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Correspondence between anatomical locations and points on the area–distance curve of acoustic rhinometry in an artificial model of a 5-year-old Japanese child

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Abstract

Determining the correspondence between points on the area–distance curve derived from acoustic rhinometry and the anatomical landmarks in the nasal and nasopharyngeal airway is important for the clinical evaluation of obstructive sleep apnea in children. In this study, area–distance curves derived from acoustic rhinometry (SER-2000; Rhino Metrics Co., Ltd., Denmark) were measured in a life-size, artificial, soft-silicon, upper-airway model of a healthy 5-year-old child (Koken Co., Ltd., Japan). We created obstacles in both the nasal cavity and nasopharynx with clay, simulating various grades of adenoid hypertorophy. On the area–distance curve, the anterior portion of the inferior turbinate corresponded to the region between the second notch and third peak, the posterior end of the nasal septum corresponded to the third peak, and the adenoid corresponded to the region from immediately after the third peak to 8 mm posterior to the fourth notch. The measured adenoidal volume matched the actual volume of the simulated adenoid; however, the measured airway volume of the nasopharynx according to acoustic rhinometry was far greater than the actual volume of the model. We conclude that the landmarks identified on the area–distance curve and the changes in adenoid volume measured with acoustic rhinometry have potential clinical application. However, acoustic rhinometry measurements of nasopharynx airway volume could be improved.

Keywords: Nasal cavity, Nasopharynx, Acoustic rhinometry, Children, Obstructive sleep apnea

Introduction

Rhinomanometry is a well-established method for the physiological evaluation of nasal patency.[1] In contrast, acoustic rhinometry (AR), which provides morphological information for objective nasal assessment,[2,3] has problems that need to be resolved before it can be considered suitable for widespread application. Four main issues have been identified.[1] First, the true direction of sound through the nasal cavity in AR is unclear. Second, the directions of the sectional areas of AR in the nasal cavity are obscure. Third, the geographical precision of AR in the nasal cavity is unclear. Fourth, AR may be inadequate when measuring the posterior nasal cavity and nasopharynx.

The evaluation of adenoid hypertorophy is especially important when assessing the suitability of adenoidectomy in children with obstructive sleep apnea (OSA). AR may be suitable for the objective assessment of adenoid hypertrophy; various evaluation procedures have been employed to assess adenoid hypertorophy in children with OSA and to verify objective changes after adenoidectomy.[4–11] In recent years, nasal obstruction has also been shown to be an important cause of OSA in children.[12,13] Given these factors, objective assessment of nasal patency with AR is also necessary in children with OSA.[14] However, for this technique to be truly valuable in a clinical setting, research is needed to clarify the correspondence between the anatomy of the nasal and nasopharyngeal airways and points on the AR area–distance curve and to assess the proportional change after nasal treatment and adenoidectomy.

In this study, we attempted to correlate anatomical locations in the nasal cavity and the nasopharynx of an artificial model with points on the AR area–distance curve.

Materials and methods

This study was conducted using a life-size, artificial, soft-silicon, upper-airway model of a healthy 5-year-old child (Koken Co., Ltd., Japan) because there is a significant increase in adenoid size from 3 to 6 years of age.[15] AR was performed with an SER-2000 Acoustic Rhinometer (Rhino Metrics Co., Ltd., Denmark; Figure 1) and measured with and without obstacles. It was measured AR area–distance curves under identical conditions by a single examiner. Artificial obstacles were simulated in the model with clay, as follows:

1) Two grades of entire inferior turbinate hypertrophy (0.4 cm³ and 0.8 cm³).
2) An obstacle at the posterior edge of the nasal septum.
3) An obstacle at the posterior end of the nasopharynx (Figure 2).
4) Four grades of adenoid hypertorophy in the nasopharynx (Grade 1: 0.4 cm³; Grade 2: 0.8 cm³; Grade 3: 1.2 cm³; and Grade 4: 1.6 cm³).

