultrasound (HIFU) therapy with coblation for the treatment of inferior turbinate hypertrophy (ITH).

Methods. In this randomized controlled clinical trial, 20 patients underwent inferior turbinate surgery, which consisted of either HIFU or coblation therapy. Efficacy, safety, and tolerability were evaluated by subjective symptom scores, acoustic rhinometry, and nasal endoscopy.

Results. The modified nasal obstruction symptom evaluation (NOSE) score and nasal obstruction visual analog scale (NO-VAS) significantly decreased in both groups 12 weeks postoperatively. The between-group differences in the evaluation scores were not statistically significant. On nasal endoscopy, the HIFU patients showed improvements in mucosal swelling sooner than the patients undergoing coblation therapy. Nasal crusting significantly increased in the patients undergoing coblation compared to the patients undergoing HIFU therapy until postoperative week 4. Mucosal preservation was superior in the HIFU patients. Although HIFU was less painful than coblation therapy during the procedure, the difference was not significant (4.9 vs. 6.3, $P=0.143$). The difference in global satisfaction between the two groups was not statistically significant, although satisfaction was slightly higher among the HIFU patients than among the coblation patients (4.6 vs. 4.1, $P=0.393$).

Conclusion. HIFU provided results similar to those of coblation therapy for patients with nasal obstruction due to ITH, but HIFU therapy caused less discomfort during the procedure. HIFU therapy appears to be a good noninvasive alternative to the current surgical modalities for ITH.

Keywords. *High-Intensity Focused Ultrasound; Turbinates; Hypertrophy; Nasal Obstruction; Radiofrequency Ablation*

INTRODUCTION

Inferior turbinate hypertrophy (ITH) is one of the most common causes of chronic nasal obstruction [1-3]. Since more than 50% of air introduced from the outside forms a constant airflow along the inferior turbinate, an enlarged inferior turbinate leads to increased resistance to airflow and difficulty breathing through the nose. ITH is commonly observed in patients with allergic rhinitis (AR) or septal deviation [4]. Topical corticosteroids, antihistamines, decongestants, and mast cell stabilizers are considered the primary treatments for ITH. However, surgical treatment is often required for patients who are refractory to medical therapy. A variety of surgical techniques, including partial or total turbinectomy, submucosal resection, microdebrider-assisted turbinoplasty, and radiofrequency turbinoplasty, are used to widen the nasal airways in patients with ITH. The severity of complications

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varies with the increasing extent of invasiveness, and ranges from minor bleeding to marked hemorrhage, synechia, crusting, foul odor, pain, hyposmia, and chronic dryness [5]. Although many studies have compared the various surgical techniques, the optimal treatment has not yet been established [2,4,6,7].

High-intensity focused ultrasound (HIFU) is a new noninvasive treatment modality that focuses an ultrasound beam on the target tissue in the body and generates high energy, which selectively and rapidly causes coagulation necrosis of the target tissue without damaging adjacent tissues or superficial tissues. HIFU has been recently applied in an increasing number of medical fields, including oncology, urology, ophthalmology, and otorhinolaryngology [8,9]. Several studies have found that HIFU was as effective as first-line drug treatment for symptomatic relief in patients with persistent AR, markedly reducing their nasal symptoms and improving their quality of life [10]. We recently demonstrated the efficacy and safety of HIFU turbinoplasty in an animal model. HIFU turbinoplasty showed no complications, such as bleeding or scar formation, and efficiently reduced the turbinate size in a porcine model. Histological examinations showed decreased glandular structure and increased fibrosis in the HIFU-treated group [11]. However, few studies have compared the efficacy of HIFU therapy and coblation for the treatment of ITH in real-world patients.

We recently developed a new surgical device that uses HIFU for the treatment of ITH. Here, we report our clinical trial of patients with nasal obstruction due to ITH who underwent coblation or HIFU therapy, with the aim of demonstrating that HIFU therapy is not inferior to coblation for the treatment of ITH, along with a comparison of subjective satisfaction and complications between the two methods.

