Correlations Between Acoustic Rhinometry, Subjective Symptoms, and Endoscopic Findings in Symptomatic Children With Nasal Obstruction

Andre Isaac, MD; Michael Major, DDS, MSc, FRCDC; Manisha Witmans, MD, FRCP; Yaser Alrajhi, MD, FRCSC; Carlos Flores-Mir, DSc, MSc; Paul Major, DDS, MSc; Noura Alsufyani, BDS, MSc; Mohamed Korayem, DMD, MSc; Hamdy El-Hakim, MD, FRCSC

IMPORTANCE Nasal obstruction is common in children and difficult to quantify objectively. Symptom quantification is paramount for surgical and medical decision making. Acoustic rhinometry is a relatively new technique aimed at the objective assessment of nasal obstruction. There is no standardized method for the objective assessment of the pediatric nasal airway.

OBJECTIVE To explore the correlations between acoustic rhinometry (AR), subjective symptoms, and endoscopic findings in children presenting with nasal obstruction.

DESIGN, SETTING, AND PARTICIPANTS A cross-sectional, exploratory, diagnostic study of prospectively collected data from a multidisciplinary airway clinic (pulmonology, orthodontics, and otolaryngology) database at a tertiary academic referral center. Data were collected over a 2-year period (2010-2012) from 65 nonsyndromic children (38 boys) 7 years and older (mean [SD] age, 10.3 [2.5] years [range, 7-14 years]), presenting with persistent nasal obstructive symptoms for at least 1 year, without signs and symptoms of sinus disease.

INTERVENTIONS We collected patient demographics and medical history information including allergy, asthma, and sleep-disordered breathing. Subjective nasal obstruction was scored using a visual analog scale (VAS). Sleep-disordered breathing was assessed using overnight pulse oximetry. The adenoid size, septal position, and visual severity of chronic rhinitis (endoscopic rhinitis score [ERS]) were rated on nasal endoscopy by 2 independent reviewers and validated by agreement. Acoustic rhinometry (AR) was undertaken before and after use of a decongestant.

MAIN OUTCOMES AND MEASURES Correlation and multiple regression analyses were performed to explore interrelationships between subjective nasal obstruction VAS, AR, and nasal endoscopy.

RESULTS Among the 65 patients, 28 (43%) had symptoms of sleep-disordered breathing, 14 (22%) had allergic rhinitis, 10 (15%) had asthma, 27 (41%) had grade 3 or 4 adenoidal obstruction, 28 (43%) had an ERS of 2, 6 (9%) had an ERS of 3, and 19 (29%) had septal deviation. Significant correlations were found between subjective nasal obstruction VAS score and ERS \( r = -0.364, P = .003 \), ERS and minimal cross-sectional area before decongestion \( r = -0.278, P = .03 \), and adenoid size and calculated nasal resistance after decongestion \( r = 0.430, P < .001 \). Multiple regression analysis showed that the ERS was the only significant predictor of VAS score (\( B \) of \(-22.098\); 95% CI, \(-35.56\) to \(-8.61\) [\( P = .002 \)]. No predictors were identified for AR variables.

CONCLUSIONS AND RELEVANCE Among the evaluated tools, endoscopy appears to be the most reliable tool to estimate the degree of subjective nasal symptoms.

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Author Affiliations: Division of Otolaryngology–Head and Neck Surgery, Department of Surgery, University of Alberta, Edmonton, Alberta, Canada (Isaac, Alrajhi, El-Hakim); Division of Orthodontics, School of Dentistry, University of Alberta, Edmonton, Alberta, Canada (M. Major, Flores-Mir, P. Major, Alsufyani, Korayem); Division of Pediatric Pulmonology, Department of Pediatrics, Stollery Children’s Hospital, Edmonton, Alberta, Canada (Witmans); Division of Pediatric Surgery, Department of Surgery, Stollery Children’s Hospital, Edmonton, Alberta, Canada (Alrajhi, El-Hakim).

