Can the Acoustic Rhinometry Reflect the Real Volume Change of the Nasal Cavity?

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ABSTRACT
Background and Objectives Acoustic rhinometry (AR) measures nasal cavity geometry by analyzing reflected acoustic impulses. The authors aimed to find out whether AR could reflect the volume change developed from conchotomy. Materials and Methods To establish the test-retest reliability of the AR, 20 normal nasal cavities were tested with AR before conducting main study. The volumes of the 31 conchotomy specimens were measured with water displacement method (WDM). The nasal volume changes in accordance with conchotomy operations were measured with AR, and the paired values were compared. Results AR revealed highly consistent results as there was statistically significant correlation between test and retest values ($r = 0.98$, $p<0.0001$). The volume of the conchotomy specimens measured with WDM was $1.40\pm 0.63$ cm$^3$ (mean$\pm$ SD) and the volume change measured with AR was $1.49\pm 1.48$ cm$^3$ (mean$\pm$ SD). There was statistically significant correlation between the two values ($r = 0.55$, $p<0.01$), though they were not so consistent with each other. Conclusion The nasal volume change after conchotomy measured with AR correlates with the conchotomy specimen volume with statistical significance, though the correlation between them does not always show consistency.

KEY WORDS Acoustic rhinometry · Conchotomy · Water displacement method · Nasal volume.

INTRODUCTION

Acoustic rhinometry (AR) measures the cross-sectional area and volume of the nasal cavity by analyzing reflected acoustic impulses, thus it can be employed to study the change of nasal cavity mucosa, abnormal structure and physiological conditions.

As objective methods for diagnosing nasal diseases or comparing conditions before and after operations, radiological examinations such as computerized tomo-gram (CT) and magnetic resonance imaging (MRI), peak flowmeter, spirometry, body plethysmography, rhinostereometer, rhinomanometry, and AR are used.\(^1\)\(^3\)

The advantages of AR include non-invasiveness and high reproducibility of the tests. However, the precisness of the results measured by AR has been controversial and studies related with the issue have been conducted. Hilberg \(^1\) measured the cross-sectional area and volume of nasal cavity from a dead body with CT and compared the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR. Meanwhile, Min \(^2\) reported that there was a linear correlation between cross-sectional area and volume of nasal cavity from a dead body with CT and the values with ones measured by AR.
MATERIALS AND METHODS

Subjects

Eighteen patients who visited the hospital with nasal obstruction as their chief complaint and were diagnosed with chronic hypertrophic rhinitis (CHR) were selected for this study, and they underwent conchotomy operations which were done by a single surgeon. Of the total 18, 14 were male and 4 were female with an average age of 28 years, ranging from 15 years to 46 years. Of them, 17 patients also had deviated nasal septum, four had allergic rhinitis, and one chronic sinusitis. A total of 31 conchotomies were conducted including bilateral conchotomy in 13 patients and unilateral conchotomy in 5 patients. The 31 nasal cavities were the study subjects. The 17 patients with deviated nasal septum were treated with septoplasty and the one with chronic sinusitis was treated with endoscopic sinus surgery at the same time (Table 1).

Methods

The patients were placed in a supine position with their heads up about 30. After a tampon anesthesia for 10 minutes with a gauze dampened with 2% lidocaine and 1:100,000 epinephrine, the nasal septum and inferior turbinates of the patients were also injected with a mixture of 1% lidocaine and 1:100,000 epinephrine. Then, we waited for 10 minutes before we began the operation. On the 17 patients having deviated nasal septum, septoplasty was conducted first. After septoplasty, the first AR was taken just before conducting conchotomy. The conchotomy was carried out with conchotome scissors and a bipolar coagulator was used in case of bleeding. When too much time (longer than 10 minutes) was needed for conchotomy and bleeding control, the patients were excluded from the study. Immediately after the conchotomy, the second AR was conducted. The endoscopic sinus surgery (ESS) which was performed in the first case was conducted after the second AR. The acoustic rhinometer employed was made by Eccovision Acoustic Rhinometry System (Hood Laboratories, Pembroke, Mass., USA) which was set to measure nasal cavity volume from the nostril to the posterior area up to 7 cm. The nose tip was inserted by making an angle ranging from 40 to 70 against the nasal floor and size of the nose tip was large enough that the end of the tip was not allowed to enter into the nasal cavity more than 2 mm. During the examination, the patients were told to hold their breath. We took care that the nasal septum would not be pushed by the nose tip and the measurement was done by a single examiner.

When the nasal cavity volume before and after the conchotomy is measured with AR, the volume change developed from the conchotomy can be obtained. The nasal cavity volume after the conchotomy minus the volume measured before the conchotomy is the volume change (Fig. 1).

The real volume of the resected turbinate was measured by water displacement method (WDM). A 10 ml plastic syringe was removed with its plunger and the tip of the needle was curved to prevent water leaking. Then it was filled with 5 ml distilled water and the conchotomy specimen was put in. The specimen heightens the water level in the syringe, and the change of the water level can be interpreted as the real volume of the

![Fig. 1. Acoustic rhinometry (AR) before and after conchotomy. Shaded area represents nasal volume change after conchotomy.](image-url)
specimen (Fig. 2). Changes of nasal volume measured with AR were compared with the volume of conchotomy specimen measured with WDM.

To confirm the preciseness of the testing equipment and the reproducibility of the tests, two rounds of AR were conducted on 20 nostrils of 10 normal male subjects without nasal diseases at 5-minute intervals. The test-retest reliability was confirmed by measuring the nasal cavity volume from the nostril to posterior area up to 7 cm.

