ORIGINAL CONTRIBUTION

Rhinology, 48, 224-227, 2010

Accuracy of acoustic rhinometry versus computed tomography in the evaluation of nasal cavity in patients with nasal polyposis*

R. Muñoz-Cano[1,2], R. Salvador[3], A. Valero[1,2], J. Berenguer[3], I. Alobid[2,4], J. Bartra[1,2], J.M. Guilemany[2,4], J. Mullol[2,4], C. Picado C[1,2]

1 Allergy Unit, Pneumology and Allergy Department, Hospital Clínic – IDIBAPS, Universitat de Barcelona, Barcelona, Spain
2 Centro de Investigaciones Biomédicas en Red de Enfermedades Respiratorias (CIBERES), Spain
3 Neuroradiology Section, Imaging Diagnostic Center. Hospital Clínic, Barcelona, Spain
4 Rhinology Unit & Smell Clinic, ENT Department, Hospital Clínic – IDIBAPS, Barcelona, Spain

SUMMARY

Background: *Acoustic rhinometry (AR) accuracy in the diagnosis and follow-up of nasal polyps is as yet unclear. Our objective was to study its accuracy compared with computed tomography (CT) in patients with nasal polyps.*
Methods: *We studied 29 patients diagnosed of nasal polyposis by nasal endoscopy. In all patients sinunasal CT-scan, AR and nasal nitric oxide (NO) were assessed. Nasal volumes between 0 and 5 (V_{0-5}) and 5 and 9 (V_{5-9}) centimetres from nasal inlet were measured with AR and CT-scan, by using Pearson and intraclass correlation coefficient tests.*
Results: *All patients (29,79% males, mean age 48.2 yr [range 34-61]) had nasal polyps (score 2-3 on Lildholdt classification, score 0-3). Measurements (right plus left sides) were: AR 8.9 ± 0.8 cm3 (V_{0-5}) and 15.5 ± 3.6 cm3 (V_{5-9}); CT 6.5 ± 0.4 cm3 (V_{0-5}) and 6.3 ± 0.8 cm3 (V_{5-9}). Pearson correlation was $r = 0.67$ ($p < 0.01$) for V0-5 and $r = 0.62$ ($p < 0.05$) for V_{5-9}. Intraclass correlation coefficient test was 0.51 (V_{0-5}) and 0.28 (V_{5-9}) for consistency; and 0.43 (V_{0-5}) and 0.23 ($V_{5-9)}$ for absolute agreement. Low levels of NO (312.3 ± 43.8 ppb) were found and the correlation between NO levels and volumes (V_{0-5} or V_{0-9}) measured by AR was not statistically significant.*
Conclusions: *Compared to CT-scan, AR measurements accurately reflect the geometry of nasal cavity volumes in patients with nasal polyps, with a better assessment in the anterior part of the nasal cavity.*

Key words: accuracy, acoustic rhinometry, CT-scan, nasal polyps, nasal nitric oxide.

INTRODUCTION

Chronic rhinosinusitis (CRS) is a significant health problem which creates a large financial burden on society and presents a real challenge to physicians due to its severity and chronic evolution [(1)]. Nasal polyposis (NP) is considered a subgroup of CRS and is usually associated with asthma and aspirin intolerance. In the general population the prevalence of NP is 2-4% and in patients with asthma it ranges from 7 to 15%, whereas in NSAID-sensitive patients NP are found in 36 to 96%. Nasal obstruction, rhinorrea, loss of smell and facial pain are the most frequent reported symptoms. Nasal obstruction is one of the most disturbing symptoms in these patients and is associated with a reduced quality of life [(1)].

Several tools have been used to evaluate nasal obstruction, including computed tomography (CT) scan, magnetic resonance imaging (MRI), acoustic rhinometry (AR) and rhinomanometry. However, CT scan of the paranasal sinuses has become the examination of choice for the imaging evaluation of CRS/NP, as it has an excellent correlation with nasal endoscopy [(2)]. CT-scan provides objective evidence for a topographic diagnosis, it can be used for staging NP and it is indicated before endoscopic sinus surgery [(1)]. AR is a technique that provides accurate geometric measurements of nasal cavities by analysing reflected acoustic impulses; it is a non-invasive, rapid and reliable method that can be performed easily with minimal patient cooperation [(3,4)]. AR has been used to characterize the geometry of the nasal cavities, to assess the severity of nasal obstruction and to evaluate patients' response to medical and surgical treatment.