MATERIALS AND METHODS

Study design

This was a prospective, randomized, comparative surgical trial conducted from September 2019 to April 2020. The study recruited patients older than 19 years and younger than 65 years, who visited our outpatient clinic with nasal obstruction (greater than 4 out of 10 on the visual analog scale [VAS]) secondary to ITH and refractory to medical treatment longer than three months. We enrolled not only the AR patients but the patients with nasal obstruction with ITH regardless of atopy status. Patients were excluded if they had marked deviation of the nasal septum, perforated nasal septum, collapsed nasal valve, acute/chronic rhinosinusitis with/without nasal polyps, sinonasal tumor, asthma, previous nasal surgery; or they were receiving systemic corticosteroids or long-acting antihistamines for another systemic disease. Patients using a topical/systemic antihistamine, decongestant, corticosteroid, leukotriene modifier, or topical anticholinergic could participate in the study after 2 weeks of washout period. The patients were assigned according to a 1:1 ratio by a block randomization method into two treatment groups of 10 patients each.

Institutional Review Board of Seoul National University Hospital (No. 1906-097-1040) approval was obtained prior to initiation of the study. Informed consent was obtained from every study patient. The HIFU device used in this study was approved for human use by the Ministry of Food and Drug Safety of Republic of Korea.

Procedures

All procedures were performed under the guidance of a 4-mm–diameter, 0° rigid nasal endoscope (Karl Storz) by a single surgeon in an outpatient clinic. After informed consent was obtained from the patient, 4% lidocaine-soaked cotton pledgets were applied to the patient's bilateral nasal cavities for approximately 5 minutes. Each patient then underwent inferior turbinate surgery by either a HIFU or coblation procedure.

The Rhin-Hi system (GTG Wellness Co.) (Fig. 1A) equipped with a 4-mm-diameter, straight, rigid probe (Fig. 1B) was used for the HIFU procedure. The ultrasound emitter window was placed on the mucosa of the inferior turbinate, and then scanned between front and back followed by up and down (Fig. 1C). The scan speed on the lateral wall was 2 mm/sec. The power of each pulse was 1.5 J, with an interval time between each pulse of 1.5 seconds. The total treatment time for both sides was 6–8 minutes. A total of 120 shots were applied to both inferior turbinates, and the projection depth was adjusted to 3 mm.

The Coblator II surgery system equipped with the Reflex Ultra 45 wand (ArthroCare ENT) was used for the coblation procedure. The system was set at a power level of 6 in the coblation mode. After being advanced through the mucosal area, the wand was advanced to the submucosal plane up until the bend in the wand. Beginning posteriorly and moving anteriorly, the probe was activated for 10–15 seconds on each side of the turbinate. After the procedure, bleeding was controlled prior to discharge of the patient to his/her home.

HIGHLIGHTS

- High-intensity focused ultrasound (HIFU) is a new noninvasive treatment modality that focuses an ultrasound beam on the target tissue in the body and generates high energy, causing selective and rapid coagulation necrosis of the target tissue without damaging adjacent tissues or superficial tissues.
- In this clinical trial that included 20 adults, HIFU treatment showed improvements comparable to coblation in patients with nasal obstruction due to inferior turbinate hypertrophy.
- HIFU can be an effective and safe noninvasive alternative to the current surgical modalities for inferior turbinate hypertrophy.

