

Rhinometry Studies (updated 02/22/10)

A. Related to Snoring, Sleep Disordered Breathing, and Obstructive Sleep Apnea

1). Acoustic Rhinometry: A diagnostic Tool for Patients with Chronic Rhonchopathies Rhinology, 1992

Authors: H. Lenders and W. Pirsig

Conclusion: “Acoustic rhinometry is a quick, non-invasive and objective method to measure the cross-sectional areas and volumes of the nasal cavities.”

“Clinically recognizable irregular movements of the soft palate in rhonchopaths can be visualized by AR in 94% of all patients.”

“This study shows that AR helps to evaluate anatomical stenosis of the nasal cavities and irregular movements in the velopharyngeal segment.”

2). Acoustic Reflection: Review and Clinical Applications for sleep-Disordered Breathing Sleep and Breathing, 2002

Authors: J. S. Viviano, D.D.S.

Conclusion: “The potential clinical usefulness of AR in the treatment of patients with SDB involves all stages of treatment: initial screening of patients, establishing patient candidacy, evaluating nasal patency, determining mandibular posture that optimizes airway patency, determining orthotic titration settings, and verifying continued efficacy of orthotic settings at follow-up. The use of AR could facilitate front-line efforts in isolating afflicted individuals; ensure a higher level of success for surgical, positional, and airway orthotic therapies; eliminate the possibility that an undiagnosed nasal obstruction could interfere with successful treatment; establish orthotic construction parameters; and objectively verify the orthotics’ continued effectiveness. “

3). *Acoustic Rhinometry Predicts Tolerance of Nasal Continuous Positive Airway Pressure: A Pilot Study*
American Journal of Rhinology, 2006

Authors: L. G. Morris, J. Setlur, O. E. Burschtin, D. L. Steward, J. B. Jacobs and K. C. Lee

Conclusion: “Objective evaluation of the nasal airway is helpful in predicting patients who will not tolerate nCPAP. The data from the group of patients in this study suggest that inferior turbinate hypertrophy—a cross-sectional area of $<0.6 \text{ cm}^2$ or a $\text{CSA}_2 < \text{CSA}_1$ —may be a sensitive and specific predictor of CPAP intolerance. Additional study is necessary to confirm these findings. The correlation between nasal airway size and CPAP tolerance provides a physiological rationale for the findings that nasal surgery improves adherence with nCPAP therapy.”

B. Related to Nasal Cavity Geometry and Measurement

1). *Acoustic Rhinometry: Evaluation of Nasal Cavity Geometry by Acoustic Reflection*
Journal of Applied Physiology, 1989

Authors: O. Hilberg, A. C. Jackson, D. L. Swift, and O. F. Pedersen

Conclusion: “The clinical cases in this study are examples of the applicability of acoustic reflection measurements in the nose. Tumors in the nasal cavity and the epipharynx can be diagnosed, and the treatment can be monitored in a much simpler and much less invasive way than by use of CT scans. It may be possible to diagnose and localize septum deviations and hypertrophia of the turbinates to facilitate surgical correction. The applicability seems wide. Testing for allergic afflictions would be an area of considerable interest. Investigation of the pharynx through the nose instead of through the mouth would be a possibility in sleeping disorders. It is concluded that the acoustic reflection technique produces highly accurate measurements of the nasal cavity geometry. The method seems very suitable for nasal measurements and is potentially useful for investigating physiological as well as pathological changes in the nose by this simple technique. It is easy to perform, is non-invasive, and requires no patient cooperation and thus can be applied even in infants [after further experimentation and modifications related to equipment size].”

2). *Nasal Cavity Geometry Measured by Acoustic Rhinometry and Computed Tomography*

Archives of Otolaryngology—Head and Neck Surgery, 1997

Authors: L. Gilain, MD, A. Coste, MD, F. Ricolfi, MD, E. Dahan, MD, Marliac, MD, R. Peynegre, MD, A. Harf, MD, B. Louis, PhD

Conclusion: “Acoustic rhinometry may be particularly well suited to the evaluation of anterior nasal geometry during clinical studies. In conclusion, this study comparing in vivo acoustic and CT data indicates that acoustic rhinometry provides reliable measurements in the first part of the nose, particularly in the area of the nasal valve.”

3). *Normative Standards for Nasal Cross-sectional Areas by Race as Measured by Acoustic Rhinometry*

Otolaryngology—Head and Neck Surgery, 1998

Authors: J. P. Corey, A. Gungor, R. Nelson, X. Liu, and J. Fredberg

Conclusion: “The importance of our data is that racial differences in nasal geometry can be demonstrated by AR. Because of these differences in nasal dimensions, “normal values” for nasal volumes and cross-sectional areas should be calculated according to race. The clinical implications of the normative values may serve to guide the physician in preoperative evaluation and during endoscopy and operations.”

4). *Detection of the Nasal Cycle with Acoustic Rhinometry: Techniques and Applications*

Otolaryngology—Head and Neck Surgery, 1999

Authors: A. Gungor, R. Moinuddin, R. H. Nelson, and J. P. Corey

Conclusion: “Acoustic rhinometry is an appropriate method for detecting and recording the nasal cycle in normal subjects in terms of the cross-sectional areas and volume of the nasal cavity.”

“When AR is used to evaluate volume changes in the nasal cavity by means of the template tool and technique, it can provide accurate measurements and assess nasal volume changes accordingly. For repeated nasal volume measurements by AR over a prolonged period, use of a template can reduce operator-dependent error in CSA2 measurements to zero and operator-dependent error in volume measurements to 11%.”