Corresponding Author: Andre Isaac, MD, 2C3.57 Walter Mackenzie Centre, Edmonton, AB T6G 2R7, Canada (aisaac@ualberta.ca).
nasal obstruction is a common complaint in children. Its causes are varied and multifactorial, including adenoid hypertrophy, septal deviation, rhinitis of various causes, congenital conditions, and others. Chronic nasal obstruction can have notable effects on a child’s quality of life. Allergic rhinitis can predispose a child to comorbidities such as otitis media, sinusitis, and asthma. Adenoid hypertrophy can have notable effects on sleep quality and can predispose patients to serious cardiopulmonary complications. Despite this, nasal obstruction as a symptom is notoriously difficult to quantify objectively, particularly when the developmental stage and age of the child can influence subjective perception and communication of symptoms and signs. Conventionally, nasal endoscopy (NE) has been the most widely accepted (although nonstandardized) method of quantifying nasal and nasopharyngeal patency. Although NE is uniformly accepted by otolaryngologists as a tool to identify the source of nasal obstruction and perhaps target medical and surgical treatment, it has important limitations. Specifically, NE can be subject to considerable interpreter or user bias and is difficult to perform in young, uncooperative children.

Acoustic rhinometry (AR) is a relatively newer technique for assessing the upper airway. It has been argued that AR offers an objective tool for quantifying nasal obstruction and that it has shown some utility in pediatric nasal diseases. Acoustic rhinometry is based on the principle of acoustic reflections: audible tones that are directed into the nasal cavity and are reflected back to create a cross-sectional map of areas of nasal obstruction as a function of the distance from the nostril. Its potential advantages include noninvasiveness and freedom of observer bias. Nevertheless, it requires patient cooperation and a precise technique to gain reliable readings. Acoustic rhinometry has been studied mainly in children before and after adenoidectomy and has been shown to correlate with increases in size of the nasopharyngeal airway and symptom improvement in intra-subject observations, with correlation coefficients as high as 0.771. Acoustic rhinometry has also been shown to correlate with other measures such as polysomnography and radiographic findings (x-ray films and computed tomographic scans). However, few studies have aimed to correlate AR measurements with findings on NE and visual analog scales (VAS) in symptomatic children. These studies have been conducted almost exclusively on asymptomatic children, and the results have been mixed and inconclusive. Two studies that studied AR vs NE in symptomatic children showed poor correlation. Consequently, some authors have suggested that AR is useful in intervention assessment studies, rather than comparative or controlled studies. To our knowledge, the relation between AR measurements, NE, and VAS in the same symptomatic patient population has not been previously examined. It is critical to compare these methods in the same population, as AR data can be highly variable depending on the population examined.

The aim of our study was to explore how AR variables correlate with NE findings and symptoms as reported on a VAS in children with subjective nasal obstruction.

Methods
We conducted a prospective, observational, cross-sectional study at a tertiary care center (The Stollery Children’s Hospital, Edmonton, Alberta, Canada) over a 2-year period. Health research ethics board approval was obtained prior to study commencement. Written consent was obtained from each child’s parent or legal guardian, and assent was obtained from children as appropriate, according to developmental stage. The eligible patients were children 7 years and older, who presented with a subjective complaint of nasal obstruction for longer than 1 year, without symptoms and signs of sinus disease. Patients were excluded from the study if they were diagnosed as having congenital craniofacial syndromes or developmental delay; were unable or unwilling to undergo AR or NE or complete the VAS; or were experiencing an active upper respiratory tract infection at the time of evaluation. The sources of the referral were primary care physicians and several tier specialists.

The patients underwent a systematic evaluation on the same day in a multidisciplinary clinic (an orthodontist, a pediatric otolaryngologist, and a pediatric pulmonologist). The data collected included demographics, race/ethnicity, the presence or absence of physician diagnosed allergic rhinitis and/or asthma, prematurity at birth (<36 weeks gestation), obesity (>95 percentile BMI for age and sex), and symptoms of snoring and/or sleep-disordered breathing. Each child was also evaluated for signs of sleep-disordered breathing using overnight pulse oximetry and graded using a previously validated scale.

As part of the full protocol of the multidisciplinary evaluation, a full orthodontic assessment was performed. The patients underwent AR testing using an Eccovision 4.50 acoustic rhinometer (Sleep Group Solutions). Acoustic rhinometry consisted of 3 standardized trials in each nostril, both before and after decongestion with xylometazoline, 0.1%. Variables measured included the minimum cross-sectional area (MCA), distance to MCA, nasal volume, and calculated nasal resistance (CalcR).

In addition to a general inquiry about otolaryngological complaints, a specific rhinological symptom inquiry was made. Individual scores were gathered for nasal obstruction (and sinusitis), headache (and location), rhinorrhea (posterior and anterior), smell, and taste symptoms over the course of the previous year. The children scored their symptoms on a VAS from 0 to 100, in inverse proportion to the severity, and the attending parent(s) helped identify the duration of symptoms. These questions were used to exclude patients with signs and symptoms of sinus disease. The VAS score used for the purpose of the analysis was based on the question, “How well were you able to breathe out of your nose on most days, over the past year, zero meaning not being able to breathe at all, and one hundred meaning perfect breathing?”

