Original Article

Acoustic Rhinometric values for Saudi normal adult Volunteers and patients with different nasal obstruction conditions

Fahd A. Alharbi,[1] Mohamed R. Ahmed[1,2]

[1]Department of Otolaryngology-Head and Neck Surgery, Faculty of Medicine, Jazan University, Saudi Arabia, [2]Department of Otolaryngology-Head and Neck Surgery, Faculty of Medicine, Suez Canal University, Ismailia, Egypt

Correspondence to: Fahd A. Alharbi, Email: fahdalharbi3@gmail.com

Objective: ***Acoustic rhinometry is a new objective tool for the diagnosis of nasal obstruction.***

Aim: ***To provide normal values of nasal volume in Saudi adults as a local reference.***

Patient and Methods: ***240 normal adult volunteers and100 patients with different nasal obstruction conditions were examined with acoustic rhinometry to evaluate the minimal cross sectional area (MCA) , the distance to minimal cross sectional area (DMCA) and the nasal cavity volume (NCV) from nostril to 5 cm inside the nasal cavity.***

Results: ***The mean acoustic rhinometry parameters in normal Saudi adult volunteers were MCA = 0.66 +/-0.12 (cm2), DMCA = 1.67 +/- 0.31 (cm) and NCV 8.12 +/- 2.1 (cm3). Patients with a deviated nasal septum had an NCA that increased in the deviated side and differs from 0.28 +/- 0.17 cm2 to 0.48 +/- 0.09 cm2. The DMCA values differed between the deviated sides from 2.19 +/- 0.28 cm to 1.96 +/- 0.39 cm in the other side. The NCV also increased in the deviated side and varied between both sides from 4.26 +/- 2.31 cm 3 to 7.21 +/- 2.73 cm 3.***

Conclusion: ***Acoustic rhinometry is non-invasive, rapid objective test can evaluate patients with chronic nasal obstruction.***

Keywords: ***Acoustic rhinometry, Normal values, Saudi.***

INTRODUCTION

Nasal breathing without difficulty is a complex matter and is influenced by several factors.(1) The measurement of nasal resistance is important for understanding the pathophysiology of nasal obstruction. However, it is difficult to define the normal range of nasal resistance.(2)

Acoustic rhinometry (AR) is a new objective tool used to diagnose nasal obstruction and a method to assess the geometry of nasal cavity. It has the advantage of being fast, painless, accurate and needs no patient cooperation.(3-4) The normal value may be influenced by various factors including race, which may reflect on the anatomical configuration of the nose and nasal cavity thus producing different measurements on using the rhinometry.(5)

AR makes it possible to detect a trend in the relationship between either a decrease at the minimal cross-sectional area or a decrease in the total volume from 0 to 7 cm into the nasal cavity and congestion, also determine the anatomic site of the obstruction.(6-7) Nasal obstruction is an important symptom, not a diagnosis, may have one or a combination of many disease of upper airway such chronic sinus infections, nasal polyps, inferior turbinate hypertrophy and structural deformities of the nasal septum. It affects personal well-being and his quality of life.(8-10)

There has been no study on determining these normal values in saudis population up to now. The aim of this study was to provide normal values for nasal volume in adult Saudi population without nasal obstruction as a local reference and compare these results with patients with chronic nasal obstruction undergoing nasal surgery evaluated pre and post-operative using AR.

PATIENTS AND METHODS

The ethical committee of faculty of medicine at Jazan University approved the study protocol and a written consent was obtained from all normal and patient volunteers. This study was done in the ENT- Head and Neck Surgery Department, Jazan General Hospital, Jazan, Saudi Arabia from June 2011 to April 2013. Two-hundred fourty normal healthy adult Saudi volunteers, age ranged from18 to 50 years old, without nasal complaint (confirmed by an anterior rhinoscopic examination and nasal endoscope examination) to establish a reference value for AR parameter. Volunteers with history of a systemic disease, history of nasal surgery, history of allergy, sinusitis & nasal polyposis were exluded.