5). *Effect of Nasal Surgery on the Nasal Cavity as Determined by Acoustic Rhinometry*
Otolaryngology—Head and Neck Surgery, 1999

Authors: B. Kemker, X. Liu, A. Gungor, R. Moinuddin, and J. P. Corey

Conclusion: “Potentially, because AR is a quick, painless, non-invasive, and inexpensive technique to objectively evaluate the nasal cavity, it could be used routinely to document surgical outcomes and success. In combination with normative data, it could be used before surgery to objectively document the necessity of surgical intervention. The potential cost would be less than a second surgical opinion, which is commonly required. It has the potential to be used routinely, like audiograms and tympanograms are used in ear surgery, to document medical necessity and preoperative and postoperative success or failure.”

6). *The Acoustic Assessment of Nasal Area in Infants*
American Journal of Rhinology, 1994

Authors: J. E. Buenting, R. M. Dalston, and A. F. Drake

Conclusion: “The modified AR device (a narrow diameter wave tube) can be used to generate acceptably accurate area-distance functions of the infant nasal cavity.”

“The modified AR device is best suited to analysis of nasal valve area and demonstrates progressively greater errors in more distal area estimations.”

“The modified AR device can generate acceptably accurate volume measurements of the infant nasal cavity.”

“The accuracy of the modified AR device in distal area determinations is likely adequate to evaluate choanal patency versus occlusion and the device may have utility in screening for choanal atresia in infants.”

“The modified AR device accurately assessed distance to the choana, and can likely be used to measure palate length in infants.”

7). *Nasal Airway dimensions in Term Neonates Measured by Continuous Wide-band Noise Acoustic Rhinometry*
Acta Otolaryngologica, 1997

Authors: P. G. Djupesland and B. Lyholm

Conclusion: “The results presented in this study, confirming those from previous studies (11, 13), further emphasize the potentials and advantages of the acoustic reflection technique as an investigative tool in studies of respiratory dynamics in infants. The examination takes only seconds to perform, is non-invasive, accurate, has no adverse effects, can be repeated indefinitely and requires minimal co-operation”

8). *Adult Nasal Volumes Assessed by Acoustic Rhinometry*
Brazilian Journal of Otorhinolaryngology, 2007

Authors: I. E. K. Trindade, A. de Oliveira, C. Gomes, A. C. M. Sampaio-Teixeria, S. H. K. Trindade

Conclusion: “...We concluded that acoustic rhinometry, compared to computed tomography, provides accurate measurements up to the turbinates, with lower accuracy in posterior regions. Evidence also shows that these technical limitations do not invalidate the clinical usefulness of this method for posterior regions of the nasal cavity. The method may be employed in comparisons in the same subject, such as when investigating relative volume variations caused by velar movement in silent speech, or to analyze variations caused by surgery (tonsillectomies, septoplasty/turbinectomy, or maxillomandibular osteotomy), taking into account that systematic errors are common, that random errors may be minimized, and that measurements are reproducible in the same subject.”

“The different volumes verified in this study are representative of internal nasal dimensions in adults with no nasal obstruction, and may be taken as reference values for comparative studies involving populations with various nasal diseases.”

9). *Anatomic Correlates of Acoustic Rhinometry as Measured by Rigid Nasal Endoscopy*
Otolaryngology—Head and Neck Surgery, 1999

Authors: J. P. Corey, V. P. Nalbone, B. A. Ng

Conclusion: “Acoustic Rhinometry (AR) evaluates the cross-sectional areas and volume of the nasal cavity through acoustic reflections. Successive valleys displayed on an AR graph are believed to correspond to anatomic landmarks. To assess the anatomic accuracy of AR, we performed AR and endoscopic measurements with a rigid endoscope in 85 normal human subjects after topical decongestion. Endoscopic measurements were recorded for distances between the midcolumella and the nasal valve, the anterior end of the inferior turbinate, the anterior end of the middle turbinate, the midportion of the middle turbinate, and the posterior nasopharynx. The first AR valley most closely corresponded with endoscopic measurements of the nasal valve. The second valley had a mean value that corresponded with the anterior end of the inferior turbinate. The third valley matched best with the values of the anterior end of the middle turbinate. Nasopharyngeal measurements by each modality yielded a good agreement. AR appears to correspond to nasal anatomic landmarks but not in an exact point-to-point manner.”

“We conclude that AR, although primarily a research tool at this time, may be a useful tool in evaluating the condition of the anatomic landmarks of the nose.”

10). *The Role of Acoustic Rhinometry in Studying the Nasal Cycle*
Rhinology, 1993

Authors: E. W. Fisher, G. K. Scadding, V. J. Lund

Conclusion: “Magnetic resonance Imaging is one way of expanding the sphere of study to the whole nasal cavity and paranasal sinuses, although it is prohibitively expensive for large scale studies. Acoustic rhinometry does not provide as extensive geometric information as MRI, but allow the whole nasal cavity and nasopharynx to be analyzed, and is thus superior to rhinomanometry in studying the [nasal] cycle. The method also requires minimal subject cooperation, is rapid (3.5 min for four analyses), reproducible, inexpensive (comparable to rhinomanometry) and does not depend on nasal airflow. This pilot study shows that the technique can usefully be applied to studying the nasal cycle.”