The nose was prepared with lidocaine, 4%, and xylometazoline, 0.1%, for NE. A flexible 2.2-mm endoscope was used for examining the nasal cavity, nasopharynx, oropharynx, hypopharynx, and larynx. The nasal findings were limited to the absence or presence of septal deviation, degree of
chronic hypertrophic rhinitis, adenoid size, and confirmation of absence of signs of sinusitis.

Because no validated scale exists for assessing septal deviation and chronic rhinitis on endoscopy, we created our own scoring systems for these variables and validated them with interrater agreement. Septal deviation was graded on a 3-point scale (1, absent; 2, <50% compromise of nasal patency; 3, >50% compromise of nasal patency). The degree of chronic rhinitis, based on the assessment of the 2 sides, was rated as 1 of 3 grades, termed the endoscopic rhinitis score (ERS). Grade 1 was no obstruction to either side (mild or no rhinitis); grade 2, obstruction to 1 side only (without deviation of the septum); and grade 3, bilateral obstruction. An obstruction was deemed present if more than 50% compromise of patency was observed. This obstruction included turbinate hypertrophy and/or inflamed mucosa, after the removal of excess secretions using nasal decongestion. Adenoid size was graded on a 4-point scale (1, <25%; 2, 25%-49%; 3, 50%-74%; and 4, >75% compromise of the nasopharynx), according to a previously published validated scale.14

Descriptive statistics were used for the parameters of the cohort. Weighted Cohen kappa (κ) was used to measure the interrater agreement for NE findings (adenoid size, ERS, and septal deviation). Pearson correlation coefficients (r) were calculated between VAS and NE variables; VAS and AR variables; and AR and NE variables. Multiple regression analysis was performed to determine which variables were predictive of VAS results. The dependent variable was VAS score (0-100), while the independent variables were presence or absence of allergy, presence or absence of asthma, presence or absence of sleep-disordered breathing diagnosed by physician, MCA (before and after decongestion), nasal volume (before and after decongestion), calcR (before and after decongestion), ERS, septal deviation, and adenoid size.

### Results

Eighty-four consecutive patients were evaluated between February 2011 and June 2013 for nasal obstructive symptoms and met the inclusion criteria. Eight patients were unable to undergo NE, and 9 did not undergo AR. Therefore, 65 patients were included in the analysis. The basic demographic information and medical history of this cohort is summarized in Table 1. The mean (SD) age of the patients was 10.3 (2.1) years (range, 7-14 years), and 38 (58%) were male. Of the 65 patients, 28 (43%) had symptoms of sleep-disordered breathing, 14 (22%) had a history of physician-diagnosed seasonal or perennial allergic rhinitis (Table 1), 6 (9%) were obese, and 4 had a history of prematurity (6%). Eleven patients (17%) had an overnight oximetry study consistent with obstructive sleep apnea, as indicated by an abnormal McGill Oximetry Score (MOS)31 (median MOS, 1 [interquartile range, 1-2]).

The patients’ NE findings are summarized in Table 2. Twenty-seven patients (41%) had grade 3 or 4 adenoidal obstruction. Twenty-eight patients (43%) had an ERS of 2, and 6 patients (9%) had an ERS of 3. Nineteen patients (29%) had septal deviation. The weighted κ score for interrater agreement between the 2 surgeons on the endoscopy findings was 0.630 for adenoid size and 0.616 for ERS, indicating a good agreement. The mean (SD) VAS score for subjective nasal obstruction was 58 (27) (range, 10-100).

The ERS was the only NE variable that significantly correlated with VAS scores ($r = -0.36$, $p = .003$; coefficient of de-

#### Table 1. Group Parameters and Associated Medical Conditions

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Patients* (%)</th>
<th>Asthma 10 (15)</th>
<th>History of prematurity 4 (6)</th>
<th>Obese 6 (9)</th>
<th>Symptoms of SDB 28 (43)</th>
<th>Allergy 14 (22)</th>
<th>Asthma 10 (15)</th>
<th>Abnormal MOS31 11 (17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>10.3 (2.1)</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>12</td>
<td>22</td>
<td>15</td>
<td>26</td>
</tr>
<tr>
<td>Male</td>
<td>38 (58)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>12</td>
<td>15</td>
<td>12</td>
</tr>
</tbody>
</table>

Abbreviations: MOS, McGill Oximetry Score; SDB, sleep-disordered breathing.