Hundred patients (18 – 50 years old), with chronic nasal obstruction who were scheduled to undergo a nasal surgery were subjected to AR after a complete history, anterior rhinoscopic examination, nasal endoscope examination and computer tomography scan (twenty patients with an anterior septal deviation alone, fourty patients with an inferior turbinate hypertrophy (ITH), twenty-five patients with nasal polyposis and fifteen patients with chronic Rhino sinusitis).

Study plan: AR study was done for all normal volunteers and patients (preoperatively and 8 weeks postoperatively). The test is performed using PC- based Eccovision system (model AR-1003), Hood laboratories Inc., Pembroke, MA, USA. This system uses amplitudes and arrival times of echoes to construct the acoustic rhinogram which represents the entire nasal cavity as a function of distance from the nostril. To assess the nasal geometry through measuring minimal cross sectional area (MCA), distance to minimal cross sectional area (DMCA) and nasal cavity volume (NCV) from nostril to 5 cm inside the nasal cavity.

The technique performed in a sitting position, before and after using topical decongestion in each side of the nasal cavity. A properly fitted nosepiece was selected (three nosepiece were used with an opening diameter of 1.25 to 0.8 cm, 1.25 to 1.1 cm and 1.25 to 1.3 cm) and a thin layer of ointment was applied to prevent any acoustic leakage from the junction between the nostril and nosepiece. Special care was taken not to distort the nasal valve anatomy and to position the nosepiece in such way that it is in light contact with the nostril during the assessment. All AR measurements were repeated five times to ensure the results were reproducible.

A computer sends in sound waves via a tube placed at the nostril. A microphone picks up the reflected waves, and the computer plots the topography of a cross-section of the nose. The first notch in the area-distance curve, named I-notch, indicates the nasal valve and the second notch, named C-notch, indicates the head of inferior turbinate. Before each measurement, AR is calibrated with a calibration tube (length 20 cm, outside diameter 1.9 cm, inside diameter 1.26 cm).[10-11]

Statistical analysis: Using a Microsoft Excel program for the descriptive analysis for N group to establish Saudi reference values for AR. T - Test was used to compare pre- and postoperative AR parameters in the nasal obstruction group. Chi square test was used to correlate patients' subjective improvements with the objective AR parameters.

RESULTS

240 normal volunteers, 112 males and 128 females with mean age of 26.4 years - without any nasal symptoms or signs. AR was recorded to establish Saudi reference values. The mean MCA was 0.66 +/-0.12 cm^2, the mean DMCA was 1.67+/- 0.31 cm while the t NCV was 8.12+/- 2.1cm^3 without any significant difference between right or left sides or any statically difference according to male and female dissociation as showed in (Fig. 1).

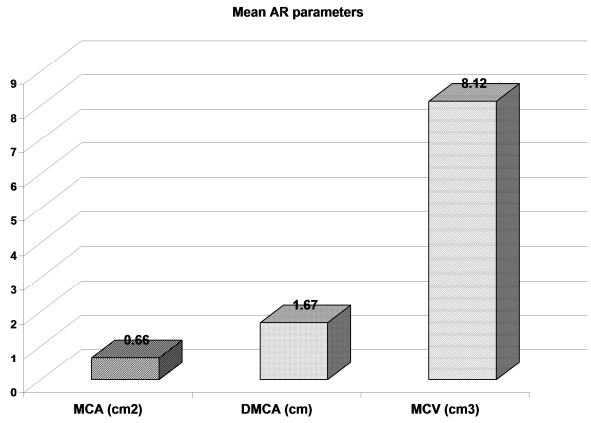

Fig 1 Mean AR parameters in normal Saudi volunteers.