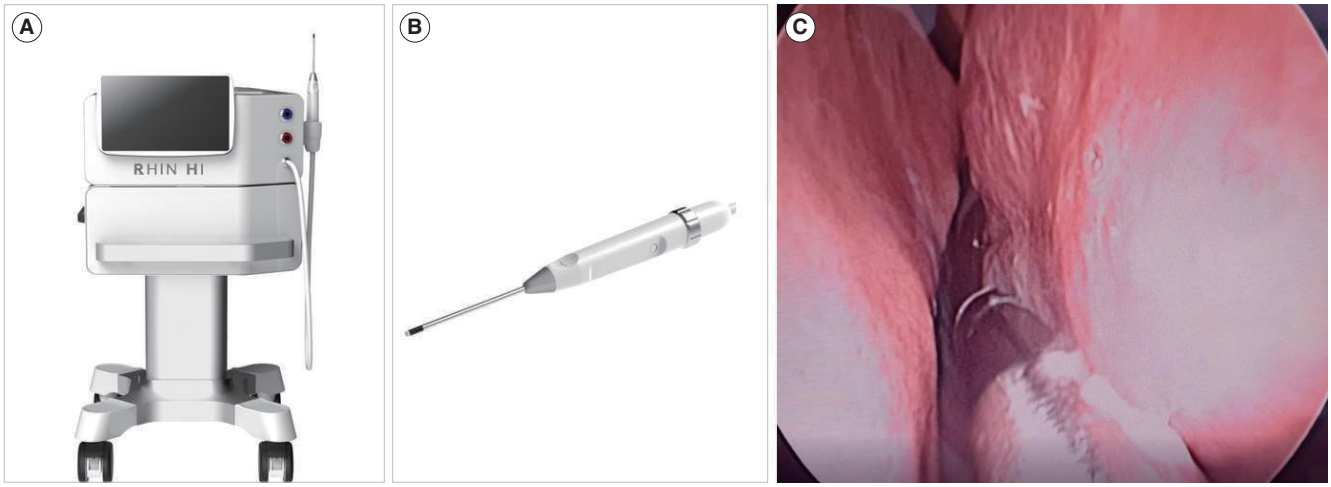

Fig. 1. (A) The Rhin-Hi system. (B) Probe of the Rhin-Hi system. (C) High-intensity focused ultrasound procedure under nasal endoscopic guidance.

Table 1. Modified nasal obstruction symptom evaluation questionnaire

Symptom	Not a problem	Very mild problem	Moderate problem	Fairly bad problem	Severe problem
Nasal stuffiness	0	1	2	3	4
Trouble breathing through nose	0	1	2	3	4
Trouble sleeping	0	1	2	3	4
Unable to obtain sufficient air through the nose during exercise	0	1	2	3	4

Evaluation

Nasal stuffiness was evaluated on a modified questionnaire consisting of a nasal obstruction symptom evaluation (NOSE), which consisted of four questions. Each question was graded on a Likert scale ranging from 0 (not a problem) to 4 (severe problem) (Table 1). The nasal obstruction visual analog scale (NO-VAS) was also performed to quantify nasal obstruction. NO-VAS used a continuous scale ranging from 0 to 10, where 0 corresponds to no obstruction and 10 corresponds to complete obstruction. The patients also underwent acoustic rhinometry (Eccovision Acoustic Rhinometer, HOOD Laboratories) to measure total nasal volume (TNV), minimal cross-sectional area (MCA) and nasal endoscopy to assess the degree of mucosal swelling, discharge, and crusting; which was based on 5-point scale (0–4). One otolaryngology specialist who was blinded without knowing the patient group rated the endoscopic findings. The questionnaires and examinations were assessed at every visit (before surgery; and at 2, 4, and 12 postoperative weeks). Pain during the procedure was assessed by a VAS. Each patient's global satisfaction was assessed based on 6-point scale (0–5) at postoperative week 12.

Statistical analysis

The Wilcoxon signed rank test was used to compare the results of acoustic rhinometry and subjective symptom scores before and after treatment within the same group, and the Mann-Whitney test was used to compare the results of acoustic rhinometry and subjective symptom scores between the two patient groups. The Mann-Whitney test was used to compare the global satisfaction score and pain score between the two groups. A P-value <0.05 was considered to be statistically significant. Statistical analysis was performed by the IBM SPSS ver. 20 (IBM Corp.).

RESULTS

Participant characteristics

In total, 20 participants (10 men, 10 women) were recruited from September 2019 to April 2020 for this study, with 10 patients each in the HIFU and coblation groups. The mean patient age in the HIFU and coblation groups was 40.1±10.5 years and 37.1±12.5 years, respectively (P=0.656). The male-to-female ratios in the HIFU and coblation groups were 6:4 and 4:6, respectively (P=0.361). At the preoperative visit, the two groups did not show significant differences in the modified NOSE and NO-VAS scores or the findings of acoustic rhinometry and nasal endoscopy (Table 2).

Effectiveness

The scores of the modified NOSE and NO-VAS evaluations began to improve within 2 weeks postoperatively in both groups.

Table 2. Baseline patient characteristics and preoperative status

Variable	HIFU (n=10)	Coblation (n=10)	*P*-value
Age (yr)	40.1±10.5	37.1±12.5	0.361
Sex (male:female)	6 : 4	4 : 6	0.656
Modified NOSE score			
Stuffiness	2.8±0.4	2.5±0.5	0.280
Trouble breathing	2.9±0.7	2.5±0.5	0.280
Trouble sleeping	2.9±0.6	2.6±0.7	0.315
Trouble exercise	2.9±0.7	2.4±0.7	0.165
NO-VAS score	7.01±0.84	6.82±1.11	0.631
MCA (cm^2)			
Right	0.52±0.11	0.50±0.11	0.971
Left	0.53±0.12	0.51±0.12	0.853
TNV (cm^3)			
Right	7.55±2.53	5.92±1.49	0.123
Left	6.89±1.61	6.71±2.06	0.971
Nasal endoscopy			
Swelling	3.20±0.35	3.25±0.42	0.684
Discharge	1.50±0.85	1.15±0.91	0.353
Crust	0.05±0.16	0.40±0.57	0.218