11). *Acoustic Rhinometry: Evaluation of the Nasal Cavity with Septal Deviations, Before and After Septoplasty*
Laryngoscope, 1989

Authors: L. F. Grymer, O. Hilberg, O. Elbrond, O. F. Pedersen

Conclusion: “Acoustic rhinometry seems very suitable for evaluation of the nasal cavity in cases where septoplasty and turbinoplasty is considered, as well as for the postoperative evaluation. It provides an objective documentation of the visual impression of the nasal cavity, quantitative evaluation, and topical information of mucosal and skeletal changes either physiological or inferred by surgery or decongestion.”

“The reproducibility of acoustic rhinometry is high. In the initial evaluation of the method we found the coefficient of variation of the acoustic areas to be less than 2% compared with 15% for the rhinomanometric measurements.”

“The measurements with acoustic rhinometry are easy to perform and require little cooperation from the patients.”

12). *The Nasal Valve and Current Technology*
American Journal of Rhinology, 1996

Authors: P. Cole and R. Roithmann

Conclusion: “Although it is an invaluable diagnostic technique, imaging is not employed for assessment of nasal patency, but both rhinomanometry and acoustic rhinometry are widely used for this purpose. The latter two techniques are sensitive and objective, and they provide complementary information on patency of the nasal airway.”

“Rhinomanometry is more invasive and less expeditious than acoustic rhinometry, and the latter technique is of particular value in assessment of rapidly changing mucovascular conditions as in nasal challenge experiments. Mucosal volume change also is accurately measured acoustically and precise anatomical information that is generated graphically is helpful to the nasal surgeon.”

“It is noted in closing that objective assessment of the nasal airways can be minimally invasive and can produce results that are as accurate as other acceptable clinical laboratory tests when adequate equipment and proficient operators are employed.”

13). *The Objective Assessment of Nasal Patency*
ENT Journal, 1993

Authors: V. W. S. Lai and J. P. Corey

Conclusion: “Acoustic Rhinometry may become a helpful diagnostic tool as use of the technique grows. It may help the clinician in making an anatomical diagnosis to pinpoint the location and etiologic factors causing nasal obstruction. It also allows the clinician to objectively document the degree of nasal obstruction and monitor the effectiveness of treatment.”

14). *Acoustic Rhinometry: Values from Adults with Subjective Normal Nasal Patency*
Rhinology, 1991

Authors: L. F. Grymer, O. Hilberg, O. F. Pedersen, and T. R. Rasmussen

Conclusion: “The cross-sectional area of the nasal cavity increases in antero-posterior direction.”

“The minimal cross-sectional area (MCA) is located in the anterior part of the nose, in some individuals probably at the head of the inferior turbinate, and after decongestion it moves anteriorly to the ostium internum.”

“The maximum effect of decongestion is found in the middle part of the nasal cavity, at the level of the middle turbinate.”

“The amount of mucosa in the posterior part of the nose seems to be more pronounced in males than in females.”

15). *Nasal Cavity Geometry of Healthy Adults Assessed Using Acoustic Rhinometry*
Brazilian Journal of Otorhinolaryngology, 2008

Authors: A. de Oliveira Camargo Gomes, A. C. Martins Sampaio-Teixeira, S. H. Kiemle Trinadade, I. E. Kiemle Trinadade

Conclusion: “This study used acoustic rhinometry to determine the reference values for nasal cross-sectional areas to be used, for comparison purposes, in the analysis of adults with functional and/or anatomical nasal obstruction. The findings we gathered reinforce the relevance of rhinometry as a valuable tool to enhance the

assessment of nasal patency and better understand nasal and respiratory physiology.”

16). *Confirming Nasal Airway Patency Observed on Panoramic and Posterior-Anterior Cephalometric Radiographs Using an Acoustic Rhinometer*
(Accepted for Publication, 11/23/2009)

Authors: Jorge Landa, Alfred Rich, and Matthew Finkelman

Conclusion: “A very strong correlation was found between the anterior nasal cross-sectional area calculated from the radiographs, and the anterior nasal cross-sectional area and nasal volume from the rhinometer.

“The acoustic rhinometer can be a very instrumental and reliable adjunct during the course of treating a dental or orthodontic patient. By noting the nasal health status of the patient in detail before and throughout treatment, the dentist or orthodontist can properly account for the role of the nasal airway in diagnosis, treatment planning, and outcomes assessments and make a proper referral to the otolaryngologist for treatment if need be.”

17). *Adherence to Continuous Positive Airway Pressure Therapy*
The Proceedings of the American Thoracic Society , 2008

Authors: Terri E. Weaver and Ronald R. Grunstein

Relevance: “There is emerging evidence that increased nasal resistance affects CPAP use and initial acceptance of this treatment. Using acoustic rhinometry to measure the internal dimensions of the airway, those patients with smaller nasal cross-sectional area and reduced volume were much less likely to be adherent. Age-adjusted minimum cross-sectional area explained 22% of the variance in CPAP adherence. Interestingly, self-reported nasal stuffiness was not associated with nasal dimensions. Nasal resistance/obstruction also seems to influence the initial acceptance of CPAP treatment, with increased nasal pressure resulting in a 50% greater chance of rejecting CPAP as a treatment. Acceptance of CPAP was improved with nasal surgery, suggesting that the nasal cavity should be thoroughly evaluated before treatment, and surgery initiated for patients presenting with either total nasal resistance of more than 0.38 mm Hg/cm³ per second, nasal obstruction that would not be decreased with medical treatment, nasal septum deviation, or inferior turbinate hypertrophy.”

