■ ORIGINAL ARTICLES

The Use of Acoustic Rhinometry for the Assessment of Adenoid Hypertrophy: A Clinical Study

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Objective: In our study, we employed the method of acoustic rhinometry for preoperative and postoperative (after adenoidectomy) evaluation of 25 children between 3-12 years of age who suffered from adenoid hypertrophy.
Material and method: This method showed with accuracy the changes of the dimensions of the nasal cavity following the operation. The parameters which were evaluated prior and subsequent to the operation were the diameter of the nasal cavity in the area of the adenoids and the total volume of the nasal passage.
Results: As shown by acoustic rhinometry, the change of the cross-sectional area of the nasopharynx was 59.43% on average. Similarly, the augmentation of the volume of the nasal cavity was 46.39% on average. The change of the dimensions of the nasal cavity paralleled the alteration of clinical symptoms.
Conclusions: In conclusion, we can assume that acoustic rhinometry can show with accuracy the dimensions of the nasal cavity, especially at the front part. It is also very useful in the assessment of the efficiency of the treatment in cases of nasal obstruction and especially of adenoid hypertrophy.

Key words: Adenoids. Acoustic rhinometry. Hypertrophy.

Rinometría acústica en la valoración de la hipertrofia adenoidea. Estudio clínico
Objetivo: En nuestro estudio, utilizamos el método de rinometría acústica para la evaluación prequirúrgica y posquirúrgica (tras adenoidectomía) de 25 niños entre 3 y 12 años que presentaban hipertrofia adenoidea.
Material y método: Este método mostró con precisión los cambios en las dimensiones de la cavidad nasal tras la intervención. Los parámetros evaluados antes y después de la intervención fueron el diámetro de la cavidad nasal en el área de las adenoides y el volumen total del paso nasal.
Resultados: Como se observa por la rinometría acústica, el cambio en el área transversal de la nasofaringe fue de media del 59,43 %. De forma similar, el aumento de volumen de la cavidad nasal fue del 46,39 % de media. El cambio en las dimensiones de la cavidad nasal fue paralelo a las alteraciones de los síntomas clínicos.
Conclusiones: En conclusión, podemos asumir que la rinometría acústica puede mostrar con precisión las dimensiones de la cavidad nasal, especialmente en la parte frontal. También es muy útil en la valoración de la eficiencia del tratamiento en caso de obstrucción nasal y, especialmente, de hipertrofia adenoidea.

Palabras clave: Adenoides. Rinometría acústica. Hipertrofia.

INTRODUCTION

The nose is a very important factor in the overall functions of the respiratory system. The objective evaluation of the effectiveness of the nose, and especially its permeability, is required both for clinical diagnosis and to evaluate the effectiveness of treatment. Consequently, it was necessary to develop methods that could evaluate nasal permeability. These methods gave us the opportunity to determine the anatomic and functional conditions of the nose. Of these methods, the best known is rhinometry, which measures the resistance of the nasal passage to the flow of air.[1]

The biggest drawback is that rhinometry requires the collaboration of the patient. This creates problems in the use of the rhinomanometer in children and especially in very young children. Therefore, it was necessary to develop a new method for the objective assessment of nasal permeability which did not have the disadvantages of rhinomanometry.[2]

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Received February 21, 2008.
Accepted for publication July 18, 2008.

Table 1. Total Volume (mL) of the Nasal Cavity Before and After Adenoidectomy

Pre-operative			*Post-operative*		
Left Nasal Opening	*Right Nasal Opening*	*Total*	*Left Nasal Opening*	*Right Nasal Opening*	*Total*
4.97	3.46	8.40	5.95	6.34	8.43
4.47	2.55	7.02	12.10	4.28	16.38
4.36	3.21	7.57	10.30	9.32	19.62
5.02	4.68	9.70	11.20	5.47	16.67
6.65	4.47	11.12	9.63	5.08	14.71
10.30	4.36	14.66	16.10	5.74	21.84
11.90	3.79	15.69	6.38	5.69	12.07
4.29	4.43	8.72	4.49	3.00	7.49
2.24	2.06	4.30	2.07	3.68	5.75
4.80	2.80	7.60	3.49	4.62	8.11
4.16	4.66	8.82	4.21	4.76	8.97
5.24	7.40	12.24	5.24	7.40	12.64
3.25	2.94	6.19	14.80	11.90	26.70
4.33	3.20	7.53	10.20	9.21	19.41
4.43	2.40	6.83	11.09	4.10	15.19
6.42	4.10	10.52	9.10	5.00	14.10
5.08	4.26	2.34	11.10	5.11	16.21
2.08	2.01	4.09	2.01	3.13	5.14
4.11	4.43	8.54	4.23	4.70	9.03
11.02	4.02	15.04	6.33	5.62	11.95
10.01	4.11	14.12	15.09	5.03	20.12
6.22	4.19	10.41	9.23	5.01	14.24
4.22	4.41	8.63	4.46	3.70	8.16
2.20	2.10	4.30	2.32	3.20	5.52
6.21	4.40	10.61	9.60	5.00	14.60