*Received for publication: April 7, 2009; accepted: July 5, 2009

DOI:10.4193/Rhin09.067

Although AR has been used to study several nasal conditions, its accuracy in patients with NP is as yet unclear. AR is not a technique to be used for the diagnosis. However, it is useful in the follow-up after medical and surgical treatment. This technique has previously been used to monitor the medical treatment of nasal polyposis [5] and to study the nasal volume before and after polypectomy [6]. CT-scan and MRI have been used as references in the evaluation of AR accuracy in cadavers, health volunteers and patients with turbinate hypertrophy [7-9], but never in patients with NP.

Measurements of nasal nitric oxide (nNO) can be used to assess nasal inflammation in NP patients [10,11].

The aim of the present study was to assess the accuracy of AR compared with CT-scan, which is the current golden-standard in the evaluation of nasal cavities in patients with NP. A secondary objective was to evaluate nasal inflammation by measuring nNO.

MATERIALS AND METHODS

Patients

All patients (n = 29, 79% males) had NP (score 2 to 3 on Lildholdt classification, score ranging 0-3) [12]. The mean age was 48.2 ± 13.6 yr (range 34-61). NP was diagnosed by nasal endoscopy. All patients were treated with intranasal corticosteroids.

All patients were submitted to sinus CT-scan, AR and nasal NO measurements and were evaluated by the same otorhinolaryngologist, allergologist and radiologist. These controls were performed on the same day, without any vasoconstrictor, and consecutively, with CT going first and then AR.

Acoustic rhinometry

Nasal volumes were measure by AR (Acoustic rhinometer SER 2000 RhinoMetrics, Lynge, Denmark) (Figure 1). All AR measurements were repeated three times and then averaged, in order to ensure the reproducibility of the results. The technique allowed us to analyse the minimum cross-sectional area (mCSA) and the distance to this point from the nostril

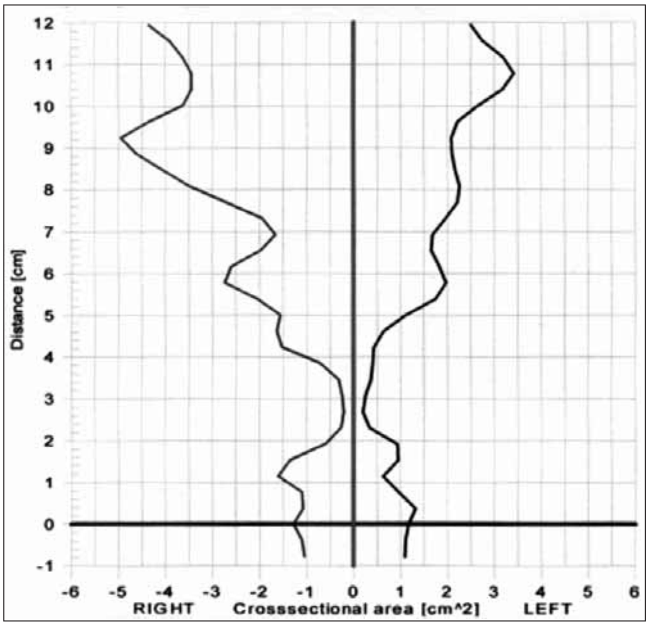

Figure 1. AR measurement of patient with nasal polyposis.
Nasal inlet corresponds to centimeter 0; cavum corresponds to centimeter 12; right and left lines represent sound wave reflection.

(dmCSA). The software also analyzed two volume regions: the anterior, defined as a region from the nostril to 5 cm into the nasal cavity (V0-5), and the posterior, defined as a region from 5 to 9 cm into the nasal cavity (V5-9). All measurements were performed in both the right and left nasal cavities [13].

CT scanning

All CT-scan explorations were made with a Siemens Somatom Plus 4 CT (Siemens, Erlangen, Germany) in a protocol designed for image-guided paranasal sinus surgery. The protocol consisted in an axial acquisition with the patient in a supine position and a neutral head position, with 3 mm slice thickness and 1 mm table increment and a matrix of 512 x 512 ranging from the upper margin of the frontal sinuses to the lower margin of the upper dental arch. Image post-processing performed on a Leonardo VD30B (Syngo, Siemens AG, Berlín and

Table 1. Acoustic rhinometry (AR) and sinusal Computed Tomography (CT) scan measurement in patients with CRS and nasal polyps.