18). *Acoustic Rhinometry Reliability*

Sleep Apnea Research Group

Principal Investigator: Edward M. Weaver, MD, MPH

Co-Investigators: Judy Stenstrom LPN, BA

This study confirms the inter-rater and test-retest reliabilities of minimum cross-sectional area measurements of the nasal airway using acoustic rhinometry.

Methods - Two separate examiners measured minimum cross-sectional area with acoustic rhinometry on 25 normal volunteers on three consecutive days. Intraclass correlation coefficients were calculated.

Results - The overall mean minimum cross-sectional area was $0.61 \pm 0.20 \text{ cm}^2$, consistent with published norms. Inter-rater correlation was 0.83. Test-retest correlations over 15-minute, one-day, and two-day intervals were 0.80, 0.74, and 0.57, respectively. Decreased test-retest correlation over two days likely represents gradual real change in the intranasal dimensions.

Interpretation - Acoustic rhinometry has good to excellent reliability.

19). *Comparison of Anatomic, Physiologic, and Subjective Measures of the Nasal Airway*

Sleep Apnea Research Group

Principal Investigator: Derek J. Lam, MD

Co-Principal Investigator: Edward M. Weaver, MD, MPH

Co-Investigators: Kathryn T. James, PA, MPH

American Journal of Rhinology (in press)

Background - Studies comparing different categories of nasal measures have reported inconsistent results. We sought to compare validated measures of the nasal airway: anatomic (acoustic rhinometry), physiologic (nasal peak inspiratory flow), and subjective experience (Nasal Obstruction Symptom Evaluation Scale and a visual analog scale).

Methods - This prospective cross-sectional study of 290 non-rhinologic patients included upright and supine rhinometry (minimum cross sectional area and volume) and flow (mean and maximum) measurements, as well as subjective measures.

Associations between measures were evaluated with Spearman correlations and multivariate linear regression, adjusting for age, sex, race, body mass index, and smoking history.

Results - Correlations between objective (rhinometry and flow) and subjective categories of nasal measures ranged from -0.16 to 0.03 (mean correlation -0.07 ± 0.05), with 0 significant correlations of 16 tested. Correlations between anatomic (rhinometry) and physiologic (flow) categories ranged from 0.04 to 0.15 (mean correlation 0.10 ± 0.03), with 0 significant correlations of 16 tested. In contrast, within each category (rhinometry, flow, and subjective), all correlations were significant (13 correlations, all $p < 0.001$) and ranged from 0.62 to 0.99. Of 16 adjusted associations between objective and subjective measures, 14 were not significant ($p > 0.05$); only upright and supine minimum cross sectional area were significantly associated with the visual analog scale (both $p < 0.05$).

Conclusions - Validated anatomic, physiologic, and subjective nasal measures may assess different aspects of the nasal airway and provide complementary information. Future studies should aim to develop a composite measure including components from all three categories of nasal measurement.

20). Development of a Composite Measure of the Nasal Airway
Sleep Apnea Research Group

Principal Investigator: Derek J. Lam, MD

Co-Principal Investigator: Edward M. Weaver, MD, MPH

Co-Investigators: Kathryn T. James, PA, MPH; Danna Lei, BS; Aliya Hashemi BS;
Benjamin Reed

Sponsor: American Academy of Otolaryngology-Head & Neck Surgery

Objectives:

1. Develop a composite measure of the nasal airway including objective and subjective validated parameters.
2. Validate the composite measure in an independent sample of patients.

Background - Acoustic rhinometry and nasal peak inspiratory flow are validated methods for measuring anatomic and functional aspects of the nasal airway. The Nasal Obstruction Subjective Evaluation (NOSE) scale is a validated measure of the subjective experience of nasal airway obstruction and a visual analog scale is

another means of measuring subjective nasal obstruction. Our preliminary data indicate that the objective nasal parameters do not correlate with the subjective measures of nasal obstruction, suggesting they may measure different aspects of the nasal airway. We hypothesize that a composite measure will be a more sensitive and responsive measure of the nasal airway compared to any single measure.

Study Design - Prospective cohort study of 300 consecutive new sleep apnea patients being evaluated with multiple nasal measures at baseline and followed for CPAP use. Instrument will be developed with first 200 patients and validated with next 100 patients.

Methods - The instrument will be developed using 1) multivariable linear regression analysis to develop a multivariable model, and 2) conjunctive consolidation to create a three-stage “nasal obstruction index,” using components of the NOSE scale, nasal obstruction visual analog scale, physician nasal exam, acoustic rhinometry parameters, and nasal flow parameters that are most strongly associated with nasal outcomes. These components will be combined in a single composite score (linear regression model) or a three-stage index (conjunctive consolidation), and each will be tested in an independent sample for hypothesized associations between the nasal airway and other relevant variables.

Conclusion - A composite score will represent a more comprehensive measure of the nasal airway compared to any single measure. We predict such a measure will offer superior prognostication of nasal outcomes and will have broad applications in otolaryngology and related fields.

C. Related to Allergic and/or Vasomotor Rhinitis

1). *Diagnostic Value of Acoustic Rhinometry: Patients with Allergic and Vasomotor Rhinitis Compare with Normal Controls*
Rhinology, 1990

Authors: H. Lenders and W. Pirsig

Conclusion: "...acoustic rhinometry seems to be more sensitive than Rhinomanometry for the diagnosis of allergic and vasomotor rhinitis. In addition, the capabilities of acoustic rhinometry to precisely localize and quantify the most resistive area can be used to plan surgery as well as to follow up the surgical treatment by anterior turbinoplasty. In another paper (in preparation) we will show that all findings and results presented here can be found not only in patients with a straight septum, but also in patients with septal deviations. In conclusion acoustic rhinometry enables the exact measurement of the size and location of a nasal obstruction, thus providing the base to differentiate between valve stenosis, turbinate hypertrophy, septum deviation, polyps, or other masses in the nasal cavity."