20 patients, 12 males and 8 females (mean age of 29.7 years) with anterior septal deviation alone, 9 with left side deviation while 11 with right side deviation. AR parameters were compared pre- and 8 weeks postoperatively after Septoplasty operation. The MCA increased where the deviation present and changed from

0.28 +/- 0.17 cm^2 to 0.48 +/- 0.09 cm^2 which was a significant change, while in the contra lateral side for the deviation, the MCA changed from 0.48 +/- 0.08 cm^2 to 0.47 +/- 0.17 cm^2 without any statistical significance.

The DMCA changed in the side of deviation from 2.19 +/- 0.28 cm to 1.96 +/- 0.39 cm which was not a significant change, while in the contra lateral side for deviation changed from 1.86 +/- 0.27 cm to 1.87 +/- 0.41 cm without a statistical significance. The t NCV increase in deviated side and changed from 4.26 +/- 2.31 cm^3 to 7.21 +/- 2.73 cm^3 which was a significant change, while in the contra lateral side for deviation changed from 7.57 +/- 1.98 cm^3 to 7.38 +/- 2.37 cm^3 without a statistical significance as seen in (Table 1).

Table 1 Comparison between AR parameters in DS group pre & post septoplasty

Mean	MCA (cm^2)		DMCA (cm)		NCV (cm^3)	
	Dev	Contra	Dev	Contra	Dev	Contra
Pre	0.28	0.56	2.19	1.86	4.26	7.57
Post	0.48	0.47	1.96	1.87	7.21	7.38
P value	*<0.001	0.081	0.019	0.0354	*<0.001	0.0863

*= significant Dev=deviated

40 patients with bilateral inferior turbinate hypertrophy ITH, 13males and 27 females, with mean age 34.6 years old subjected to partial inferior turbinectomy. AR parameters compared pre- and 8 weeks postoperatively. The mean MCA was 0.32 +/- 0.14 cm^2 increased postoperative to 0.64 +/- 0.12 cm^2 which was a significant change, The mean DMCA was 3.39+/- 0.31 cm decreased postoperative to 1.76 +/- 0.21 cm which was a significant change while The t NCV was 5.98 +/- 1.82 cm^3 increased post-operative to 8.16 +/- 1.64 cm^3 which was a significant change as seen in (Table 2, Fig. 2).

Table 2 Comparison between AR parameters in ITH pre & post-operative

Mean	MCA (cm^2)	DMCA (cm)	NCV (cm^3)
Pre	0.32	3.39	5.98
Post	0.64	1.76	8.16
P value	*<0.001	*<0.001	*<0.001

*= significant ITH= inferior turbinate hypertrophy

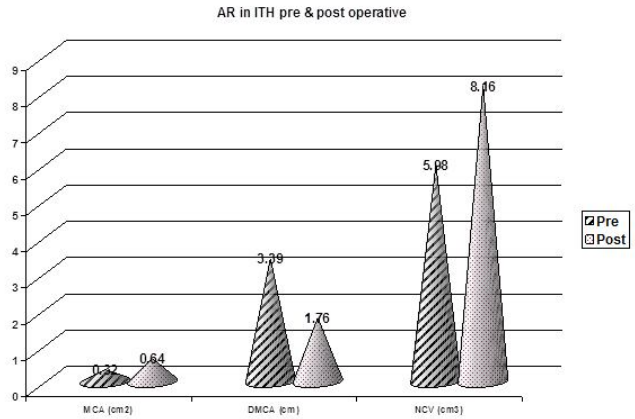

Fig 2 AR in ITH pre & post-operative.

25 patients with bilateral nasal polyposis, 19 males & 6 females, with mean age 37.2years old subjected to Functional endoscopic sinus surgery (FESS). AR parameters compared pre- and 8 weeks postoperatively. The mean MCA was 0.29+/- 0.08 cm^2 increased postoperative to 0.53 +/- 0.16 cm^2 which was a significant change, The mean DMCA was 2.27+/- 0.49 cm decreased postoperatively to 1.92 +/- 0.19 cm which was not a significant change while the t NCV was 4.12 +/- 1.12 cm^3 increased postoperatively to 9.27 +/- 2.09 cm^3 which was a significant change as showen in (Table 3, Fig 3).