* Data are given as number (percentage) of patients except for mean (SD) age.

#### Table 2. Correlation Analysis Between Nasal Endoscopy Findings and VAS

<table>
<thead>
<tr>
<th>Nasal Endoscopy Observation</th>
<th>Patients, No. (%) (N = 65)</th>
<th>VAS Correlation Coefficient (r)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adenoid size</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (&lt;25%&lt;sup&gt;a&lt;/sup&gt;)</td>
<td>30 (46)</td>
<td>−0.04</td>
<td>.75</td>
</tr>
<tr>
<td>2 (25%-50%&lt;sup&gt;a&lt;/sup&gt;)</td>
<td>8 (12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 (50%-75%&lt;sup&gt;a&lt;/sup&gt;)</td>
<td>19 (29)</td>
<td>−0.36</td>
<td>.003</td>
</tr>
<tr>
<td>4 (&gt;75%&lt;sup&gt;a&lt;/sup&gt;)</td>
<td>8 (12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERS&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>31 (48)</td>
<td>−0.36</td>
<td>.003</td>
</tr>
<tr>
<td>2</td>
<td>28 (43)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>6 (9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Septal deviation grade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (Absent)</td>
<td>46 (71)</td>
<td>−0.15</td>
<td>.23</td>
</tr>
<tr>
<td>2 (&lt;50%&lt;sup&gt;a&lt;/sup&gt;)</td>
<td>10 (15)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 (&gt;50%&lt;sup&gt;a&lt;/sup&gt;)</td>
<td>9 (14)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: ERS, endoscopic rhinitis score; VAS, visual analog scale.

<sup>a</sup> Percentages indicate compromise of the nasopharynx.

<sup>b</sup> ERS: 1, no obstruction to either side (mild or no rhinitis); 2, obstruction to 1 side only (without deviation of the septum); and 3, bilateral obstruction.

<sup>c</sup> Percentages indicate compromise of nasal patency.
Discussion

The quantification of subjective nasal obstruction has gained considerable attention in the recent literature, particularly using AR. The potential applications are broad, with particular promise in pediatric nasal airway diseases. However, a recent systematic review by Andre et al \(^{22}\) reported an extremely wide variation of conclusions in the literature, from those arguing for a correlation between AR variables and nasal obstruction, to those who argue a complete lack thereof, which is consistent with our literature review.\(^{15,17,19,23,24}\) Our results indicate that AR measurements do not consistently correlate well with symptom scores on VAS. Previous studies by Haavisto et al \(^{17}\) and Larsson et al \(^{18}\) showed a weak correlation between AR variables and VAS score in asymptomatic children before nasal decongestion \((r = 0.21)\) or after histamine provocation \((r = 0.24).\(^{17,18}\) However this does not seem to apply to symptomatic children according to our results and others.\(^{10,22}\) This may be owing to the heterogeneous reasons of nasal obstruction encountered in our cohort, as opposed to an asymptomatic patient population that had been artificially stimulated in a standardized manner (with histamine provocation). Mendez et al \(^{25}\) studied symptomatic children diagnosed with allergic rhinitis and did not find a correlation between AR variables and symptom scores. They did demonstrate, however, a negative correlation between nasal resistance and symptom score with unilateral assessments \((r = −0.59),\) but this was only true for control patients and only for the most obstructed nostril.\(^{25}\) Unilateral symptoms were not studied in the present study; however, the utility of unilateral correlations is debatable in day-to-day practice, as patients tend to judge the overall patency of the nose, which is more clinically significant. Thus, it seems that in all children with nasal obstructive symptoms, AR variables do not accurately reflect the child’s perception of the degree of nasal obstruction.

Nasal endoscopy seems to be more reliable method of assessing the nasal airway in children. Our weighted \(k\) scores showed a good interrater agreement, which indicates that our method of assessing the severity of chronic rhinitis in children is reliable. In this sense, ERS appears to be useful in predicting symptomatology on VAS in children with nasal obstruction, although its explanation capability was only of 13%. We postulate that other significant variables come into play such as the age of the child or other pathologic conditions in the nasal airway. Because of the sample size, these could not be analyzed in the present study.

