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Size assessment of adenoid and nasopharyngeal airway by acoustic rhinometry in children

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Abstract

Adenoid hypertrophy is known as the most common cause of nasal obstruction in children; thus, adenoidectomy with, or without, tonsillectomy is one of the most commonly performed surgical procedures in the paediatric population. Although many methods have been suggested, few studies have reported on how to assess adenoid size, pre-operatively. Acoustic rhinometry is an objective technique as well as a non-invasive method, which can be easily used in young children. This study confirmed that acoustic rhinometry is a non-invasive and objective technique for assessing the geometry of the nasal cavity and nasopharynx. Forty children were evaluated using symptomology, two different radiological measurements and acoustic rhinometry; the results were compared with endoscopic findings. Clinical symptoms and A/N ratio measured with Fujioka's method significantly correlated with the endoscopic assessment findings ($r = 0.769$ and 0.604 respectively). Significant increases in the cross-sectional area and volume of the nasopharynx were observed at the adenoid notch after adenoidectomy ($p<0.005$ and $p<0.005$, respectively). Acoustic rhinometry showed a high degree of correlation of which adenoid occupied the nasopharyngeal airway under endoscopic examination ($r = 0.771$). Thus, the study concluded that acoustic rhinometry can be as good an objective method for measuring adenoid sizes as endoscopy and can be used as one of the pre-operative examination tools for adenoidectomy.

Key words: Adenoids; Nasal obstruction; Nasal cavity; Evaluation studies

Introduction

The adenoid (pharyngeal tonsil) is one of the peripheral lymphoepithelial organs, that plays an important role in the immune system where a variety of microorganisms, and antigens present in food and inhaled air first come in contact with the body. However, its complete function has remained unknown (Kim *et al.*, 1995; Woo *et al.*, 1995). Adenoid hypertrophy is one of the most common diseases in the paediatric population, and can cause nasal obstruction, snoring, mouth breathing, and alteration in facial development in children. It can also cause viral and bacterial pathogens to migrate to the adjacent nasal cavities, paranasal sinuses and middle ears. Thus, adenoid hypertrophy is often accompanied by otological and rhinological problems, such as recurrent otitis media and chronic paranasal sinusitis when adenoidectomy as well as tonsillectomy may be in order. However, unlike tonsils, the visual inspection of the adenoid is difficult to carry out in children (Kim *et al.*, 1995; Woo *et al.*, 1995). Until now, the following methods have been used in documenting sizes of adenoid hypertrophy: 1) recording of obstructive symptoms (Crepeau *et al.*, 1982; Elwany, 1987; Wormald and Prescott, 1992), 2) transnasal fibrescopic examination (Wormald and Prescott, 1992; Wang *et al.*, 1997), 3) transoral posterior rhinoscopic examination, 4) radiological evaluation, such as lateral radiography of the adenoid and nasopharyngeal magnetic resonance imaging (MRI), (Fujioka *et al.*, 1979; Sorensen *et al.*, 1980; Crepeau *et al.*, 1982; Cohen and Konak, 1985; Elwany, 1987; Cohen *et al.*, 1992; Wormald and Prescott, 1992; Lim and Cheong, 1994; Wang *et al.*, 1997), 5) rhinomanometry, and 6) acoustic rhinometry (Kim *et al.*, 1995; Woo *et al.*, 1995).

However, none of the above methods has been widely accepted or implemented due to the lack of standards or the difficulty in implementing the methods.

Thirty paediatric patients who had suffered from nasal obstruction and mouth breathing were selected in this study to undergo adenoidectomy. They were evaluated with acoustic rhinometry; the results were compared with the clinical symptoms, endoscopic findings and various radiographical evaluations.

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Subjects and methods

Subjects

Thirty patients were referred from the ENT outpatient clinic of the Catholic University of Korea to undergo adenoidectomy (and/or tonsillectomy). This study group was composed of 18 boys and 12 girls ages ranging from five to eight years (mean 6.4 years). The control group consisted of 10 children in the age range of five to eight years selected from children who visited the ENT outpatient clinic. They showed no symptoms such as mouth breathing, snoring and nasal stuffiness, and had no previous histories of nasal septal deviation or intranasal polyp, and were free from any acute nasal symptoms during the preceding several weeks. Prior to the study, an informed consent was obtained from the parents of all the participating subjects.