A more modern examination that evaluate the permeability of the nose is acoustic rhinometry. This method is based on the analysis of the sound reflected from the walls of the nasal cavity. The curve presented by the acoustic manometer shows the points where the nasal cavity narrows in relation to the distance from the nasal vestibule.[3,4]

The history of acoustic rhinometry is not very long. It began in 1987 when Andrew C. Jackson of Boston University's Department of Biomedical Engineering took his knowledge to the University of Aarthus in Denmark.

His theory on measuring the size of the cavity through sound was not new. It was used in the past to study the tracheal rings, but nobody had used this method in the nasal cavity. The use of this method at the University of Aarthus led to the development of acoustic rhinometry.

In 1989, Hilberg described acoustic rhinometry for the first time as a simple, fast and non-invasive test for the study of the geometry of the nasal cavity. The accuracy of this method was verified by a number of applications in models, tests in cadavers and in vivo.[4,5] Research continues to increase the accuracy and clinical usefulness of this method.[6-8]

The acoustic rhinometry device sends a sound to the interior of the nasal cavity through a nozzle that is carefully placed at the entrance of each nasal opening. The sound sent by the acoustic rhinometer is reflected on the walls of the nose and a part of it returns to the insertion point of the acoustic rhinometer and is then recorded by a microphone. The characteristics of the resonance change in relation to the dimensions of the nasal cavity. A computer analyzes the reflected sound and the result takes the form of a curve that gives us the surface of the nasal cavity at each point in relation to the distance from the vestibule of the nose.

In this study, efforts have been made to evaluate the efficiency and accuracy of this method compared with another conventional method in the detection of adenoid hypertrophy and, as a result, to evaluate the effectiveness of the surgical treatment.

MATERIAL AND METHOD

Acoustic rhinometry was used in 25 children between 3 and 12 years of age, all presenting adenoid hypertrophy diagnosed by medical history, clinical examination and other paraclinical objective methods, such as the classic x-ray of the soft tissue in the nasopharynx and endoscopic examination with flexible nasopharyngoscope as well as by rhinomanometry.

The children had no recent history (during the previous month) of common cold, perennial rhinitis or chronic respiratory symptoms. None received chronic medication and drugs were not allowed during the 48 hours prior to the initial day of the study. Children with nasal structural abnormalities during the otolaryngology examination, septal deviation, hypertrophy of cornets, and polyps were excluded. Informed consent was previously obtained from all participants.

We studied the shape of the curve of the acoustic rhinometry, as well as the values of the minimal transverse area of the nose in the nasopharynx and the total volume of the nasal cavity (Table 1).

The instrument used was the AL type acoustic rhinomanometer from GM Instruments, with observance of all necessary pre-conditions to achieve accurate and reliable measurements.

The acoustic rhinomanometry was carried out according to the clinical guidelines of the Committee on Standardization of Acoustic Rhinometry.[5] The latest guidelines[9] for rhinometry remain, in general, unchanged and their most important part is: *a)* trained staff should carry out quality assurance tests on the equipment; *b)* daily monitoring with a standard nose should be performed, as well as testing the straightness of the pipe; *c)* a calibration check should be performed weekly; d) environmental conditions must be stable; and *e)* the reproducibility and acceptance of the measurements should be assessed. A standard nose is a plastic model with circular areas providing an area-distance function based on multiple records in a normal nose and is used to test and calibrate the equipment.

The above method was used a month after a surgical intervention in the 25 children selected for adenoidectomy to treat adenoid hypertrophy.

Our measurements showed that the average distance from the nostril to the adenoid in the pre-operative curves of the acoustic rhinometry was 6.70 (0.78) cm, equivalent to the findings of other studies.[10,11] A later study similar to ours also indicated, in the x-ray examination, an increase in the linear distance of the airspace of the nasopharynx according to age (from 12.47 mm at an age of 4-5 years to 20.36 mm at an age of 14-15 years).[12]

Table 2. Statistical Analysis

Paired Student *t* test		
Average, mL	8.9996	13.3220
Standard deviation	3.5238	5.5904
SEM	0.7048	1.1181
n=25, *t*=3.7156, df=24, standard error difference = 1.163		
Confidence interval:		
Mean post-operative minus pre-operative volume equal to 4.3224 mL		
95% confidence interval for this difference, 1.9214-6.7234		
P=.0011		

RESULTS

During the preoperative evaluation, we measured the area of both nasal cavities in the 25 children as well as the minimum section area at the nasopharynx level, with an average result of 2.5 cm^2, with values between 0.9 and 4.5 cm^2. We also obtained measurements for the volume of each nostril and the total volume of both, with an average result of 10 cm^3 and values between 4.3 and 14 cm^3 (Table 1).