2). *The Role of Acoustic Rhinometry in Nasal Provocation Testing*
Ear, Nose and Throat Journal, 1997

Authors: R. Roithmann, MD, I. Shpirer, MD, P. Cole, MD, J. Chapnik, MD, J. P. Szalai, PhD, N. Zamel, MD

Conclusion: "We conclude that acoustic rhinometry is an alternative objective method for measuring nasal mucosa responses to allergen challenge and is as sensitive as nasal airflow resistance measurements. The method is simple, non-invasive, comfortable for the patient, and requires only a few moments to perform."

3). *Evaluation of the Nasal Cavity by Acoustic Rhinometry in Normal and Allergic Subjects*
Otolaryngology—Head and Neck Surgery, 1997

Authors: J. P. Corey, MD, B. J. Kemker, MD, R. Nelson, and A. Gungor, MD

Conclusion: "Acoustic rhinometry gives a valid two-dimensional impression of the anatomy of the nasal cavity, which illustrates areas of potential

obstruction, congestion, or septal abnormalities. The technique has been demonstrated to be sensitive enough to detect local changes in vascular congestion caused by the positioning or posture of the patient and by environmental conditions. It has been used for the preoperative and postoperative evaluation of patients undergoing septoplasty, polypectomy, turbinectomy, inferior meatal antrostomy, or anterior turbinoplasty of the nasal cavity.”

“Other studies have demonstrated a possible use of acoustic rhinometry for the assessment of the nasopharynx and adenoids in evaluation before adenoidectomy and during surgical follow-up. Acoustic rhinometry has a potential use for serial evaluations, correlation with clinical examinations, evaluation of medical therapy, immunotherapy assessment, nasal provocation for allergies and documentation of therapeutic effects. Unlike Rhinomanometry, this technique does not require a flow of air through the nasal passages so that even severely congested patients may be evaluated with minimal discomfort.”

“With acoustic rhinometry, we were able to detect a statistically significant difference between normal and allergic subjects in their response to a topical decongestant at the minimal cross-sectional area. This area corresponds to the nasal valve or inferior turbinate.”

4). *An Interpretation Method for Objective Assessment of Nasal Congestion with Acoustic Rhinometry*

Laryngoscope, 2002

Authors: B. Mamikoglu, S. M. Houser, and J. P. Corey

Conclusion: “Separate computed tomography (CT) and magnetic resonance imaging (MRI) correlation studies have confirmed the reliability of AR measurements.”

“Objective nasal assessment with AR allows us to assess whether an obstruction is structural, mucosal, or mixed with an objective grading of the disease according to standardized normal values.”

5). *Acoustic Rhinometry Compared with Anterior Rhinomanometry in the Assessment of the Response to Nasal Allergen Challenge*

Clinical Otolaryngology, 1994

Authors: G. K. Scadding, Y. C. Darby, and C. E. Austin

Conclusion: “Acoustic rhinometry has a definite advantage [to rhinomanometry] because it is not dependent on airflow in the nose, and it is therefore suitable for severely congested individuals. It also appears to be more sensitive to changes in obstruction, probably because the measurement of cross-sectional area represents the location of minimal airflow, which determines the degree of obstruction experienced by the individual.”

“In conclusion, acoustic rhinometry correlates well with and is superior to Rhinomanometry in assessing the response to nasal allergen challenge, especially in patients with an initial degree of nasal obstruction.”

6). *The Use of Acoustic Rhinometry to Quantitatively Assess Changes after Intranasal Allergen Challenge*
American Journal of Rhinology, 1994

Authors: V. W. S. Lai, J. P. Corey

Conclusion: “Acoustic Rhinometry is a reliable technique for assessing the results of nasal provocation. This is a simple test to perform and is a good objective evaluation of the degree of nasal patency. Results are obtained quickly and consistently and are highly reproducible with negligible inter-examiner variation. Because it represents the cross-sectional area of the nasal cavity as a function of distance from the nares, it offers a quantitative assessment of physiological changes in the nasal mucosa. Subjective assessments of the outcome of NP such as sneezing, rhinorrhea, and stuffiness are less reliable; even our patient who had negative mRAST and negative response on NP experienced some subjective symptoms. These subjective symptoms may be attributable to local irritation.”

“Standardization is required for nasal provocation tests with the emphasis on **quantitative** and **objective** measurements. Only with standardized technique can the role of NP be more prominent in clinical and research arenas.”

D. Related to Nasal Obstruction

1). *The Objective Assessment of Nasal Patency*
Ear, Nose, and Throat Journal, 1993

Authors: V. W. S. Lai, MD and J. P. Corey, MD, FACS

Conclusion: “Acoustic Rhinometry may become a helpful diagnostic tool as use of the technique grows. It may help the clinician in making an anatomical diagnosis to pinpoint the location and etiologic factors causing nasal obstruction. It also allows the clinician to objectively document the degree of nasal obstruction and monitor the effectiveness of treatment. Perhaps in the future, acoustic rhinometry may play a role not only in research, but also in the physician office.”