Methods

1) Clinical assessment score (CAS).

The presence or absence of the following symptoms at the time of radiography was ascertained. The symptoms at the time of radiographs were observed and were divided into the following categories: Major symptom: mouth breathing, snoring, chronic nasal obstruction; Minor symptom: recurrent upper respiratory infections, recurrent otitis media, and rhinorrhoea. Recurrent upper respiratory infections were defined as having five or more episodes of the common cold per year. Recurrent otitis media was defined as having three or more episodes per six months or four or more per year.

The following scoring system was made based on symptoms: Score 1: no symptoms; Score 2: any minor symptom without major symptoms; Score 3: one major symptom; Score 4: two major symptoms; Score 5: three major symptoms.

2) Endoscopic assessment score (EAS).

To evaluate the size of the adenoids, the patients were examined with fibrescopy in the sitting position. The size of the adenoid was classified into four categories according to the degree to which the adenoid occupied the nasopharyngeal airway.

- Mild: adenoid occupying 25 per cent or less of the nasopharyngeal airway.
- Moderate: adenoid occupying 25–50 per cent of the nasopharyngeal airway.
- Moderately severe: adenoid occupying 50–75 per cent of the nasopharyngeal airway.
- Severe: adenoid occupying 75 per cent or more of the nasopharyngeal airway.

3) Radiographical assessment.

Lateral radiographs of the nasopharynx were reviewed; and the A/N ratio (described by Fujioka *et al.*, 1979) and AA diameter (described by Crepeau *et al.*, 1982) were calculated (Figure 1). The A/N ratio was obtained by dividing the value A by the value N. The adenoidal measurement, A, represented the distance from the point of maximal convexity along the inferior margin of the adenoid shadow to a line drawn along the straight part of the anterior margin of basiocciput. The nasopharyngeal space, N, was measured as the distance between the posterior-superior edge of the hard palate and the anteroinferior edge of the sphenobasioccipital synchondrosis. AA diameter represented the shortest distance between the anterior aspect of the adenoid shadow and the posterior wall of the maxillary antrum, which lay in the same plane as that of the posterior choana.

4) Acoustic rhinometry (AR).

Before checking with acoustic rhinometry, a subject blew his/her nose lightly to remove discharges and crusts in the nasal cavities; then, two puffs of 0.5 per cent phenylephrine were sprayed into each of the two nasal cavities. A nose piece was attached to fit into the nostril to maintain the proper angle of 45 degrees between the wave tube and nasal floor. The 'cross-sectional area of the adenoid' was defined by

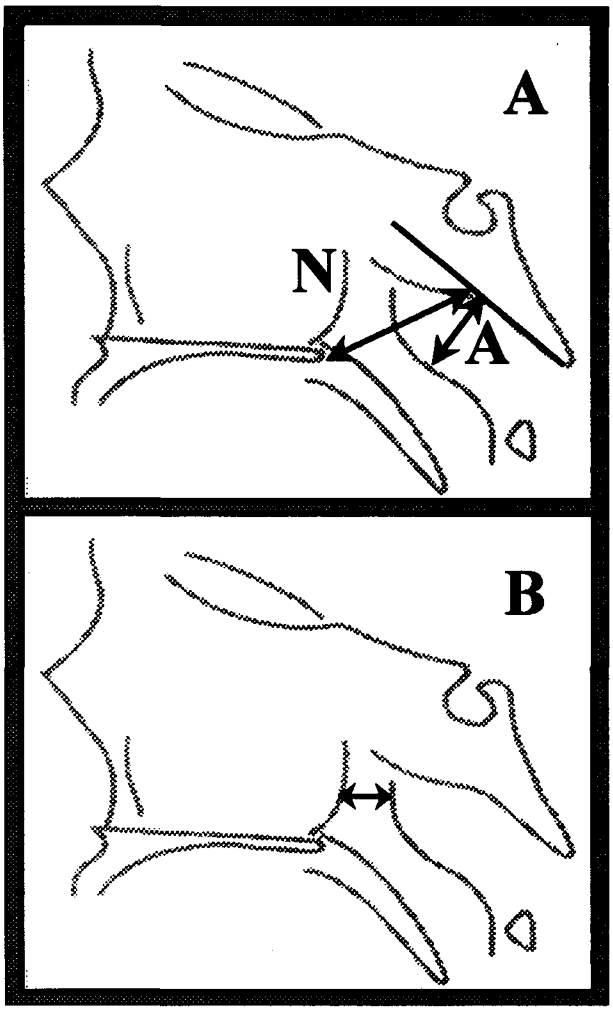

FIG. 1

Radiographical assessment. (A) A/N ratio (Fujioka's method) and (B) AA diameter (Crepeau's method).