Values are presented as mean±standard deviation.
HIFU, high-intensity focused ultrasound; NOSE, nasal obstruction symptom evaluation; NO-VAS, nasal obstruction visual analog scale; MCA, minimal cross-sectional area; TNV, total nasal volume.

Table 3. Preoperative and postoperative modified NOSE and NO-VAS scores

Variable	Preoperative	2 wk	4 wk	12 wk
Modified NOSE score				
Stuffiness				
HIFU	2.8±0.4	1.4±0.7[b]	0.9±0.6[b]	0.7±0.9[a]
Coblation	2.5±0.5	1.8±1.0[a]	1.0±0.5[b]	0.7±0.5[b]
Trouble breathing				
HIFU	2.9±0.7	1.4±0.7[a]	0.8±0.6[b]	0.4±0.5[b]
Coblation	2.5±0.5	1.7±1.1	0.9±0.6[b]	0.6±0.5[b]
Trouble sleeping				
HIFU	2.9±0.6	1.4±0.8[b]	1.0±0.8[b]	0.7±0.9[b]
Coblation	2.6±0.7	1.9±1.0[a]	0.9±0.7[a]	0.4 ±0.5[b]
Trouble exercising				
HIFU	2.9±0.7	1.4±0.8[b]	1.0±0.5[b]	0.7±0.5[b]
Coblation	2.4±0.7	1.7±0.8[a]	0.8±0.4[b]	0.5±0.5[b]
NO-VAS score				
HIFU	7.01±0.84	3.89±1.88[b]	3.38±1.96[b]	2.10±1.63[b]
Coblation	6.82±1.11	4.86±2.00[a]	2.64±1.56[b]	1.19±0.66[b]

Values are presented as mean±standard deviation.
NOSE, nasal obstruction symptom evaluation; NO-VAS, nasal obstruction visual analog scale; HIFU, high-intensity focused ultrasound.
[a]$P<0.05$ and [b]$P<0.005$: Wilcoxon signed-rank test.

At postoperative week 12, both the modified NOSE and NO-VAS scores had markedly decreased; but the differences between the patient groups were not significant (Table 3). Acoustic rhinometry was used to measure both TNV and MCA at the level of the internal valve. Although the subjective symptoms improved in both patient groups postoperatively, the TNV and MCA did not show significant differences either compared with the preoperative findings or between the groups throughout the follow-up period. Nasal endoscopy did not find significant differences in the amount of nasal discharge between both patient groups during follow-up. Mucosal swelling began to improve starting at the 2-week postoperative visit and significantly decreased at 12 weeks in both groups. However, the patients who underwent HIFU showed decreased postoperative mucosal swelling sooner than the patients undergoing coblation. At the 2-week postoperative visit, the mucosal swelling was reduced more in the HIFU patients than in the coblation patients. Nasal crusting was significantly greater in the coblation patients than in the HIFU patients until the 4-week postoperative visit. After 12 weeks, the differences between the amount of nasal crust at 12 weeks in the two groups was not significant (Fig. 2, Table 4). Although HIFU was less painful during the procedure than coblation, the difference in the degree of pain between the two groups was not significant (4.9 vs. 6.3, respectively; $P=0.143$). The difference in postoperative global satisfaction between the two groups was not statistically significant, although satisfaction was slightly higher among the HIFU patients than among the coblation patients (4.6 vs. 4.1, respectively; $P=0.393$). Every patient who underwent coblation required temporary nasal packing for bleeding control, whereas none of the HIFU patients required temporary nasal packing.

DISCUSSION

HIFU technology, which was first described more than 70 years ago, focuses an ultrasound beam on diseased tissues inside the body for a brief period. Through the mechanical, thermal, and cavitation effects (although predominantly thermal effects) of ultrasound, local temperatures in the target tissue can be increased to 70 °C–100 °C, which leads to coagulated proteins and spotty necrosis [12-14]. HIFU is completely noninvasive and only affects the target tissue, without damaging the adjacent or surrounding tissues. With these advantages, HIFU therapy is mainly used for the treatment of solid masses associated with various organs, such as prostate cancer and uterine myomas, and it is also used for dermatological treatments such as skin tightening.