After adenoidectomy, the average of the minimum section area at the nasopharynx was 3.97 cm^2. Therefore, the post-operative increase in this area was 59.4%. Similarly, the average total volume of the nasal cavities was 13.79 cm^3 post-operatively, representing an increase of 46.4% in the total volume (Figure).

These alterations coincide with the endoscopic and x-ray findings. The post-operative images showed an increase of 0.5 cm on average in the palatine and nasopharyngeal air.

Statistical analysis of these results (paired Student *t* test) was carried out using the Statistical Package for the Social Sciences application (SPSS version 16.0). The results indicate that the increase in nasopharyngeal volume after adenoidectomy is considered to be statistically significant (2-tailed values, *P*=.0011) and also corresponds with the post-operative radiological examination (Table 2).

DISCUSSION

The nose plays a very important role in the normal functioning of the respiratory system. The nose contributes mainly to the homeostasis of inhaled air and is necessary for the normal operation of the lower respiratory system. Therefore, a normal nose needs sufficient permeability but this may be affected by many diseases, such as nasal septum deviation, cornet hypertrophy, allergic rhinitis, vasomotor rhinitis and, particularly among children, adenoid hypertrophy usually requiring surgery. Disorders causing nasal obstruction require treatment which may, depending on each case, imply surgery or nasal medication.[13,14]

Acoustic rhinometry also enables us to measure the volume of each nasal cavity. Therefore, in order to obtain reliable and accurate measurements with the acoustic rhinometer, certain preconditions must be met to guarantee the outcome of the examinations. The European Rhinologic Association struck the Committee for Standardization of Acoustic Rhinometry to set out certain standards for the practical implementation of the method.[5]

Therefore, before each application of the method, the following requirements must be met: *a)* check of the equipment settings[15]; *b)* monitoring of the surroundings[15-17]; *c)* check of the patient's position[5,15,18]; *d)* monitoring of the breathing during measurements[5,15]; *e)* adjustments of the insertion in the interior of the nasal opening[18]; *f)* reproduction of the alignment of the pipe with the nasal axis[5,18]; and g) experience of the examiner.

In our study we apply these requirements as strictly as possible to ensure highly reliable results.

Using the acoustic rhinometry method on the children in our study, we found that it requires less co-operation from patients, which means that it can be more easily applied to children compared with rhinomanometry. The curve presented by acoustic rhinometry correlated well with the surface of the nasal cavity and the distance from the vestibule of the nose, as well as its volume. By measuring the adenoids before surgery, this test has been shown not to prove its value as fully as in other cases, such as septal deviation. The distance from the adenoids to the nozzle of the device is relatively long and the sound wave is distorted. Another problem with the measurements in the area is that the sound wave spreads in the nasopharyngeal area, which produces significant variations during the pre-operative measurements. Indeed, the acoustic rhinometer gives us some indication of adenoid hypertrophy by means of a notch at a distance of about 6 cm from the vestibule of the nose. The size of the notch in this area gives us an indication of the size of the adenoids. There is no of question of the usefulness of this examination in order to verify the effectiveness of adenoidectomy and the post-operative changes arising in the nasal cavity and the nasopharynx, as shown in the diagrams representing the evaluation of patients examined before and after surgery in relation to the minimum cross sectional area of the nasal cavity in the area of the nasopharynx, as well as its total volume. We found an