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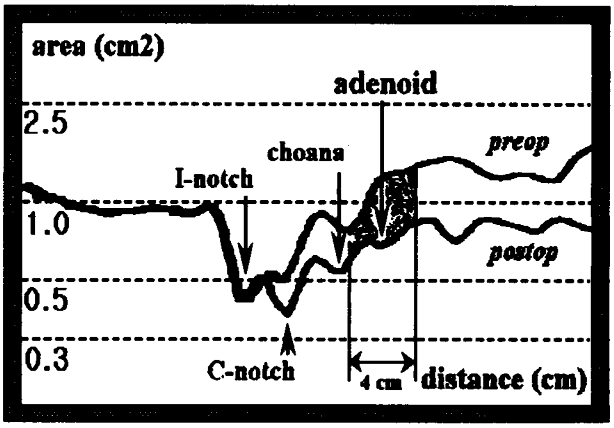

FIG. 2

Representative pre- and post-operative acoustic rhinometry of adenoid hypertrophy. The notch consistent with adenoid disappeared after adenoidectomy. The dotted area represents the volume of nasopharyngeal 4 cm-section around the adenoid notch.

subtracting the pre-operative value of the nasopharyngeal cross-sectional area from the post-operative one; these were checked at the adenoid notch on the distance-area curve before and 10 days after adenoidectomy (Figure 2). As a parameter to compare with other methods, the 'ratio (per cent) of adenoid to nasopharyngeal airway' was defined as the ratio of cross-sectional area of adenoid to post-operative nasopharyngeal cross-sectional area. The volume of 4 cm-sections of the nasopharyngeal airway that was centred on the adenoid notch of the area-distance curve was also measured before and 10 days after the adenoidectomy (Figure 2). The acoustically estimated 'volume of adenoid' was calculated by subtracting the pre-operative value from the post-operative one.

Statistical analysis

Spearman's correlation method was used to evaluate the degree of the correlation between the endoscopic examination and other methods. Comparisons between the study and control groups were evaluated using the Mann–Whitney test.

A p value < (less than) 0.05 was considered as significant.

Results

Comparison of various measurement techniques in the adenoidectomy candidate group

Spearman's correlation coefficient of the clinical symptoms, Fujioka's radiological method and acoustic rhinometry were respectively 0.769, 0.604 and 0.771 (Table I). However, the AA diameter measured by Crepeau's method did not correlate with the endoscopic assessment score, which did not agree with the findings of Crepeau. Amongst all the correlations determined, the best one was the correlation coefficient of acoustic rhinometry of 0.771.

Comparison between the control group and adenoidectomy candidate group

When the adenoidectomy group was compared with the control group, mean values of the clinical assessment, Fujioka's method and the endoscopic assessment were significantly higher in the adenoidectomy group than in the control group (Table II). However, Crepeau's AA diameter did not differ between the adenoidectomy and control groups.

Acoustic rhinometry

The distance calculated from the nostril to the adenoid notch on the acoustic rhinometry curve was 68.73 mm on average and measured approximately 69.20 mm when directly measured under endoscopic examination ($p<0.005$) (Figure 3). Significant increases in the cross-sectional area and volume of the nasopharynx were observed at the adenoid notch after adenoidectomy (respectively, $p<0.005$ and <0.005) (Figure 4). The ratio of the size of the adenoid to nasopharyngeal airway was more highly correlated ($r = 0.771$) than the degree to which the adenoid occupied the nasopharyngeal airway under endoscopic examination ($p<0.005$) (Table II). However, when retrospectively calculated with acoustic rhinometry, the cross-sectional area and volume of adenoid showed no significant correlation with the clinical or endoscopic assessments (clinical assessment; $p = 0.332$ in area/0.822 in volume, endoscopic assessment; $p = 0.917$ in area/0.346 in volume). The cross-sectional area and volume of the nasopharyngeal airway checked at the adenoid notch were significantly lower in the adenoidectomy group than in the control group ($p<0.005$ and <0.005, respectively) (Table III).