Table 3 Comparison between AR parameters in Polyposis group pre & post FESS

Mean	MCA (cm^2)	DMCA (cm)	NCV (cm^3)
Pre	0.29	2.27	4.12
Post	0.53	1.92	9.27
P value	*<0.001	0.0487	*<0.001

15 patients with bilateral chronic rhino-sinusitis, 11 males & 4 females, with mean age 39.7years subjected to FESS. AR parameters compared pre and 8 weeks postoperatively. The mean MCA was 0.32+/- 0.16 cm^2 increased postoperative to 0.56 +/- 0.11 cm^2 which was a significant change, The mean DMCA was 1.87+/- 0.35 cm decreased postoperative to 1.83+/- 0.32 cm which was not a significant change while The t NCV was 5.31+/- 1.96 cm^3 increased post-operative to 7.80 +/- 1.96 cm^3 which was a significant change as demonastrated in (Table 4, Fig. 4).

Table 4 Comparison between AR parameters in CRS group pre & post FESS

Mean	MCA (cm^2)	DMCA (cm)	NCV (cm^3)
Pre	0.32	1.87	5.31
Post	0.56	1.83	7.80
P value	*<0.001	0.4310	*<0.001

*= significant

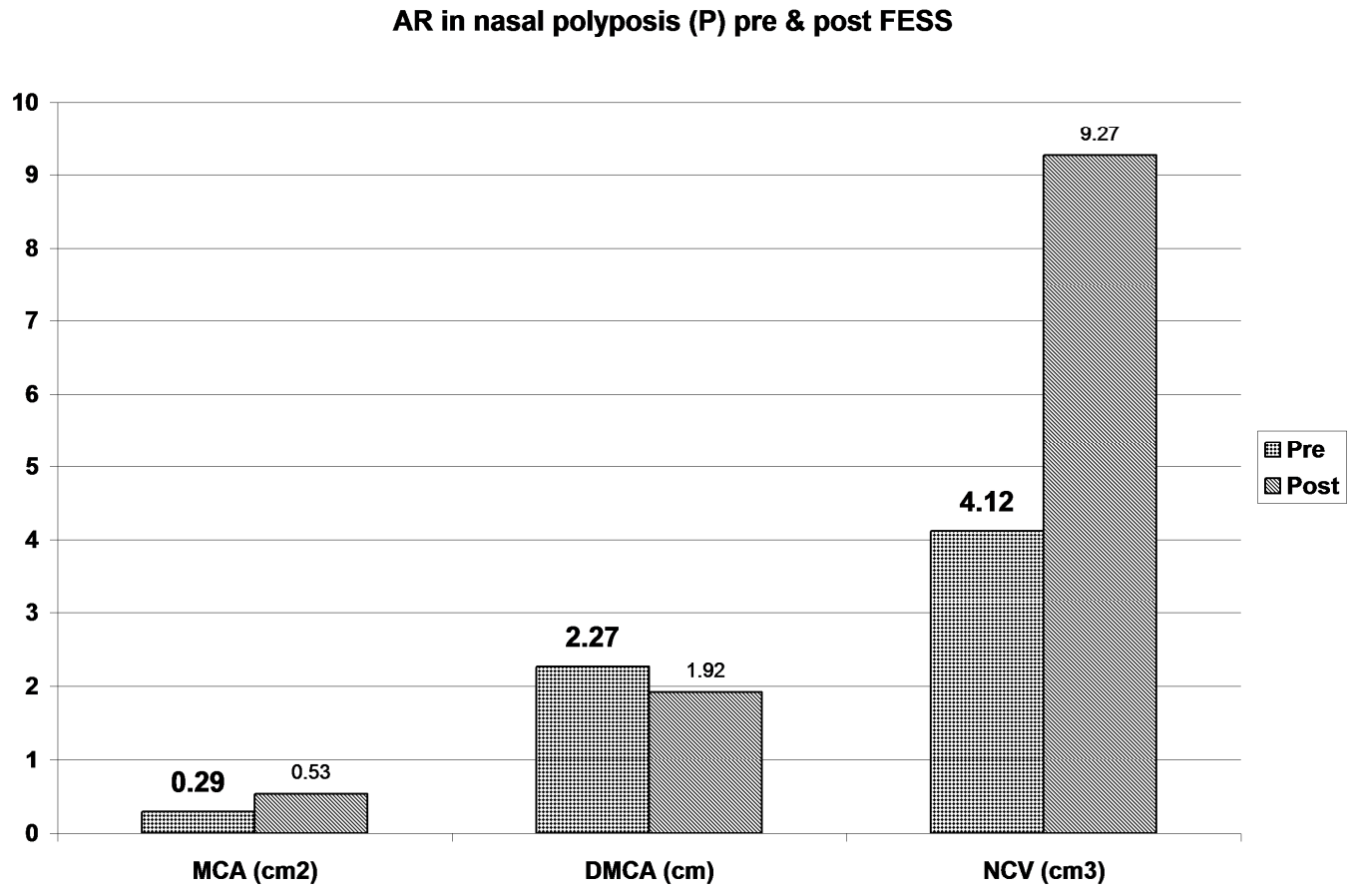

Fig 3 AR in nasal polyposis pre- and post-FESS.