We confirmed the locations of these obstacles on the area–distance curve and with quantitative analysis of the proportional changes in the inferior turbinate, adenoid, and nasopharyngeal airway.
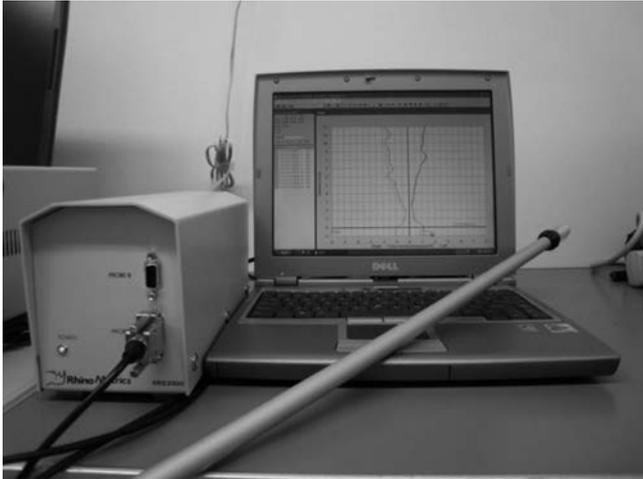
Figure 1 The acoustic rhinometer. SER-2000 Acoustic Rhinometer (Rhino Metrics Co., Ltd., Denmark)
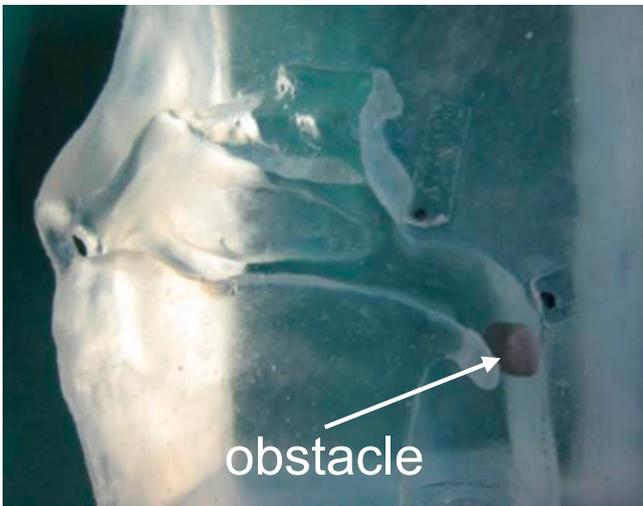

Figure 2 The artificial upper-airway model with an obstacle at the posterior end of the nasopharynx. The life-size, artificial, soft-silicon, upper-airway model of a healthy 5-year-old Japanese child (Koken Co., Ltd, Japan). The obstacle was placed at the posterior end of the nasopharynx in this model.

Results

Points on the area–distance curve of the nasal and nasopharyngeal model of a healthy 5-year-old Japanese child without any simulated obstacles are shown in Figure 3. The first dip from the anterior nostril on the area–distance curve was defined as the first notch and the following peak was defined as the first peak; these were followed by the second notch, second peak, third notch, third peak, fourth notch and fourth peak, in that order.

On the area–distance curve, all changes in the nasal turbinate began at the second notch and diminished immediately before the third peak (Figure 4). The obstacle at the posterior edge of the nasal septum was identified at the third peak (Figure 5). The obstacle at the posterior end of the nasopharynx was detected at a location 8 mm posterior to the fourth notch (Figure 6). The nasopharyngeal lumen corresponded to the area from a point
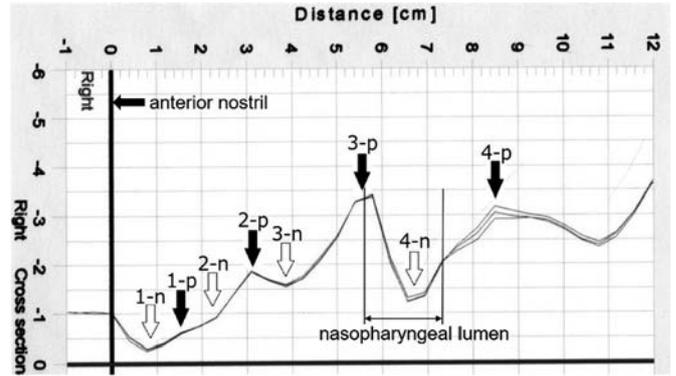

Figure 3 Points on the area–distance curve of AR in the nasal and nasopharyngeal model without simulated obstacles. The first dip from the anterior nostril of the area–distance curve was defined as the first notch (1-n), the following peak as the first peak (1-p), and so on, to the fourth peak (4-p) in order.
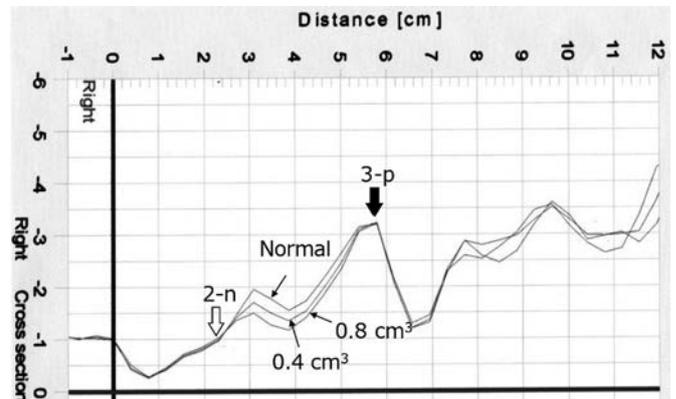