Several studies of HIFU in the field of otolaryngology have been published. Wei et al. [15] observed histological changes in the mucosa of the inferior turbinate after HIFU treatment for 11 patients with AR. The density of eosinophils and other inflammatory cells significantly decreased 1 year after treatment. The number of submucosal glands and venous sinusoids also significantly decreased 1 year post-treatment, while the ciliated epithelium and basement membranes remained well preserved after treatment. Another study reported that HIFU treatment showed comparable efficacy to first-line drug treatment in 120 patients with AR. However, complications such as nasal adhe-

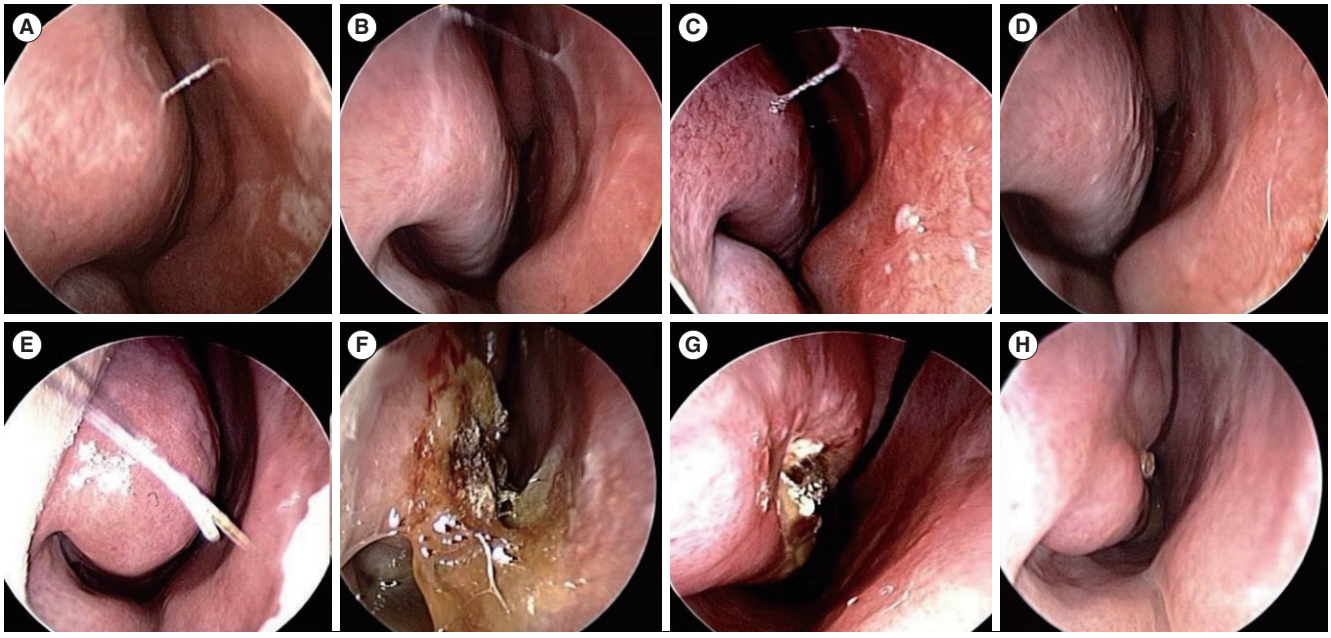

Fig. 2. Preoperative and postoperative nasal endoscopy examinations. High-intensity focused ultrasound (HIFU; A-D) and coblation (E-H). (A, E) Preoperative nasal endoscopy. (B, F) Endoscopy at postoperative week 2 showed that both HIFU and coblation reduced the volume of the inferior turbinate. Severe crust formation and mild bleeding were observed in the coblation patients, whereas the mucosal layer was completely preserved in the HIFU patients. (C, G) Nasal endoscopy at postoperative week 4. Residual crust was observed, indicating delayed mucosal recovery in the coblation patients. (D, H) The volume of the inferior turbinate was reduced in both groups, and the mucosa had recovered in the coblation patients at postoperative week 12.