TABLE I

COMPARISON OF DIAGNOSTIC MODALITIES WITH ENDOSCOPIC FINDINGS

EAS	Number	Mean CAS	Mean A/N ratio	Mean AAø	Mean AR*
Mild	1	2.00	57.63	5.80	60.19
Moderate	3	2.33 ± 0.58	59.16 ± 3.96	3.50 ± 2.29	61.47 ± 2.88
Moderately severe	10	3.90 ± 0.88	70.37 ± 6.21	3.36 ± 0.54	70.39 ± 2.44
Severe	16	4.88 ± 0.34	77.39 ± 8.88	3.24 ± 0.85	74.42 ± 2.30
Spearman's correlation coefficient		0.769	0.604	0.286	0.771
p value		<0.005	<0.005	0.126	<0.005

*: The ratio of the cross-sectional areas of the adenoid and the nasopharynx (post-operative nasopharyngeal area) on acoustic rhinometry curve.

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TABLE II
COMPARISON BETWEEN THE CONTROL AND ADENOIDECTOMY GROUP

	CAS	A/N ratio	AA ø*	EAS
Control group	0.00 ± 0.00	58.30 ± 5.78	3.78 ± 0.58	0.20 ± 0.42
Adenoidectomy candidates	2.37 ± 0.81	72.57 ± 9.73	3.39 ± 1.02	2.37 ± 0.81
p value	<0.005	<0.005	0.058	<0.005

*: AA diameter (Crepeau's method for measuring adenoid size)

Discussion

The adenoid is largest at the age of three to four years, and starts a slow regression thereafter, involutes until the age of five to six years. It functions as a compartment part of the general lymphatic system in antibody formation and the immunological surveillance system (Devgan and Leach, 1979; Fujioka *et al.*, 1979; Lim and Cheong, 1994). It is situated at the entrance of the respiratory and alimentary tracts and is known as a site of lymphocyte proliferation and elicits B-cells response when it comes in contact with antigens or activators produced by T-cells (Woo *et al.*, 1995).

Chronic inflammation of the adenoid is accompanied by adenoid hypertrophy and can be commonly found in children of age four to seven years. The hypertrophy and inflammation of the adenoid plays a role in mechanical obstruction of the nasopharyngeal airway, that results in mouth breathing, snoring and sleep apnoea. Also an affected adenoid could be the source of viral and bacterial infections, and cause inflammation of the adjacent nasal cavity, paranasal sinus and middle ear. Thus, adenoid hypertrophy is often accompanied by otological and rhinological problems, such as recurrent otitis media and chronic paranasal sinusitis (Kim *et al.*, 1995; Woo *et al.*, 1995). Many different methods have been used in evaluating the size of the adenoid, such as clinical and endoscopic findings, digital palpation and several radiographical assessment methods (Devgan and Leach, 1979).

Transoral posterior rhinoscopic or transnasal fibrescopic examination may be time-consuming due to a considerable amount of discomfort resulting from the examinations and require a certain degree of co-operation from the patients that children often are unable to provide. However, they provide an excellent visualization and documentation of the entire nasopharynx as well as the choana, and allow for a precise adenoidectomy. These techniques are particularly useful for revision cases or superiorly positioned adenoid cases projecting into the choana

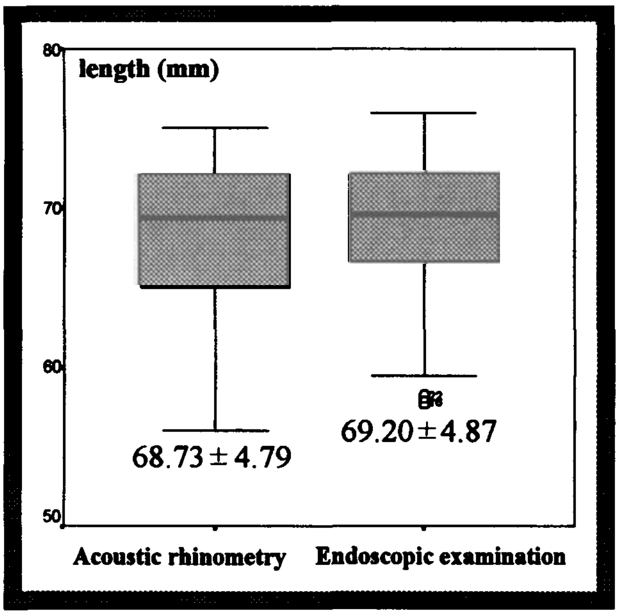

FIG. 3

Comparison of the distance from nostril to adenoid between acoustic rhinometric and endoscopic assessment.