2). *Acoustic Rhinometry: Should We Be Using It?*

Otolaryngology—Head and Neck Surgery, 2006

Authors: J. P. Corey

Conclusion: “In Summary, we should use acoustic rhinometry because it can be a valuable aid in the diagnosis of nasal airway obstruction in both adults and children. New standards for its use have been recently published. Acoustic rhinometry can now be used to aid in the clinical diagnosis of most sinonasal disorders, including ‘mixed’ pathology, and to provide objective documentation of rhinologic disorders. In conjunction with a careful clinical exam, it can provide objective documentation and diagnosis for better treatment of nasal airway blockage. An improved ability to diagnoses and to document pathology can aid us in practicing evidence-based medicine.”

3). *Preoperative and Postoperative Nasal Septal Surgery Assessment with Acoustic Rhinometry*

Otolaryngology—Head and Neck Surgery, 1997

Authors: L. Shemen and R. Hamburg

Conclusion: “AR is useful in the objective diagnosis of nasal obstruction, namely, it can assist in differentiating reversible mucosal disease from medically irreversible structural abnormalities.”

“AR can aid in the selection of appropriate management of nasal obstruction.”

“AR is useful in the objective evaluation of the relief of nasal obstruction after surgery.”

“AR is crucial in outcome analysis and forensic and medicolegal evaluation regarding nasal obstruction and its relief.”

4). *Septoplasty and Compensatory Inferior Turbinate Hypertrophy: A Randomized Study Evaluated by Acoustic Rhinometry*

The Journal of Laryngology and Otology, 1993

Authors: L.F. Grymer, P. Illum, O. Hilberg

Conclusion: “Septoplasty increased the areas of the narrow side significantly in both groups. The increase in area in group B was surprisingly little. This is probably an expression of the limitation of septoplasty in the treatment of slight septal deviations. The criteria for septal and turbinate surgery will probably have to be revised with the introduction of simple and reproducible objective methods for evaluation of the nasal cavity. Acoustic rhinometry is easy to perform and very suitable for control of the changes to the anterior part of the nose during surgery.”

“Fifty per cent of a random population with nasal obstruction and septal deviation had a severe septal deviation as defined by acoustic rhinometry.”

“If pronounced septal deviation is present, a compensatory skeletal inferior turbinate hypertrophy may be found on the opposite side and anterior conservative turbinoplasty seems advisable.”

“Mucosal inferior turbinate hypertrophy defined by acoustic rhinometry, should be expected in 32 per cent of a random population with nasal obstruction, on the side contralaterally to the main septal deviation, independent of the degree of septal deviation.”

5). *Acoustic Rhinometry in the Evaluation of Nasal Obstruction*

Laryngoscope, 1995

Authors: R. Roithmann, P. Cole, J. Chapnik, I. Shpirer, V. Hoffstein, N. Zamel

Conclusion: “From a clinical point of view, the area-distance function curve [acoustic rhinometry] helps the clinician to differentiate objectively and quantify the mucosal and the structural component of nasal obstruction and to assess results of medical and/or surgical treatment. AR findings must be considered in association with those of anterior rhinoscopy or nasal endoscopy to be correctly interpreted because different pathological conditions can produce similar curves. The main advantages of the technique are that it is

noninvasive, painless, rapidly performed, and highly reproducible.”

6). *Effect of Nasal Surgery on the Nasal Cavity as Determined by Acoustic Rhinometry*
Otolaryngology—Head and Neck Surgery, 1999

Authors: B. Kemker, X. Liu, A. Gungor, R. Moinuddin, and J.P. Corey

Conclusion: “Acoustic Rhinometry (AR) was used to objectively measure the success of septoplasty in relieving nasal obstruction caused by septal deviation.”

“AR measurements were successful in detecting increases in CSAs 1, 2, and 3 [Cross Sectional Areas] but reached statistical significance for CSA 3, representing the level of the anterior middle turbinate in the septoplasty plus other group. Symptom scores of congestion and rhinorrhea improved significantly for the septoplasty group.”

“AR volume measurements increased significantly for all subjects after surgery. This pilot study suggests that AR may be a useful, cost-effective technique to document surgical outcome and success for septoplasty surgery.”

7). *Confirming Nasal Airway Patency Observed on Panoramic and Posterior-Anterior Cephalometric Radiographs Using an Acoustic Rhinometer and ImageJ*
Tufts University—Pediatric Dentistry

Authors: Jorge Landa, Alfred Rich, and Matthew Finkelman

Rationale: “Currently, dentists and orthodontists rely on subjective visual assessment of the airway extraorally, and by analyzing panoramic radiographs and noting apparent structural and anatomical abnormalities. Once again this current modality of analysis lacks a standardized norm and is subject to human error and thus imprecise. While some recent studies have attempted to bridge this knowledge gap, there is a need to investigate a comprehensive diagnostic tool that is non-invasive and can be coupled with standard dental imaging to formulate the best objective assessment possible. This is where we believe the use of the Acoustic Rhinometer by dentists and orthodontists can serve the greatest benefit to their patients.

“The use of acoustic rhinometry as an adjunct to radiographic examination will provide an objective and non-invasive method to

assess the nasal volumetric dimensions. The technique is easy to understand and is not imposing on practitioners or patients. The cross-sectional area and volume of the nasal cavity can be assessed using the acoustic reflections from sound waves emitted from the rhinometer. The computer generated graph of nasal area versus nasal cavity distance plots waves which correspond to particular anatomical landmarks of the nasal cavity. Prior confirmation of the accuracy of these anatomical markers has been confirmed through CT and MRI investigations. The prior studies have provided us with adult norms that can be used for comparison with the readings gathered from the acoustic rhinometer, and a determination can be made as to the patency of the airway. Currently we possess little data on child or adolescent norms, and for this reason continued studies involving the acoustic rhinometer in this age group are indicated.