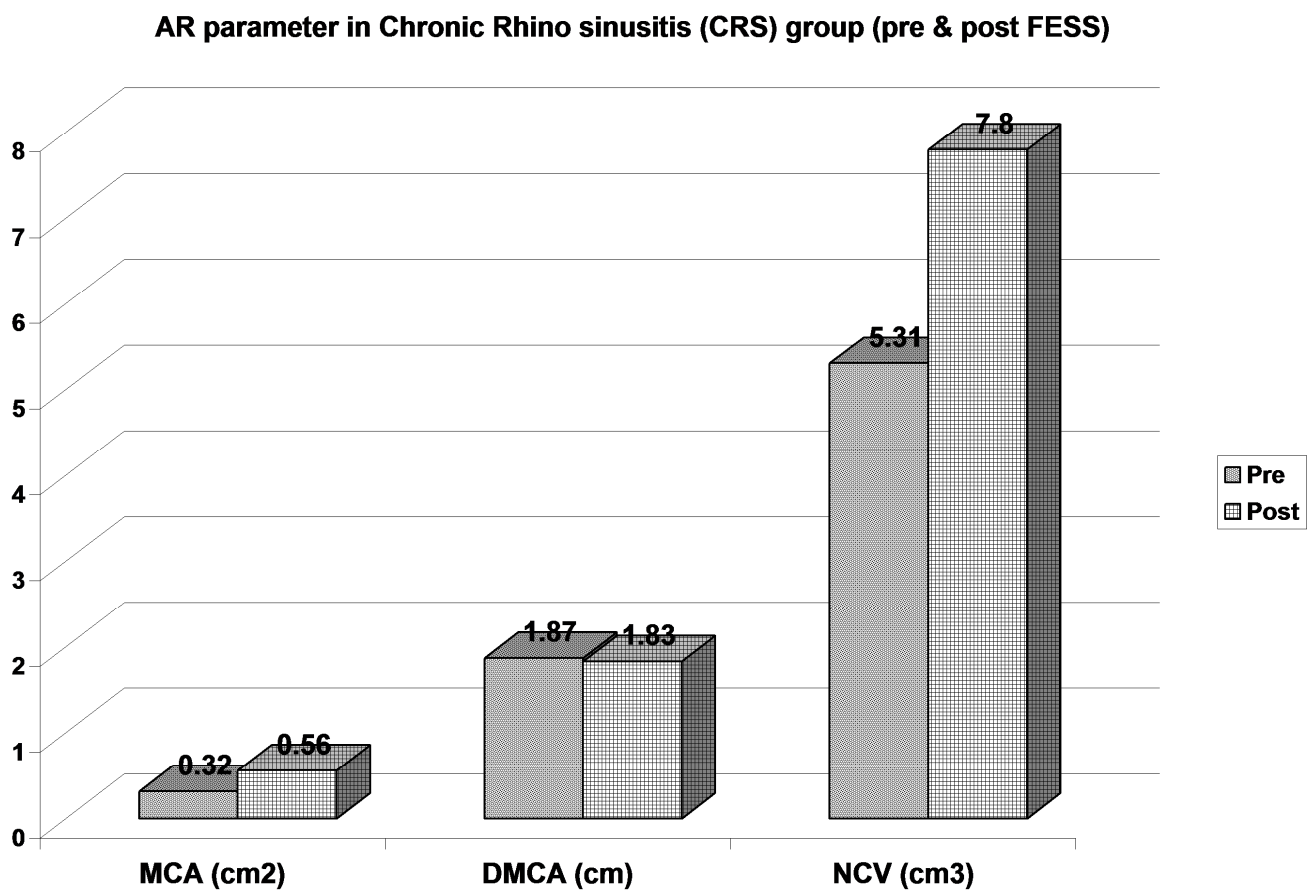

Fig 4 AR parameter in Chronic Rhino sinusitis (CRS) group (pre & post FESS).

DISCUSSION

Our study based on AR normal parameters among the saudi population as standard criteria for rhinologists and determine the value of AR in the evaluation of the patient's condition postoperatively. AR has a new parameter in evaluating the nasal patency condition such as MCA, DMCA & NCV. Therefore a standard protocol should be used as adopted in this study where we did not insert a nosepiece into the nasal vestibule to avoid its distortion similar to the recommendation of Muñoz et al 2013.[12] The nosepieces used should have different diameters to fit snugly in different nostril as mentioned by Cheng et al 2012.[13] On the other hand, the use of ointment or gel does help but the operator usually depends on his ability to judge the acoustic seal for example, by hearing the sound differently.[8]

In our study , we kept the tube in line with the dorsum of the nose , as mentioned by Bakke et al 2008 who found that more vertical sagittal angles are known to shift the I and C notches anteriorly.[8] The stability of the tube during test is very important as we held the tube with thumb and index finger with the rest of the other fingers on the subject's chin for stabilizing the tube as mentioned by Straszek et al 2008.[14] In our study 240 normal adult volunteers (480 nasal cavities) were examined to create a local reference for the three AR parameters and theses parameters may be different in various studies secondary to racial anatomical factor as mentioned by Alireza et al 2008.[1]