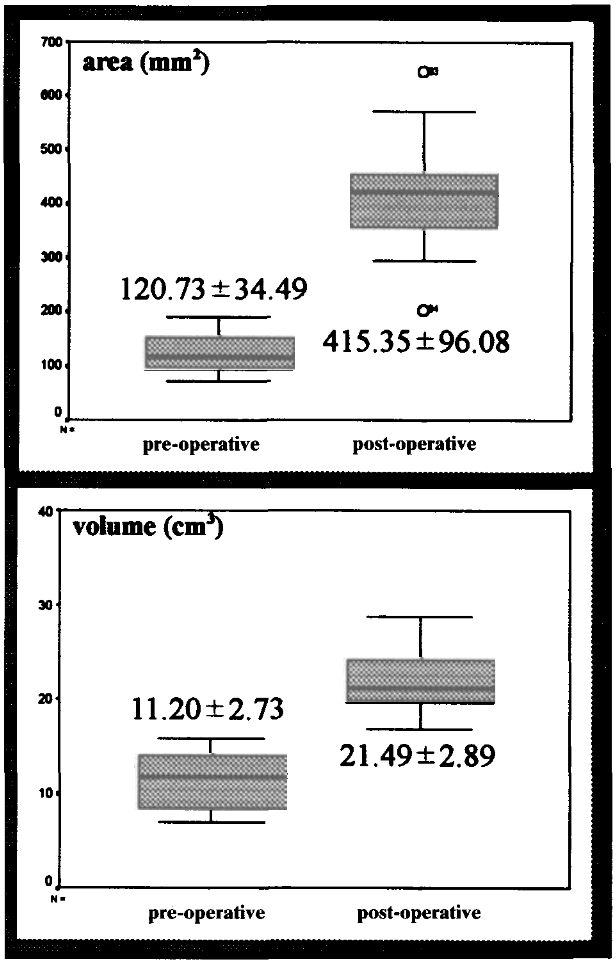

FIG. 4

Comparison of cross-sectional area and nasopharyngeal airway in pre- and post-adenoidectomy groups by acoustic rhinometry. (A) cross-sectional area at adenoid notch. (B) volume of nasopharyngeal 4 cm-section around adenoid notch. Both parameters were significantly increased after the adenoidectomy.

TABLE III
ASSESSMENT OF THE CROSS-SECTIONAL AREA AND THE VOLUME OF NASOPHARYNGEAL AIRWAY WITH ACOUSTIC RHINOMETRY

	Cross-sectional area at adenoid notch (mm^2)	Volume of nasopharyngeal 4 cm-section around adenoid (cm^3)
Adenoidectomy group	120.73 ± 34.49*	11.20 ± 2.73*
Post-adenoidectomy group	415.35 ± 96.08†	21.49 ± 2.89†
Control group	286.60 ± 77.33*†	16.32 ± 2.72*†

*: $p<0.005$.
†: $p<0.005$.

(Crepeau *et al.*, 1982; Wormald and Prescott, 1992). In this study, it took five to 10 minutes to evaluate the nasopharyngeal airway using a fibrescope on ENT outpatients since it caused a considerable amount of discomfort and anxiety in children.

Digital palpation can be distressing to children and therefore unsatisfactory as a means of evaluating the size of adenoid in patients at ENT outpatient clinic. Other important facts are the poor reproducibility between observers and the fact that the size of the adenoid relative to nasopharynx is probably more important than its absolute size (Crepeau *et al.*, 1982; Lim and Cheong, 1994).