“It is proposed that using the acoustic rhinometer readings, cephalometric analysis, and ImageJ calculations will yield a correlation between standard dental imaging and examination and airway patency assessment. The need for a definitive and non-invasive evaluation tool conventional to the dental exam can be fulfilled after establishing a relationship between the cephalometric radiographs, panoramic radiographs, and acoustic rhinometer. This comprehensive evaluation method will be instrumental in making multidisciplinary intervention to correct craniofacial abnormalities and nasal airway obstruction.”

Conclusion: “While the acoustic rhinometer is not readily available at most dentists’ office, the technology is becoming more affordable, and the clinician can acquire the skills and technique necessary to operate the equipment through workshops and practice. Furthermore, the ImageJ program is available for free download from the NIH, and scanned or digital radiographic images can easily be traced in the dental setting. The relationship established between the rhinometer and ImageJ in this project confirms the validity of either or both methods in identifying nasal airway obstruction. By noting the nasal health status of the patient in detail before and throughout treatment, the dentist or orthodontist can properly account for the role of the nasal airway in diagnosis, treatment planning, and outcomes assessments, and make a proper referral to the otolaryngologist for treatment if need be.”

8.) *Physiological change in nasal patency in response to changes in posture, temperature, and humidity measured by acoustic rhinometry.*

Authors, Lal Devyani; Gorges Melissa L; Ungkhara Girapong; Reidy Patrick M; Corey Jacquelynne P

Abstract:

BACKGROUND: Acoustic rhinometry has been used to assess nasal patency and to calculate nasal cavity volume. This study used acoustic rhinometry to assess changes in nasal patency after alterations in posture, unilateral mechanical obstruction, temperature, and humidity. **METHODS:** Eight healthy adult volunteer subjects underwent acoustic rhinometry during the following conditions: (1) sitting position (control), (2) supine position, (3) left lateral recumbent position, (4) nostril unilaterally mechanically blocked, (5) ice pack on neck, (6) drinking cold water, (7) drinking hot water, (8) nasal nebulizer, and (9) oxymetazoline decongestant. **RESULTS:** Two distinct patterns emerged based on the total nasal cavity volumes in response to the decongestant. Subjects with initial unilateral nasal cavity volumes near the mean had an expected increase in total volume after the topical decongestant administration. There were two subjects with initial volumes of 1 SD above the mean that had a paradoxical decrease in total volume in response to the decongestant. In all subjects, there was a significant decrease in the volume of each of the nasal cavities in response to ingestion of hot water at 1 minute. There was a significant decrease in the volume of the smaller of the two nasal cavities in response to nebulizer treatment and hot water ingestion at 5 minutes. Total nasal cavity volume changes were not significant for any of the variables. **CONCLUSION:** Changes in nasal cavity volumes were detected by acoustic rhinometry after alterations in posture, unilateral mechanical obstruction, temperature, and humidity. Nebulizer treatment and hot water ingestion caused a significant decrease in nasal volume. The nose of a healthy patient was able to adapt to environmental and physiological changes to maintain a consistent total nasal volume within 15 minutes.

9). *Acoustic rhinometry predicts tolerance of nasal continuous positive airway pressure: A Pilot Study.*

Am J Rhinol 2006

Authors: Morris, L.G., Setlur, j., Burschtin, O.E., Steward, D.L., Jacobs, J.B., Lee, K.C.

Abstract:

BACKGROUND: Nasal continuous positive airway pressure (nCPAP) is usually the first-line intervention for obstructive sleep apnea, but up to 50% of patients are unable to tolerate therapy because of discomfort-usually nasal complaints. No factors have been definitively correlated with nCPAP tolerance, although nasal cross-sectional area has been correlated with the level of CPAP pressure, and nasal surgery improves nCPAP compliance. This study examined the relationship between nasal cross-sectional area and nCPAP tolerance. **METHODS:** We performed acoustic rhinometry on 34 obstructive sleep apnea patients at the time of the initial sleep study. Patients titrated to nCPAP were interviewed 18 months after starting therapy to determine CPAP tolerance. Demographic, polysomnographic, and nasal cross-sectional area data were compared between CPAP-tolerant and -intolerant patients. **RESULTS:** Between 13 tolerant and 12 intolerant patients, there were no significant differences in age, gender, body mass index, CPAP level, respiratory disturbance index, or subjective nasal obstruction. Cross-sectional area at the inferior turbinate differed significantly between the two groups ($p=0.03$). This remained significant after multivariate analysis for possibly confounding variables. A cross-sectional area cutoff of 0.6 cm² at the head of the inferior turbinate carried a sensitivity of 75% and specificity of 77% for CPAP intolerance in this patient group. **CONCLUSION:** Nasal airway obstruction correlated with CPAP tolerance, supporting an important role for the nose in CPAP, and providing a physiological basis for improved CPAP compliance after nasal surgery. Objective nasal evaluation, but not the subjective report of nasal obstruction, may be helpful in the management of these patients.

10). *Abnormalities on Nasal Exam Associated with Decreased CPAP Tolerance and Use*

Sleep Apnea Research Group

Principal Investigators: N. Husen, MD; E.M. Weaver, MD

Abstract: “Poor tolerance and inadequate use are the greatest limitations to CPAP therapy for sleep apnea. This retrospective cohort study evaluated 306 patients who were prescribed CPAP therapy for sleep apnea at the University of Washington’s Sleep Disorders Center during the period January 2000 thru August 2002. Nasal exam findings, polysomnography and CPAP data were extracted from medical charts.