	V_{0-5}		V_{5-9}		V_{0-9}	
	AR	**CT**	**AR**	**CT**	**AR**	**CT**
Mean cm^3 ± SD	8.9 ± 4.1	6.5 ± 1.9	15.5 ± 17.8	6.3 ± 4.3	24.4 ± 21.8	12.8 ± 5.8
	Intraclass correlation coefficient test (ICC)					
Consistency	0.515		0.277		0.334	
Absolute agreement	0.427		0.234		0.279	
	Pearson Correlation coefficient test (r)					
	0.67 ($p < 0.0005$)		0.59 ($p = 0.002$)		0.65 ($p = 0.001$)	

SD: standard deviation
V_{0-5}: volume between 0 and 5 centimetres from nasal inlet.
V_{5-9}: volume between 5 and 9 centimetres from nasal inlet.
V_{0-9}: volume between 0 and 9 centimetres from nasal inlet.
ICC: <0.40: bad; 0.41-0.75: good; > 0.75: very good.

Munich, Germany) workstation included 3D reconstructions and MPR reformats, resulting in coronal images of 3-mm-thick slices perpendicular to the hard palate roof at a total length of 12 cm from the tip of the nose. The volume of each nasal cavity was obtained by adding areas for each coronal image. Areas were calculated with a manual ROI with 500 and -1024 HU limits.

NO measurements

Nasal nitric oxide measurements were performed by chemiluminescence (SIR, System N6008 NO tracer, Madrid, Spain), following a standardized method, repeated three times and then averaged, in order to ensure the reproducibility of the results [(10)].

Statistical analysis

Data analysis was performed with the statistical package SPSS 14.0. The data are presented as mean ± SD (standard deviation). The relationship between the AR and CT volume data was tested by the Pearson correlation and intraclass correlation coefficient tests. Values of $p < 0.05$ were considered statistically significant.

RESULTS

CT and AR measurements values are expressed as right plus left sides (Table 1). All data volumes were higher when assessed by AR in comparison with CT-scan (V_{0-5}: 8.9 vs 6.5 cm^3; V5-9: 15.5 vs 6.3 cm^3; V0-9: 24.4 vs 12.8 cm^3). The dmCSA measured by AR was 4.7 ± 2 cm for the left side and 4.2 ± 2.2 cm for the right side. Mean values for NO were 312.2 ± 43.8 ppb. The correlation between NO levels and volumes (V_{0-5} or V_{0-9}) measured by AR was not statistically significant.

A statistically significant correlation between AR and CT was observed in the anterior part of the nasal cavity (V_{0-5}) when measured by the Pearson correlation coefficient test ($r = 0.67$, $p < 0.0005$) (Figure 2a). In contrast, weak correlations were found in the posterior segment of the nose (V_{5-9}) ($r = 0.57$, $p = 0.002$) and in the total volume (V_{0-9}) ($r = 0.65$, $p = 0.001$) (Figure 2b). When the correlation was performed with the intraclass coefficient test, a good consistency and absolute agreement was found in V_{0-5}, but not in V_{5-9}.

DISCUSSION

Although the accuracy of AR in studying the geometry of nasal cavities is well documented in several diseases, to our knowledge this is the first study that evaluates the accuracy of AR compared with CT-scan in patients with CRS and NP. We have demonstrated that AR measurements reflect the nasal volumes in patients with NP reasonably well, and that its accuracy is better in the evaluation of the anterior part of the nasal cavity (V_{0-5}). Compared with CT-scan (considered the gold standard), AR shows a good intraclass correlation coefficient, both for consistency (0.515) and absolute agreement (0.427) in the first 5 cm. Beyond this point the correlation is worse. On the other hand, the Pearson test shows a good correlation in both V_{0-5} ($r = 0.67$) and V_{5-9} ($r = 0.59$). The statistical test of choice for studying the agreement between two tests is, however, the intraclass correlation coefficient test. Previous studies have suggested the low reliability of AR measurements for both posterior nasal cavities and beyond any major obstruction [(13)]. We found the narrowest part of the nasal cavity between 4 and 5 cm (4.7 ± 2 cm for the left side and 4.2 ± 2.2 cm for the right side). So it could be the reason for the lower accuracy of AR measurements in posterior nasal cavities (V_{5-9}).