Over the past 20 years, several methods of radiographical assessment of the size of the adenoid have been reported (Figure 5). Johannesson (1968) drew a perpendicular line to the base of skull at the pharyngeal process and measured the mean thickness of the soft tissue. Maran *et al.* (1971) measured the size of the adenoid with a line drawn from central upper incisor tooth to the posterior edge of the hard palate. Fujioka *et al.* (1979) used the ratio of the following two parameters to express the size of adenoid: (1) the adenoidal measurement; the line was dropped perpendicularly from the point of maximal convexity to a line drawn along the straight part of the anterior margin of the basiocciput, and (2) the nasopharyngeal measurement; a line between the posterior edge of hard palate and the skull base, specifically, the anterior edge of the sphenobasiocci-pital synchondrosis. Hibbert *et al.* (1979) measured the distance between the anterior end of the adenoid and the choana, as well as the size of the soft tissue of adenoid, emphasizing the importance of the first measurement. Sorensen *et al.* (1980) measured several lines along the adenoid and nasopharyngeal airway, and compared all of them to determine the significance of their relationships. Crepeau *et al.* (1982) modified Hibbert's method and measured two parameters; the supero-inferior diameter, which represented a line drawn perpendicular to the base of skull on pharyngeal tubercle and the antroade-noidal diameter, which represented the distance between the anterior end of the adenoid and the choanae. The latter parameter was emphasized more to compare symptoms, especially when sinusitis was present. Cohen and Konak (1985) suggested a simpler and easier method. The thickness of the soft palate and the air column immediately posterior to the palate was measured and the ratio between the two parameters was compared, stressing more than the thickness of the adenoid. Since many studies stressed how much the nasopharyngeal airway was obstructed using the absolute size of adenoid to determine the obstructive symptoms in adenoid hypertrophy Fujioka's and Crepeau's methods were selected in the present study for evaluating the size of adenoid. In our study, Crepeau's radiological measurement did not correlate with endoscopic and clinical assessments. These two latter results were not consistent with other studies. Despite the fact that these methods easily estimate the size of adenoid pre-operatively, all radiological methods risk exposing children to ionizing radiation, some methods require much time, and clinicians face a difficulty in calculating the obtained parameters. Also, it is occasionally difficult to find a reference point on X-rays, and it may lose its meaning as the

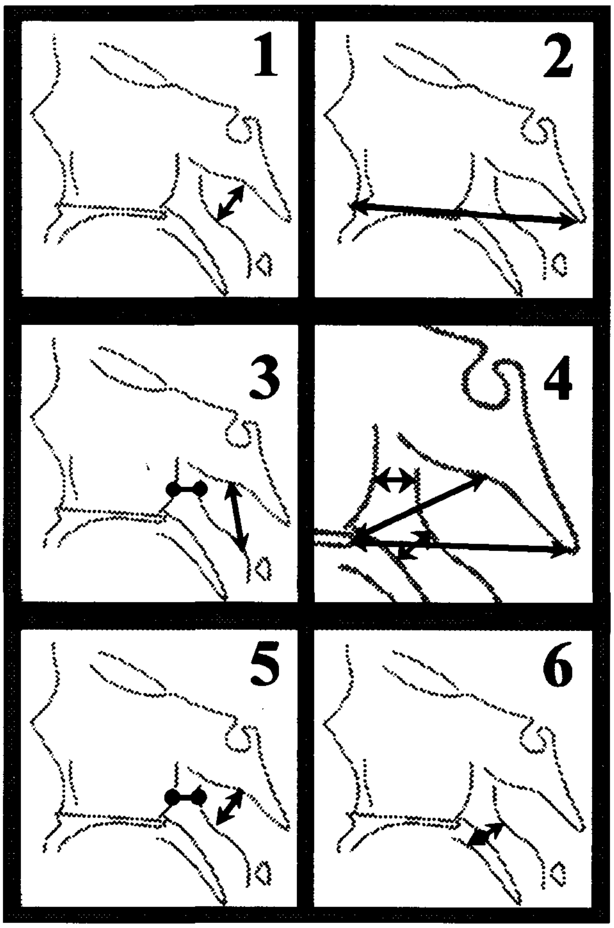

FIG. 5

Graphical synopsis of various methods cited for measuring the size of adenoid: 1) Johannesen, 2) Maran *et al.*, 3) Hibbert and Stell, 4) Sorensen *et al.*, 5) Crepeau *et al.*, 6) Cohen and Konak.