Figure 4 Changes in the area–distance curve with inferior turbinate hypertrophy. Changes in the nasal inferior turbinate began at the second notch and diminished immediately before the third peak on the area–distance curve.
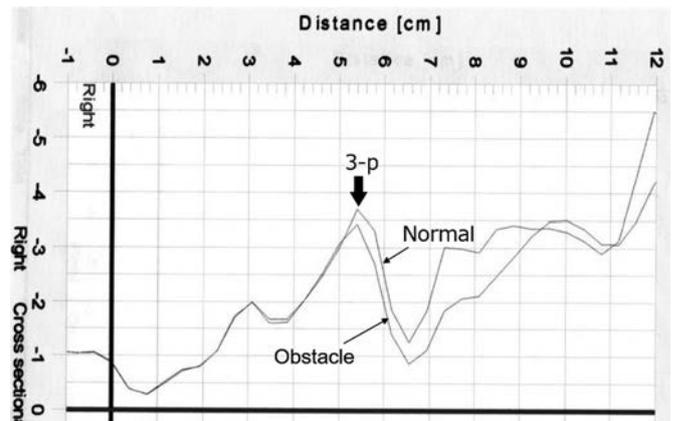

Figure 5 Changes in the area–distance curve with an obstacle at the posterior edge of the nasal septum. The obstacle at the posterior edge of the nasal septum in the model was identified at the third peak on the area–distance curve.

immediately after the third peak to a point 8 mm posterior to the fourth notch. The changes on the area–distance curve with the four grades of simulated adenoid hypertrophy are shown in
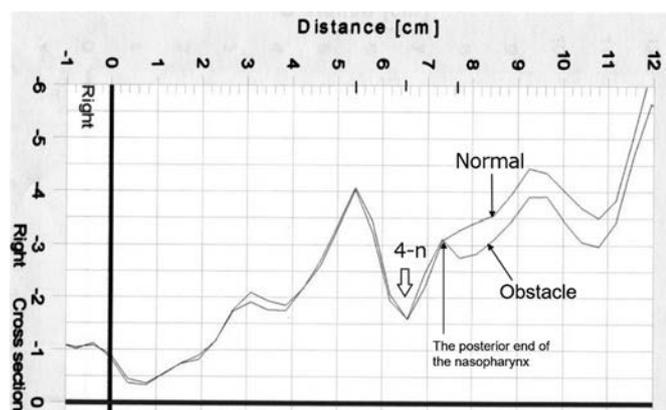
Figure 6   Changes in the area–distance curve with an obstacle at the posterior end of the nasopharynx. The obstacle at the posterior end of the nasopharynx was detected at 8 mm posterior to the fourth notch on the area–distance curve.
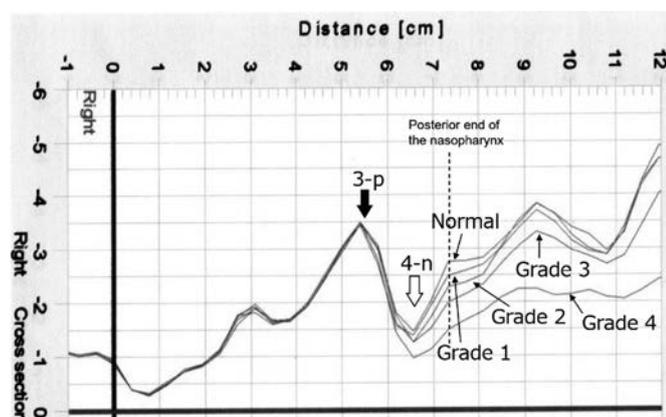

Figure 7   The changes on the area–distance curve by grade of simulated adenoidal hypertrophy. The nasopharyngeal lumen was located between the point immediately after the third peak and the point 8 mm posterior to the fourth notch. Grade 1: 0.4 cm^3, Grade 2: 0.8 cm^3, Grade 3: 1.2 cm^3, and Grade 4: 1.6 cm^3

Figure 7.