Conclusions: “Patients with an abnormal nasal exam, but not nasal symptoms, were found to have decreased CPAP use and tolerance. This fact should be confirmed with a prospective cohort study. These data suggest that treatment of nasal conditions should be considered before prescribing CPAP as this may improve CPAP tolerance and use.”

11). *Acoustic rhinometry predicts tolerance of nasal continuous positive airway pressure: A pilot study*

American Journal of Rhinology, Volume 20, Number 2, March-April 2006 , pp. 133-137(5)

Authors: Morris, Luc G.; Setlur, Jennifer; Burschtin, Omar E.; Steward, David L.; Jacobs, Joseph B.; Lee, Kelvin C.

Abstract:

Background: Nasal continuous positive airway pressure (nCPAP) is usually the first-line intervention for obstructive sleep apnea, but up to 50% of patients are unable to tolerate therapy because of discomfort—usually nasal complaints. No factors have been definitively correlated with nCPAP tolerance, although nasal cross-sectional area has been correlated with the level of CPAP pressure, and nasal surgery improves nCPAP compliance. This study examined the relationship between nasal cross-sectional area and nCPAP tolerance.

Methods: We performed acoustic rhinometry on 34 obstructive sleep apnea patients at the time of the initial sleep study. Patients titrated to nCPAP were interviewed 18 months after starting

therapy to determine CPAP tolerance. Demographic, polysomnographic, and nasal cross-sectional area data were compared between CPAP-tolerant and -intolerant patients.

Results: Between 13 tolerant and 12 intolerant patients, there were no significant differences in age, gender, body mass index, CPAP level, respiratory disturbance index, or subjective nasal obstruction. Cross-sectional area at the inferior turbinate differed significantly between the two groups ($p = 0.03$). This remained significant after multivariate analysis for possibly confounding variables. A cross-sectional area cutoff of 0.6 cm^2 at the head of the inferior turbinate carried a sensitivity of 75% and specificity of 77% for CPAP intolerance in this patient group.

Conclusion: Nasal airway obstruction correlated with CPAP tolerance, supporting an important role for the nose in CPAP, and providing a physiological basis for improved CPAP compliance after nasal surgery. Objective nasal evaluation, but not the subjective report of nasal obstruction, may be helpful in the management of these patients.

12). *Nasal Obstruction and CPAP Outcomes Cohort Study*
Sleep Apnea Research Group

Principal Investigator: Edward M. Weaver, MD, MPH

Co-Investigators: Richard Deyo, MD, MPH; Vishesh Kapur, MD, MPH; Michael Vitiello, PhD; Allan I. Pack, MB, ChB, PhD; Derek Lam, MD

Introduction:

Obstructive sleep apnea syndrome is defined as symptomatic repetitive obstruction of the upper airway during sleep (1) and occurs in 2 – 4% of adults (2). Nasal CPAP is the first line treatment for sleep apnea due to its safety and efficacy. Wearing the device usually normalizes physiologic sleep parameters and may reduce the risk of medical complications associated with sleep apnea(3-5). CPAP users have improved symptoms, function, and quality of life(6, 7).

Inadequate use is the major limitation to CPAP therapy(8, 9). Emerging data indicate 6 hours per night is required for adequate effect(8), yet objective measures suggest $< 35\%$ of CPAP patients meet this threshold (10, 11). We hypothesize that nasal obstruction is associated with decreased CPAP use and ultimately reduced CPAP treatment effect.

This prospective cohort study is currently underway at the University of Washington's Sleep Disorders Center in Seattle, WA. The Seattle Sleep Cohort is comprised of patients recruited at the time of initial polysomnography in the Sleep Lab and are being followed for six months. The current rate of enrollment is approximately three hundred per year. Participants are asked to complete a questionnaire and undergo non-invasive nasal measurements at baseline as well as complete a follow-up questionnaire at six months.

This observational cohort study will be useful for prognosticating outcomes in new CPAP patients. This information will help identify patients who may require extra attention with CPAP and may ultimately benefit from nasal surgery. It may also help define the level of nasal obstruction that impacts CPAP usage and quality of life outcomes.

Research Questions

Specific Aim - To determine whether nasal obstruction influences CPAP treatment outcomes above and beyond other behavioral and biomedical factors.

Primary Hypothesis - Among patients prescribed CPAP for sleep apnea, those with nasal obstruction experience less improvement in sleep apnea quality of life than those without nasal obstruction.

Secondary Hypothesis - Among patients prescribed CPAP for sleep apnea:

- those with nasal obstruction use CPAP less than those without nasal obstruction
- those with nasal obstruction require higher CPAP pressure than those without nasal obstruction, controlling for sleep apnea severity.
- there are "dose-response" relationships between the severity of baseline nasal obstruction and CPAP pressure level, CPAP usage, and degree of improvement in sleep apnea quality of life.

Measures: - In this study, the nasal airway is measured objectively and subjectively. The primary objective measure is obtained via acoustic rhinometry. Acoustic rhinometry is objective, validated, reliable, clinically useful, quick and easy to perform, noninvasive, inexpensive, and widely used for measuring the nasal airway (12,13). It uses acoustic reflectance to produce a profile of the cross-sectional area across the full length of the nasal cavity.