For the statistical analysis, the Spearman rank correlation coefficient test was employed and the statistical significance was judged at $p$-value $< 0.05$.

**RESULTS**

**Test-retest reliability of AR on normal subjects**

The nasal cavity volume from the nostril to 7 cm posteriorly on 20 nasal cavities of 10 normal adult subjects in the first AR measurement was $10.5 \pm 5.7$ cm$^3$ (5.7-16.9 cm$^3$) on average. The second AR test conducted five minutes after the first test showed the average nasal cavity volume to be $10.5 \pm 5.2$ cm$^3$ (5.2-17.4 cm$^3$), revealing a high test-retest reliability. ($r = 0.98$, $p < 0.0001$, Fig. 3).

**Changes of nasal cavity volume measured with AR before and after conchotomy**

The nasal cavity volume from nostril to 7 cm posteriorly measured before conchotomy was $9.66 \pm 5.89$ cm$^3$ (5.89-12.51 cm$^3$) on average and was recorded to be $11.5 \pm 7.84$ cm$^3$ (8.46-18.2 cm$^3$) on average after conchotomy, showing that the volume increased by $1.49 \pm 1.48$ cm$^3$ on average (Fig. 4). But in two nasal cavities where the conchotomy specimen volume measured with WDM was smaller than 1 cm$^3$, the nasal cavity volume measured actually decreased after the conchotomy.
**The volume of conchotomy specimen measured with WDM**

The volume of resected inferior turbinate ranged from 0.4 to 2.8 cm$^3$, showing a big difference between each patient with an average value of 1.40 cm$^3$ (SD, 0.63 cm$^3$) (Fig. 4).

**Correlation between AR and WDM measured volumes**

The change of nasal cavity volume measured with AR was 1.49 cm$^3$, which is compared to the conchotomy specimen volume of 1.40 cm$^3$ measured with WDM, showing no significant difference. There was a statistically significant correlation between volumes measured with the two methods ($r = 0.55$, $p < 0.01$, Fig. 4). In 14 specimens, the AR measured volume was bigger and in 16 specimens the WDM measured volume was bigger, suggesting rough functional relation between them, even if not an exact one.

**DISCUSSION**

The applications of AR has been increasing since 1989 when Hilberg et al.$^{1}$ reported its clinical effectiveness in examining the nasal cavity. Its merits include easy testing, objectivity, quantitative analysis on the nasal cavity structure, etc and thus various clinical applications have been reported.$^{3-7}$

To evaluate the characteristics of AR, several studies were conducted on the correlation between nasal cavity volume measured with AR and other objective testing methods. In addition to reports on significant correlations between cross-sectional areas measured with CT and AR mentioned in the introduction part,$^{12}$ a significant correlation between the nasal cavity volume measured AR before and six weeks after the nasal polypektomy, and the nasal polyp volume measured with WDM at the time of surgery was confirmed.$^{30}$ There was also a report on a significant correlation between the volume of the nasopharynx before and after adenoidectomy, and the volume of adenoids.$^9$

It is required to know whether the nasal cavity volume measured with AR is identified with the actual nasal cavity volume in order to judge the preciseness of the testing results of AR. In this study, the actual volume of resected inferior turbinate measured with WDM was compared with the nasal cavity volume change measured with AR. The study results also proved a significant correlation between the actual volume of resected inferior turbinate and the nasal cavity volume change measured with AR. But the correlation coefficient was not so high ($r = 0.55$), which can be explained by the following reasons. First, the change of anatomical structure due to conchotomy would have influenced the volume measurement. For example, AR is known to represent the volume of posterior part bigger than the actual volume when there is an isthmus. In a study using an experimental model, the error between the actual volume and the measured value was less than 10% when the narrowest cross sectional area was bigger than 0.4 cm$^2$, and the critical value was set at 0.4 cm$^2$. Therefore, when the cross-sectional area of the isthmus part was bigger than 0.4 cm$^2$, the volume of resected inferior turbinate was almost identified with the nasal volume change measured with AR. But when it is smaller than 0.4 cm$^2$, the two values would not be same. There was another report which showed that the measurement of the cross-sectional area with AR became incorrect as it goes further to the posterior area of the nasal cavity. In this study, the area which had not been measured before the surgery due to the hypertrophy of the inferior turbinate might be measured after the resection of the turbinate due to the anatomical change. Secondly, the volume of inferior turbinate in vivo might not remain unchanged as in a cadaver because it is connected with blood vessels and the nervous system, although the influence of the neurotransmitter or vasodilatation was minimized with tampon anesthesia. Another reason for smaller average volume of conchotomy specimen measured with WDM than the AR measured volume can be contributed to the contraction of the specimen after the surgery due to disconnecting it from blood vessels or nervous system. Thirdly, the error might be caused as the authors measured only one time during the surgery while other AR studies repeated the tests 2-3 times to obtain an average value. Not only the simple change of volume due to surgery, but the change of structure position can also influence the acoustic reflection. A change of surface, as with exposure of the turbinate bone due to resection of mucosa could influence the acoustic reflection.
CONCLUSION

After measuring the volume of the conchotomy specimen with WDM and the nasal cavity volume change with AR, we found a significant correlation between the two measured values. However, AR does not consistently reflect the change of nasal cavity volume due to conchotomy surgery.

REFERENCES