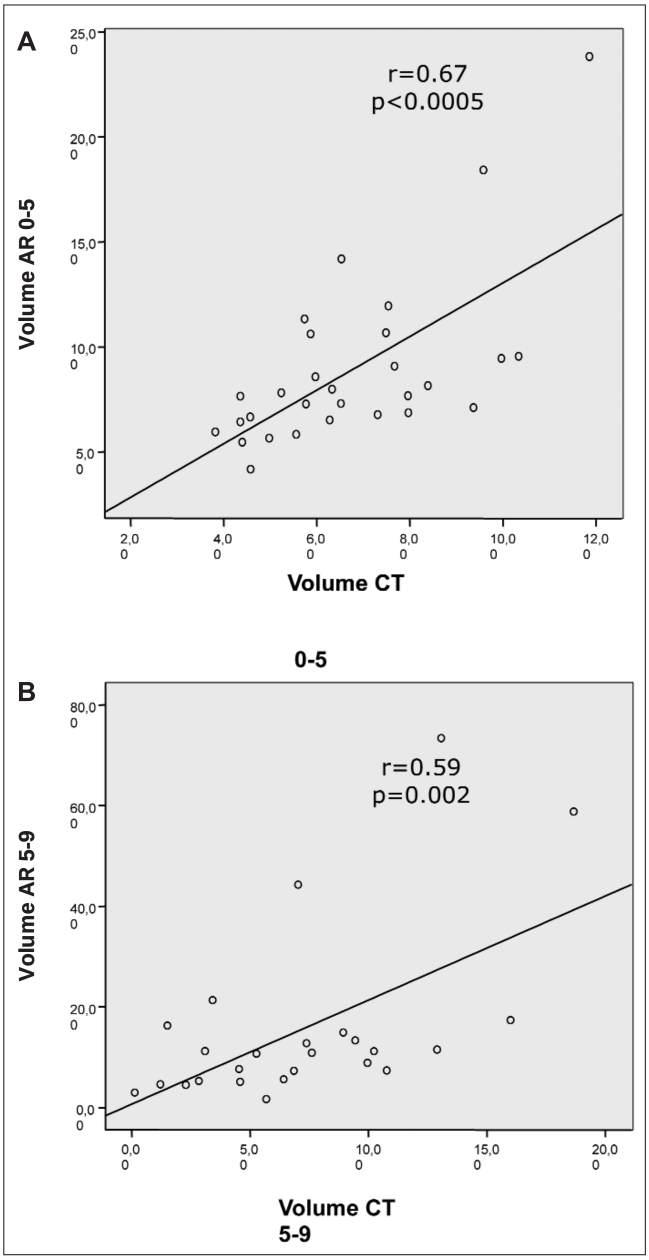

Figure 2. A) Pearson Correlation for volume between 0 and 5.
B) Pearson Correlation for volume between 5 and 9.

Several studies have compared the accuracy of AR with CT in different conditions. Hilberg et al. evaluated this relationship in cadaver models and found a good correlation (r = 0.69) [9]. Numminen et al. studied 13 patients diagnosed with CRS without NP and found a correlation of r = 0.59 [14], while Gilain et al., in a sample population of 9 patients with turbinate hypertrophy, demonstrated a better correlation (r = 0.62) [8]. Tarhna et al. evaluated the ability of AR to quantify paranasal sinus volumes and ostium size and found a good relationship when measurements were performed up to the ostiomeatal complex, whereas a bad correlation was observed beyond this point [15]. Terheyden et al. conducted a clinical study of 10 healthy volunteers and found a Person correlation value of 0.83 [16].

Nasal nitric oxide is produced in the respiratory tract, with a major contribution from the upper airways especially the maxillary sinuses. Although nasal polyposis is an inflammatory disease and we could expect high NO levels, some studies have found a decrease in nasal NO [11]. This paradoxical finding may be explained by the fact that a complete obstruction of the ostiomeatal complex by nasal polyps prevents the release of nNO from maxillary sinuses to nasal cavities. Colantonio et al. [11] classified patients with NP using the endoscopic Lund-Mackay staging scale (range 0-III), finding that nNO levels in patients with grade I were under 600 ppb, under 400 ppb with grade II and under 200 ppb with grade III. In our study population, where all patients scored 2-3 on the Lildholdt staging scale (similar limits to those of the Lund-Mackay), the nNO values were low (312.2 ± 43.8 ppb), within the same range as grade II in the Colantonio's study. However, the relationship between volumes and NO levels was not statistically significant. Thus, an increase of nNO levels could be an indirect marker of treatment response like was demonstrated by Ragab et al. [17], where the increase in nNO after medical and surgical treatment correlated with the improvement in symptom scores, endoscopic changes, and polyp grades.