In our study MCA was 0.66 +/-0.12 cm^2. Grymer et al 1991 found MCA =0.73 to 0.92 cm^2 whereas according to Zoumalan et al 2012 MCA was 0.67 cm^2 [9] These related to racial factors as mentioned by Trindade et al 2010.[15]

DMCA in our study for the normal volunteers was 1.67 +/- 0.31 cm. This corresponded with the location of the nasal valve area. According to Bloom et al 2012 it was 2.35 cm.[11] Also, Haavisto et al in 2013 reported similar distances but Lenders in 1990 reported 1.3 cm.[10] The difference may be due to variation in the used technique as the tip may shifts the curve to the right as reported by Bakke et al in 2008.[8]

NCV in our study was 8.12 +/- 2.1 cm^3 but differently reported by others as 17.77 cm^3 and 21.6 cm^3. The difference is due to the variable measurement depth inside the nose (0-6, 0-7 cm from nostril). In our study there was no correlation between sexes, Age or right and left nasal sides, this was also documented by Alireza et al 2008 who approved this and in furthermore, found no correlation with smoking in their Iranian sample.[1] AR is very useful in correlating patient's subjective symptoms and clinical signs. In our study we found AR is helpful in detecting the side, site and degree of nasal obstruction in DS, ITH, nasal polyposis & chronic rhino-sinusitis patients. This finding can be used for objectively documenting the preoperative clinical findings.