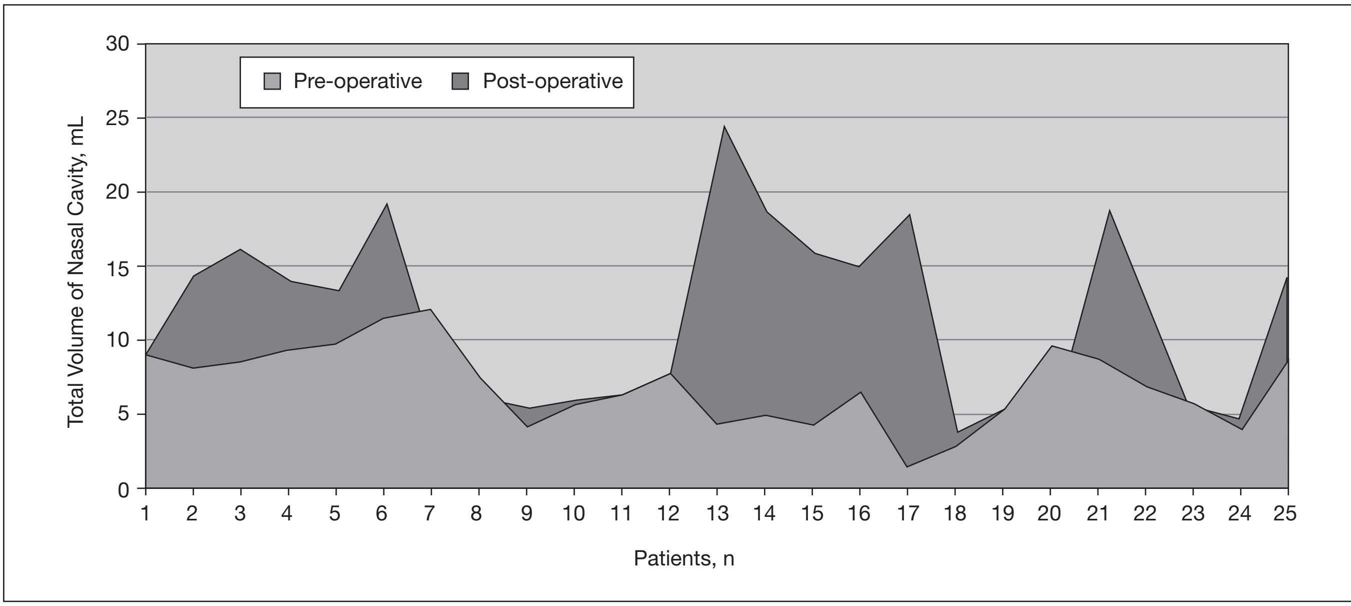

Figure. Changes in the total volume of the nasal cavity before and after surgery.

increase of 59.43% in the surface area of the nasal passage and a 46.39% increase in volume (Figure). The measurements taken before surgery varied significantly (ie, they were less precise), but at the moment they cannot be safely used in the diagnosis of adenoid hypertrophy. This conclusion was also reached by Mann et al,[7] 1997, and Fisher and Boreham,[19] 1995, in their research. However, there is no denying that acoustic rhinometry can indeed assess the changes occurring within the nasal cavity after adenoidectomy, as also noted by Kim et al,[20] 1998, in line with our results since the changes in the parameters evaluated after adenoidectomy with the previous method were consistent with clinical improvement of the symptoms of adenoid hypertrophy.

Prior to surgery, the average minimum transverse area was of 2.49 cm^2. After surgery, the average measurement in the same area was 3.97 cm^2. Therefore, the transverse area of the nasopharynx in the area of the adenoids experienced an increase of 59.43%.

As well as measuring the section in the area of the nasopharynx, we used the acoustic rhinometer to measure the total volume of the nasal cavity.

Diagnostically, the measurements of the anterior nasal passage are reasonably accurate if the air passage of the nasal valve is within the normal limits. The accuracy of these measurements may be significantly affected by diseases narrowing the anterior nasal passage, such as septal deviation, polyps, tumours, membranes, constriction, or nasal valve in the paediatric population.

In clinical studies, the oscillation of the area-distance curve beyond significant constraints may lead to errors of misinterpretation. In addition, a review of the published literature shows that many reports have presented artefacts associated with this technique as valid data. It is very important for all users to be aware of the potential sources of error in these measurements. Our results indicate that, despite the particular configuration of the nasal cavity model, they do not provide reliable information about the section areas following severe constriction.[21] Another point is that the size of the paranasal sinus ostium and the volume of the paranasal sinus provide the correct measurement, leading to significantly overstated estimates, especially in the distal part of the nasal cavity.[22] It is important to be aware of the limitations of this method, since it is the only way to avoid erroneous measurements. The accuracy of these measurements of the nasal cavity depends largely on the anatomy of the nasal passage, especially in the narrowed sections. Our results clearly confirm that acoustic rhinometry is only reliable to quantify changes in the initial part of the nasal cavity. The decline in the area of the nasal passage of the nasal valve reduces the role of acoustic rhinometry as a diagnostic tool for the measurement of the total nasal cavity.[23]

To conclude, acoustic rhinometry is a method for the measurement of the diameter of the nasal passage in relation to the distance from the nasal opening. It is the most modern method for evaluating the nasal passage and, as a result, the function of the nose.

The main information provided by acoustic rhinometry is the minimum diameter of each nasal cavity and, therefore, the total surface area at the minimum cross-section of the nasal cavity, as well as its total capacity.

The accuracy of the method is high in the area of the nasal valve where the narrowed point of the nose is located. By contrast, in the area of the nasopharynx, there are difficulties in the estimation of the dimensions of the nasal cavity.

Lastly, in children with adenoid hypertrophy, the value of acoustic rhinometry as a diagnostic method is limited. In addition, with regard to the verification of the post-operative changes in the interior of the nasal cavity, there was a significant change in the parameters evaluated.

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