The correlations found between AR and adenoid size scores on NE indicate that AR continues to provide adequate assessment of the adenoid size in symptomatic children, although.
this correlation was only found to be valid after nasal decongestion. This is also in agreement with several studies that had found significant improvement in AR variables after adenoidectomy.9-12,14,19-24,26-30 However, these studies examined mainly the cross-sectional area at the level of the post-nasal space and did examine not nasal resistance, as in our results. Because the calculated nasal resistance correlated strongly with adenoid size but not with VAS score in our patient population, adenoid hypertrophy appears to be the limiting factor in nasal resistance but does not account in total for the subjective experience of nasal obstructive symptoms. Similar results were found by Richelmann et al,19 who found that AR was not able to differentiate symptomatic children with adenoid hypertrophy from controls; however, AR was able to identify the degree of clinical improvement following adenoidectomy.

Because the correlation between MCA before decongestion and ERS was low in our study, we do not hold this to have great clinical significance, especially since the relationship between MCA and ERS did not hold after decongestion. In other studies, specific nasal cavity cross-sectional areas (besides the MCA) were shown to correlate with specific anatomic landmarks on NE,16,31 which may be clinically significant in certain subpopulations that were not studied here.

Notably, we did not account for patient age and size in our assessment of the AR variables. This is a controversial topic, as many studies have disagreed on the role of patient age, size, and total body surface area on normal AR values. Some studies have argued that the MCA does not change significantly between the ages of 7 and 14 years22-33; however, other studies have argued a strong correlation between age and MCA, as well as height and total body surface area with nasal volume.77 This may have biased our results because what is considered a “normal” MCA may be different for each patient in the study. Establishing “normal” AR values according to patient height, age, and race/ethnicity has been difficult, with studies reporting conflicting ranges.7,17,32-34,38

One limitation of this study is that the study population had some inherent heterogeneity, with 22% of patients with allergic rhinitis. The number of patients in the study was too small for individual subgroup analysis. However, because the patients were selected consecutively, this likely represents proportions of patients with chronic nasal obstruction found in day-to-day practice.

Another limitation is that NE was only performed after nasal decongestion, which is a possible confounder because this would have altered the dimensions and observed degree of obstruction in the nasal cavity. This was done to mirror common practice, as most surgeons perform NE after decongestion for patient comfort and ease of the procedure, as well as to reveal the “best possible” nasal airway, which is what is most useful in determining the need for surgery. Furthermore, because ERS was still a strong predictor of VAS score with all patients having undergone decongestion, there are still notable findings of rhinitis after decongestion.

Finally, although the MCA has been the most studied AR variable, some studies have suggested that other specific anatomic cross-sectional areas may be more sensitive measures of nasal patency, and more evidence is needed.38,39 Thus, although the MCA is not useful in quantifying symptoms in children with nasal obstruction, other specific cross-sectional areas may be useful. Care must also be taken in interpreting the lack of significant correlations found in this study because it had a small number of patients, who were to some extent heterogeneous. Thus, although in this study the ERS was the only variable that successfully predicted symptoms, other variables may have some weak predictive values that would be elucidated with a larger, more homogeneous population. Further work on specific pathologic conditions and their AR correlates in different age groups and across different conditions is warranted.

**Conclusions**

Endoscopic assessment of chronic rhinitis appears to have some predictive value for the global subjective sensation of nasal obstruction in children. The ERS appears to be more reliable than AR, which had no consistent relation to multifactorial nasal obstruction in children. Specific AR variables may be useful for evaluating the size of the adenoids but not for assessing symptoms.

**Table 5. Multiple Regression Analysis of Predictors of Visual Analog Scale Score**

<table>
<thead>
<tr>
<th>Variable</th>
<th>β Coefficient (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adenoid size</td>
<td>-3.052 (-11.904 to 5.800)</td>
<td>.49</td>
</tr>
<tr>
<td>ERS</td>
<td>-18.753 (-32.381 to -5.126)</td>
<td>.008</td>
</tr>
<tr>
<td>MCA Before decongestion</td>
<td>23.598 (28.137 to 167.744)</td>
<td>.58</td>
</tr>
<tr>
<td>After decongestion</td>
<td>84.812 (194.886 to 364.511)</td>
<td>.54</td>
</tr>
<tr>
<td>CalcR Before decongestion</td>
<td>-0.291 (-5.261 to 4.680)</td>
<td>.91</td>
</tr>
<tr>
<td>After decongestion</td>
<td>-0.076 (-9.099 to 8.947)</td>
<td>.99</td>
</tr>
</tbody>
</table>

Abbreviations: CalcR, calculated nasal resistance; ERS, endoscopic rhinitis score; MCA, minimum cross-sectional area.