CONCLUSION

In conclusion, this study demonstrates that AR is a reliable technique with good accuracy for evaluating the occupancy of nasal cavities in patients with CRS and NP. It remains to be seen, however, how AR can help us in the monitoring and follow-up of medical and surgical treatment of patients with nasal polyps.

REFERENCES

1. Fokkens W, Lund V, Mullol J; European Position Paper on Rhinosinusitis and Nasal Polyps group. European position paper on rhinosinusitis and nasal polyps 2007. Rhinology. 2007 (Suppl 20): 1-136.
2. Benítez P, Alobid I, de Haro J, et al. A short course of oral prednisone followed by intranasal budesonide is an effective treatment of severe nasal polyps. Laryngoscope. 2006; 116: 770-775.
3. Uzzaman A, Metcalfe D, Komarow H. Acoustic rhinometry in the practice of allergy. Ann Allergy Asthma Immunol. 2006; 97: 745-752.
4. Straszek SP, Schlünssen V, Sigsgaard T, Pedersen OF. Reference values for acoustic rhinometry in decongested school children and adults: the most sensitive measurement for change in nasal patency. Rhinology. 2007; 45: 36-39.
5. Eibrond O, Felding JU, Gustavsen KM. Acoustic rhinometry used as a method to monitor the effect of intramuscular injection of steroid in the treatment of nasal polyposis. J Laryngol Otol. 1991; 105: 178-180.
6. O'Flynn P. Acoustic rhinometry: validation of volume changes following intra-nasal polypectomy. Clin Otolaryngol Allied Sci. 1993; 18: 423-425.
7. Cakmak O, Co kun M, Celik H, Büyüklü F, Ozlüo lu LN. Value of acoustic rhinometry for measuring nasal valve area. Laryngoscope. 2003; 113: 295-302.
8. Gilain L, Coste A, Ricolfi F, et al. Nasal cavity geometry measured by acoustic rhinometry and computed tomography. Arch Otolaryngol Head Neck Surg. 1997; 123: 401-405.
9. Hilberg O, Jackson AC, Swift DL, Pedersen OF. Acoustic rhinometry: evaluation of nasal cavity geometry by acoustic reflection. J Appl Physiol. 1989; 66: 295-303.
10. ATS/ERS. Recommendations for standardized procedures for the online and offl ine measurement of exhaled lower respiratory nitric oxide. Am J Respir Crit Care Med. 2005; 171: 912-930.
11. Colantonio D, Brouillette L, Parikh A, Scadding GK. Paradoxical low nasal nitric oxide in nasal polyposis. Clin Exp Allergy. 2000; 32: 698-701.
12. Lildholdt T, Fogstrup J, Gammelgaard N, Kortholm B, Ulsoe C. Surgical versus medical treatment of nasal polyps. Acta Otolaryngol. 1988; 105: 140–143.
13. Hilberg O, Pedersen OF. Acoustic rhinometry: recommendations for technical specifications and standard operating procedures. Rhinology. 2000 (Suppl 16): 3-17.
14. Numminen J, Dstidar P, Heinonen T. Reliability of acoustic rhinometry. Resp Med. 2003; 97: 421-427.
15. Tarhan E, Coskun M, Ckamak O, Celik H, Cankurtaran M. Acoustic rhinometry in humans: accuracy of nasal passage area estimates, and ability to quantify paranasal sinus volume and ostium size. J Appl Physiol. 2005; 99: 616-623.
16. Terheyden H, Meaune S, Merten J, Hilberg O. Acoustic rhinometry validation by three-dimensional reconstructed computer tomographic scans. J Appl Physiol. 2000; 89: 1010-1021.
17. Ragab SM, Lund VJ, Saleh HA, Scadding G. Nasal nitric oxide in objective evaluation of chronic rhinosinusitis therapy. Allergy. 2006; 61: 717-724.

R. Muñoz-Cano
C/Villarroel
170 08036 Barcelona
Spain

Tel: +34-93-227 5540
Fax: +34-93-227 5455
E-mail: rmunoz@clinic.ub.es