Table 4. Preoperative and postoperative nasal endoscopy findings

Variable	Preoperative	2 wk	4 wk	12 wk
Swelling				
HIFU	3.20±0.35	1.65±0.71[b),c)]	1.55±0.64[b)]	1.30±0.54[b)]
Coblation	3.25±0.42	2.65±0.75[a)]	1.90±0.77[a)]	1.10±0.66[b)]
Discharge				
HIFU	1.15±0.91	0.95±0.64	0.80±0.35	0.70±0.59
Coblation	1.50±0.85	1.65±0.94	1.15±0.47	0.80±0.48
Crust				
HIFU	0.40±0.57	0.40±0.66[d)]	0.30±0.63[d)]	0.15±0.24
Coblation	0.05±0.16	2.80±0.63[b)]	1.90±0.88[a)]	0.50±0.53[a)]

HIFU, high-intensity focused ultrasound.
[a)]$P<0.05$ and [b)]$P<0.005$: Wilcoxon signed-rank test. [c)]$P<0.05$ and [d)]$P<0.005$: Mann-Whitney test.

sions, perforation of the septum, mucosal atrophy, and hyposmia were not observed, indicating that HIFU was as effective and safe as the first-line drug treatments for symptom relief in AR patients [10]. In a recent study, Zhong et al. [16] reported that compared with plasma radiofrequency ablation, HIFU therapy significantly reduced the nasal symptoms of AR patients, improved their quality of life, and could be used as adjuvant therapy for better therapeutic effects. In contrast to most previous studies, which targeted patients with AR, our study targeted patients with nasal obstruction due to ITH and demonstrated that the effectiveness of HIFU treatment was comparable to that of coblation treatment, regardless of the presence of AR.

Our study found that both HIFU and coblation therapy significantly reduced nasal obstruction, a finding consistent with previous reports. Mucosal swelling improved earlier, and less crust was formed after HIFU than after coblation. Although the difference was not statistically significant, there was also less pain during the HIFU procedure than during coblation. We think that these differences can be accounted for by the procedure itself. Although coblation therapy is minimally invasive, there is an increased risk of postoperative bleeding and pain, since the probe must be inserted into the submucosal layer of the inferior turbinate. Thus, the probe can cause bleeding, nasal crusting, and pain during the procedure. In addition, although coblation can theoretically preserve the turbinate mucosa, in clinical practice, mucosal damage often occurs during the procedure, which leads to crust formation, postoperative nasal congestion, and delayed mucosal recovery.

Because of the invasiveness of coblation, an inflammatory reaction may occur shortly after the procedure, which leads to mucosal swelling. However, HIFU can reduce the incidence of these complications, because it is a truly noninvasive technique that allows complete preservation of the nasal mucosa. Therefore, HIFU can reduce the patient's discomfort and risk of complications, especially immediately after the procedure. Furthermore, HIFU can be applied not only to the inferior turbinate mucosa, but also to other regions of the nasal mucosa, such as the muco-

sa of the septum, middle turbinate, and agger nasi. Therefore, compared with coblation, greater improvement in nasal symptoms, including those due to nasal obstruction, can be expected.

However, in our study, acoustic rhinometry assessments of the TNV and MCA did not reveal significant differences between before and after surgery or between either patient group throughout the follow-up period, indicating a discrepancy between the objective and the subjective assessments of symptoms. Several studies have reported that acoustic rhinometry did not accurately reflect subjective symptoms. Kim et al. [17] concluded that rhinomanometry and acoustic rhinometry might have no diagnostic value in estimating the severity of nasal obstruction symptoms. Another study reported that nasal endoscopy appeared to be more reliable than acoustic rhinometry for estimating the degree of subjective nasal symptoms [18]. The relatively small number of subjects is a limitation of this study. Further studies including a larger number of patients are needed. Another limitation may be that HIFU and coblation procedures were not performed on each side of the nose in one subject, which would have eliminated potential bias due to individual differences.