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reference since any movement of the soft palate and pharyngeal wall during swallowing or respiration can alter the location of the reference point.

Slawinski and Kossowska (1993) introduced acoustical methods, which were based on the fact that the prominence of the symptoms due to adenoid hypertrophy do not correlate well with the size of the adenoid but with the narrowing of the respiratory tract. Theoretically, the narrowing of respiratory tract induces a difference in air pressure, which generates sound. Jackson and Olson (1980) applied this technique to evaluate the geometry of the lower airways, and Hilberg *et al.* (1989) first used acoustic rhinometry to evaluate the cross-sectional area of the nasal cavity. Acoustic rhinometry has been used for several years in investigating the geometry of tracheal, laryngeal, and pharyngeal airways. Acoustic rhinometry is a non-invasive, painless, rapidly performed and highly reproducible method; when respiration, swallowing or other movements in upper respiratory tract were eliminated a precise, two-dimensional picture of the nasal cavities and nasopharynx could be obtained within several seconds (Lender and Pirsig, 1990; Elbrond *et al.*, 1991; Zavras *et al.*, 1994; Kim *et al.*, 1995; Roithmann *et al.*, 1995). On the distance-area curve of acoustic rhinometry, several notches were found. Lender and Pirsig (1990) defined the first notch as the 'I-notch', for isthmus nasi and the second notch as the 'C-notch', for the anterior end of inferior concha (Figure 2). Kim *et al.* (1995) found the third and fourth notches, and defined them as the choanae and the adenoid respectively. The study reported that the mean distance from the nostril to the fourth notch was 6.70 cm on average, and this value was approximately equal to the distance measured directly under endoscopy. For the present study, the third and the fourth notches were found, and the mean distance from the nostril to the fourth notch was measured to be 68.73 ± 4.79 mm that was similar to the directly measured distance by endoscopy 69.20 ± 4.87 mm (Figure 3).

In the present study a nasal decongestant was used prior to measurements by acoustic rhinometry to eliminate the possible effects of chronic rhinitis, which is one of the most prevalent conditions that causes mouth breathing in children, as Elbrond *et al.* (1991) emphasized. Unfortunately, additional sources of error exist such as anteriorly placed obstructions resulting in an underestimation of the posterior volume, palatal movements and respiratory efforts interfering with the accuracy of posterior volume and area parameters, the contralateral nasal cavity influencing the ipsilateral estimation of nasopharyngeal volumes, and viscous losses occurring in the nasal cavity. In addition, the predictive values of acoustic rhinometry are not accurate enough to be used by themselves at present since although the ratio of the size of the adenoid to the nasopharyngeal airway highly correlated with endoscopic and clinical assessments, this parameter could only be calculated post-operatively (Elbrond *et al.*, 1991; Fisher *et al.*, 1995).

The cross-sectional area of nasopharynx at the adenoid notch and volume of 4 cm-section centred to the adenoid notch were respectively 120.73 mm^2 and 11.20 cm^3 in the adenoidectomy group. These values were significantly different from those of the control group.

Conclusion

The following conclusions were drawn on the present study of 30 adenoidectomy and 10 normal children.

1) Clinical assessment and Fujioka's radiological measurement showed a good correlation with endoscopic assessment.
2) No difference was observed between the actual distance examined under the endoscope and the distance calculated using the acoustic rhinometric curve.
3) The ratio of adenoid to nasopharyngeal airway calculated by acoustic rhinometry correlated more significantly than the ratio calculated using endoscopic findings.
4) Cross-sectional areas of nasopharyngeal airway checked at adenoid notch and the volume of 4 cm-section around adenoid notch were respectively less than 150 mm^2 and 12 cm^3 in the adenoidectomy group.
5) Among all the methods used for this study, acoustic rhinometry was best for measuring the size of adenoid.
6) Since the ratio of the size of the adenoid to nasopharyngeal airway was not calculated using acoustic rhinometry pre-operatively, this parameter should not be a determining factor in adenoidectomy pre-operatively. However, if the cross-sectional area of the nasopharynx at the adenoid notch and the volume of 4 cm-section around the adenoid notch are respectively less than 150 mm^2 and 12 cm^3, adenoidectomy should be recommended for the treatment of mouth breathing.

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