With the mentioned principles, these data can be used for diagnosis of different types of rhinologic disorders, treatment planning (medical and surgical), and comparing the preoperative with postoperative results of rhinological surgeries. In our study on DS group we found that the MCA & NCV on the deviated side were significantly smaller and the DMCA was longer than the control, while MCA on the contra lateral side for deviation was smaller than the control and post operatively tend to be smaller. This may be explained by the relocation of DS to the midline in the presence of a contra lateral ITH. Alireza et al 2008 found that there was a significant difference between the narrower side of the nasal cavity with obstructive pathology and the wider side in volume and MCA.[1]

Wu et al 2013 reported postoperatively smaller MCA in the side opposite to the deviated side as a result of the correction of the septum without reduction in the ITH as also reported by Hirunwiwatkul et al 2012.[9-16] In ITH group we found that preoperative MCA & NCV was smaller than the normal control and agrees with Hirunwiwatkul et al 2012 & Swibel-Rosenthal et al 2010.[16-17] The smaller MCA increase with the respiratory effort can explain the sensation of nasal obstruction. Improvement of MCA postoperative indicates that the site of obstruction was at the nasal valve area.

In nasal polyposis group, nasal obstruction was their main complain. MCA was smaller and this agrees with Tsukidate et al 2012 who mentioned a good correlation between NCV and the volume of polyp removed at surgery.[18] After FESS, NCV increased significantly after polyps removal. Finally patients with chronic rhino-sinusitis MCA & NCV improved postoperativel after FESS.

This had been also reported by Jang et al 2013.[19] The improvement in MCA after FESS is probably due to improvement in mucosal factor after surgery but MCA did not completely normalize due to other missed factors during the operation as surgeon always concentrate on the ethmoidal region and not pay attention to other contributing factors to the obstruction as DS and ITH.

We believe that AR can strongly direct the surgeon's attention towards the nasal valve area causing obstruction in chronic rhino-sinusitis also to DS , ITH for such anatomical areas should be dealt with at the time of surgery, if the best results concerning patient's satisfaction are desired.

Objective measurements of the patients' satisfaction from treatment can also be evaluated and documented. Pre- and postoperative results can be compared and illustrated to patients. This extends the value of AR beyond its clinical value to the medicolegal aspects as well.

CONCLUSION

AR is a non-invasive, rapid objective test which can evaluate patients with chronic nasal obstruction. It is also valuable in planning IT surgery with great attention for nasal valve area pathology.

Conflict of Interest: There is no conflict of interest.

REFERENCES

1. Alireza Mohebbi MD, Mohammad Farhadi MD, Artemis Erfan MD;Assessment of Nasal Volume and Cross-Sectional Area by Acoustic Rhinometry in a Sample of Normal Adult Iranians Arch Iranian Med. 2008;11:555–8 (Archives of Iranian Medicine. 2008; 1.

2. Şeneldir L, Koten M, Adalı MK, Yağız R, Taş A, Karasalihoğlu AR. [The evaluation of the outcomes of nasal obstruction surgery by acoustic rhinometry measurements and effects of nasal obstruction on daytime sleepiness]. [Article in Turkish] Kulak Burun Bogaz Ihtis Derg. 2012;22:12-20.

3. Hu J, Lang J, Liao J, Yu W, Zhang J, Jiang T, Cao C, Zhou S, Ren D. [OSAHS patient gas up-take cross-sectional area nasopharynx sound reflection examination and significance]. [Article in Chinese] Lin Chung Er Bi Yan Hou Tou Jing Wai Ke Za Zhi. 2011;25:936-8.