This clinical trial found that HIFU treatment showed improvements comparable to coblation in patients with nasal obstruction due to ITH, but HIFU was associated with less discomfort and pain throughout the procedure. Thus, HIFU can be an effective and safe noninvasive alternative to the current surgical modalities for ITH.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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REFERENCES

1. Gindros G, Kantas I, Balatsouras DG, Kaidoglou A, Kandiloros D. Comparison of ultrasound turbinate reduction, radiofrequency tissue ablation and submucosal cauterization in inferior turbinate hypertrophy. Eur Arch Otorhinolaryngol. 2010 Nov;267(11):1727-33.
2. Hol MK, Huizing EH. Treatment of inferior turbinate pathology: a review and critical evaluation of the different techniques. Rhinology. 2000 Dec;38(4):157-66.
3. Porter MW, Hales NW, Nease CJ, Krempl GA. Long-term results of inferior turbinate hypertrophy with radiofrequency treatment: a new standard of care? Laryngoscope. 2006 Apr;116(4):554-7.
4. Passali D, Lauriello M, Anselmi M, Bellussi L. Treatment of hypertrophy of the inferior turbinate: long-term results in 382 patients randomly assigned to therapy. Ann Otol Rhinol Laryngol. 1999 Jun; 108(6):569-75.
5. Shah AN, Brewster D, Mitzen K, Mullin D. Radiofrequency coblation versus intramural bipolar cautery for the treatment of inferior turbinate hypertrophy. Ann Otol Rhinol Laryngol. 2015 Sep;124(9): 691-7.
6. Lee KC, Hwang PH, Kingdom TT. Surgical management of inferior turbinate hypertrophy in the office: three mucosal sparing techniques. Oper Tech Otolayngol Head Neck Surg. 2001 Jun;12(2):107-11.
7. Fradis M, Golz A, Danino J, Gershinski M, Goldsher M, Gaitini L, et al. Inferior turbinectomy versus submucosal diathermy for inferior turbinate hypertrophy. Ann Otol Rhinol Laryngol. 2000 Nov;109(11): 1040-5.
8. Wu F, Chen WZ, Bai J, Zou JZ, Wang ZL, Zhu H, et al. Pathological changes in human malignant carcinoma treated with high-intensity focused ultrasound. Ultrasound Med Biol. 2001 Aug;27(8):1099-106.
9. Pomonis JD, Rogers SD, Peters CM, Ghilardi JR, Mantyh PW. Expression and localization of endothelin receptors: implications for the involvement of peripheral glia in nociception. J Neurosci. 2001 Feb;21(3):999-1006.
10. Feng GF, Han ZL, Wang F, Sun BC, Dai ZY, Yang SZ, et al. Comparison of high-intensity focused ultrasound therapy under nasal endoscopy guidance versus first-line drug treatment in patients with persistent allergic rhinitis. Genet Mol Res. 2015 Aug;14(3):9865-71.
11. Kim JK, Cho SW, Kim H, Jo SC, Kim HG, Won TB, et al. Development of high-intensity focused ultrasound therapy for inferior turbinate hypertrophy. Clin Exp Otorhinolaryngol. 2022 May;15(2):160-7.
12. Kennedy JE, Ter Haar GR, Cranston D. High intensity focused ultrasound: surgery of the future? Br J Radiol. 2003 Sep;76(909):590-9.
13. Kennedy JE, Wu F, ter Haar GR, Gleeson FV, Phillips RR, Middleton MR, et al. High-intensity focused ultrasound for the treatment of liver tumours. Ultrasonics. 2004 Apr;42(1-9):931-5.
14. Leslie TA, Kennedy JE. High-intensity focused ultrasound principles, current uses, and potential for the future. Ultrasound Q. 2006 Dec; 22(4):263-72.
15. Wei H, Zhang Y, Shi L, Zhang J, Xia Y, Zang J, et al. Higher dosage of HIFU treatment may lead to higher and longer efficacy for mod-

erate to severe perennial allergic rhinitis. Int J Med Sci. 2013 Nov; 10(13):1914-20.
16. Zhong B, Li LK, Deng D, Du JT, Liu YF, Liu F, et al. Effect of high-intensity focused ultrasound versus plasma radiofrequency ablation on recurrent allergic rhinitis. Med Sci Monit. 2019 Sep;25:6775-81.
17. Kim CS, Moon BK, Jung DH, Min YG. Correlation between nasal obstruction symptoms and objective parameters of acoustic rhinometry and rhinomanometry. Auris Nasus Larynx. 1998 Jan;25(1):45-8.
18. Isaac A, Major M, Witmans M, Alrajhi Y, Flores-Mir C, Major P, et al. Correlations between acoustic rhinometry, subjective symptoms, and endoscopic findings in symptomatic children with nasal obstruction. JAMA Otolaryngol Head Neck Surg. 2015 Jun;141(6):550-5.