Quantitative analysis by an accompanying software with AR showed that the actual volumes of the models of simulated inferior nasal turbinate hypertrophy were 0.4 cm^3 and 0.8 cm^3, corresponding with AR estimates of 0.5 cm^3 and 0.91 cm^3, respectively. These differences between actual and estimated volumes were minor. The actual and estimated volumes of the simulated adenoid hypertorophy and of the nasopharyngeal lumen are shown in Tables 1 and 2, respectively. For each grade of adenoid hypertrophy, the estimated and actual adenoid volumes were almost equivalent. However, the estimated airway volumes of the nasopharynx were considerably greater than the actual volumes.

Discussion

AR has been developed as an objective method of assessing the nasal cavity and nasopharynx[1,2,3] that allows reproducible measurements.[1] Given that adenotonsillectomy is considered effective for the management of OSA in children,[4] objective evaluations of nasopharyngeal conditions are important in this

Table 1   Estimated and actual adenoid volumes by grade of hypertrophy

Hypertrophy grade	Actual volume (cm^3)	Estimated volume by AR (cm^3)
1	0.4	0.62
2	0.8	0.75
3	1.2	1.07
4	1.6	1.76

AR, acoustic rhinometry; Grade 1: 0.4 cm^3, Grade 2: 0.8 cm^3, Grade 3: 1.2 cm^3, and Grade 4: 1.6 cm^3.

Table 2   Estimated and actual nasopharyngeal airway volumes by grade of adenoidal hypertrophy

Hypertrophy grade	Actual volume (cm^3)	Estimated volume by AR (cm^3)
0	2.5	6.33
1	2.1	5.70
2	1.7	5.57
3	1.3	5.25
4	0.9	4.56

AR, acoustic rhinometry; Grade 1: 0.4 cm^3, Grade 2: 0.8 cm^3, Grade 3: 1.2 cm^3, and Grade 4: 1.6 cm^3.

population. Therefore, several authors have evaluated the role of AR in upper-airway assessment in children with OSA.[4–11] In one report, Cho et al.[6] reported that the nasopharyngeal airway was located between 2 cm before and 2 cm after the fourth notch. By contrast, Okun et al.[14] reported that the nasopharyngeal airway was between 6 cm and 8 cm posterior to the nostril. In other research, Riechelmann et al.[8] and Kim et al.[10] reported individual sections through the use of their own indicators around the nasopharynx. The differences in procedures and inconsistency of the results have caused controversy that persists to this day. Therefore, fundamental re-examination is needed to determine the precise location of the nasopharyngeal airway on AR for use as a common indicator in clinical settings. In this study, we aimed to start this process.

AR certainly appears to be useful for assessing nasal and nasopharyngeal airway conditions, but it is limited by a few issues. One major issue is that AR does not provide explicit details of the geography of the nasal cavity or nasopharynx.[1] In this study, we measured AR area–distance curves obtained with an artificial upper-airway model made of soft silicon, to which we added clay obstacles to simulate relevant disorders. On the area–distance curve, we showed that the inferior turbinate corresponded to the area between the second notch and the third peak, that the posterior end of the nasal septum corresponded to the third peak, and that adenoidal hypertorophy corresponded to the area between the third peak and 8 mm posterior to the fourth notch. These results could be used to determine landmarks when assessing area–distance curves in children, and could facilitate long-term discussions of the location of pathology and normal structures in children of this age.

The quantitative study showed that the actual volume of the simulated inferior nasal turbinate hypertrophy was comparable to the volume estimated with AR. However, although the measured adenoid volume approximated the actual volume of the simulated adenoid, the volume of the nasopharyngeal airway measured with AR was much larger than the actual volume of the model. The reason for this discrepancy may be that AR overestimates the influence of obstructions. We must acknowledge these differences between measured and actual volumes of the

nasopharyngeal airway. By contrast, the similar values of the actual and estimated volumes of the simulated adenoid indicate that the location of the adenoids on the area–distance curve was quite reliable. One limitation of this study is that we did not evaluate the differences between biological and artificial upper airways. Further validation is required to address this limitation.

In conclusion, the landmarks we identified on the area–distance curve and the volume changes measured with AR could be suitable for clinical use. However, the estimated nasopharyngeal airway volume did not correlate directly with the actual volume in the model. To further our understanding of the relevance of our findings, we must begin to use AR to assess children with OSA, and determine its efficacy for assessing nasal outcomes after treatment. Thus, clinical investigations are needed in children with OSA before and after adenotonsillectomy and other treatments.

Conflict of interest

None

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