4. Se Joong Kim, Ji Ho Choi, Eun Joong Kim, Seung Ku Lee, Seung Hoon Lee, Young Joon Jun, Je Hyeong Kim, Soichiro Miyazaki, Chol Shin: A Prospective Population-based Study of Total Nasal Resistance in Korean Subjects. Clinical and Experimental Otorhinolaryngology. 2012;5:39-43. ·

5. Mohamad Chaaban and Jacquelynne P. Corey "Assessing Nasal Air Flow", Proceedings of the American Thoracic Society. 2011; 8:70-8.

6. Wu Z, Kim YC, Khoo MC, Nayak KS. Evaluation of an independent linear model for acoustic noise on a conventional MRI scanner and implications for acoustic noise reduction. Magn Reson Med. 2013.

7. Rizvi SS, Gauthier MG. Lateralizing the collapsed nasal valves simplified: 10-year survey of a simple concealed suture technique. Laryngoscope. 2011;121:558-61.

8. Bakke JV, Norbäck D, Wieslander G, Hollund BE, Florvaag E, Haugen EN, Moen BE. Symptoms, complaints, ocular and nasal physiological signs in university staff in relation to indoor environment - temperature and gender interactions. Indoor Air. 2008;18:131-43.

9. Zoumalan RA, Constantinides M. Subjective and objective improvement in breathing after rhinoplasty. Arch Facial Plast Surg. 2012;14:423-8.

10. Haavisto LE, Sipilä JI. Acoustic rhinometry, rhinomanometry and visual analogue scale before and after septal surgery: a prospective 10-year follow-up. Clin Otolaryngol. 2013;38:23-9.

11. Bloom JD, Sridharan S, Hagiwara M, Babb JS, White WM, Constantinides M. Reformatted computed tomography to assess the internal nasal valve and association with physical examination. Arch Facial Plast Surg. 2012;14:331-5.

12. Muñoz-Cano R, Bartra J, Sanchez-Lopez J, Picado C, Bissinger I, Valero A. Acoustic rhinometry and aspirin nasal challenge in the diagnosis of aspirin-intolerant asthma: clinical finding and safety aspects. Int Arch Allergy Immunol. 2013;160:307-12.

13. Cheng PW, Fang KM, Su HW, Huang TW. Improved objective outcomes and quality of life after adenotonsillectomy with inferior turbinate reduction in pediatric obstructive sleep apnea with inferior turbinate hypertrophy. Laryngoscope. 2012;122:2850-4.

14. Straszek SP, Moeller A, Hall GL, et al. Reference values for acoustic rhinometry in children from 4 to 13 years old. Am J Rhinol. 2008;22:285-91.

15. Trindade IE, Castilho RL, Sampaio-Teixeira AC, Trindade-Suedam IK, Silva-Filho OG. Effects of orthopedic rapid maxillary expansion on internal nasal dimensions in children with cleft lip and palate assessed by acoustic rhinometry. J Craniofac Surg. 2010;21:306-11.

16. Hirunwiwatkul P, Udomchotphruet P. Efficacy study of nasal irrigation after radiofrequency tissue volume reduction for inferior turbinate hypertrophy: An equivalence randomized controlled trial. Am J Rhinol Allergy. 2012;26:497-503.

17. Swibel-Rosenthal LH, Benninger MS, Stone CH, Zacharek MA. Wound healing in the paranasal sinuses after Coblation, Part II: evaluation for endoscopic sinus surgery using a sheep model. Am J Rhinol Allergy. 2010;24:464-6.

18. Tsukidate T, Haruna S, Fukami S, Nakajima I, Konno W, Moriyama H. Long-term evaluation after endoscopic sinus surgery for chronic pediatric sinusitis with polyps. Auris Nasus Larynx. 2012;39:583-7.

19. Jang DW, Lachanas VA, Segel J, Kountakis SE. Budesonide nasal irrigations in the postoperative management of chronic rhinosinusitis. Int Forum Allergy Rhinol. 2013.