Physiology: Rhinomanometry

25

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Keywords
Rhinomanometry • Nasal obstruction • Airway resistance • Nasal airway obstruction • Nasal cavity • Nasal blockage • Nasal provocation tests

Core Messages

1. Rhinomanometry allows objective assessment of nasal resistance, the ratio of transnasal pressure over transnasal airflow measured during nasal respiration.
2. Many aspects of the study of nasal physiology have been studied with the aid of rhinomanometry.
3. Rhinomanometry assesses the overall effect of nasal airway dimension and shape on the passage of air through the nose.

25.1 Introduction

Rhinomanometry is the simultaneous measurement of airflow through the nose and pressure across the nose during breathing. Figure 25.1 shows plots of transnasal pressure and flow during respiration. As the patient inspires, the curves go downward showing a decrease in pressure and the corresponding movement of air in the direction of the lungs. As the patient changes to expiration, the curves move upward, corresponding to pressure increasing and causing the movement of air out of the nose. Dividing the maximum pressure reached during normal inspiration by the highest flow gives a nasal resistance value that correlates with the symptom of nasal obstruction in symptomatic patients. This objective test has been crucial in increasing understanding in many areas of nasal physiology. While the extent of its use varies in different parts of the world, it is still used in research and in clinical assessment of nasal function.

Resistance calculated at the maximum pressure and flow correlates with the symptom of nasal obstruction.

This chapter will provide a framework to put the role of rhinomanometry in context among the other tools used to objectively assess nasal function. The methods of rhinomanometry will be described. The research role that rhinomanometry has played in discoveries in nasal physiology will be covered including the nasal cycle, changes

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T.M. Önerci (ed.), *Nasal Physiology and Pathophysiology of Nasal Disorders*,
DOI 10.1007/978-3-642-37250-6_25, © Springer-Verlag Berlin Heidelberg 2013

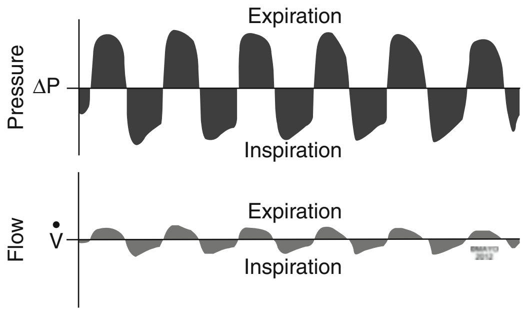


Fig. 25.1 Shows a plot of pressure and flow during respiration. As the patient inspires, the curves go downward showing a decrease in pressure and the corresponding movement of air in the direction of the lungs. As the patient changes to expiration, the curves move upward corresponding pressure increasing and the movement of air out of the nose

with growth, posture, and exercise; changes to the downside of the nose when a patient is lying down; and resistance in the normal nose and the nose with disturbed breathing function. The chapter ends with a summary of the clinical applications for which rhinomanometry has been used.

25.2 The Context of Rhinomanometry in Assessing Nasal Respiratory Function

25.2.1 What Are the Functions Associated with Nasal Respiration?

The movement of the diaphragm and lungs results in the movement of air through the nose. The passage of air through the nose is beneficial for the lungs because of the warming, humidification, and protective functions of the nose. The mucous layer in the nose can trap particulates, allowing the cilia to sweep them away (assessment of ciliary function covered by M. Jorissen in Chaps. 2 and 28). In addition, elements of the immune system are able to have contact with antigens, stimulating protective responses (covered by R. Kern in Chap. 3). Furthermore, air is delivered to the olfactory area providing the enhancement of taste and the protective function of detecting potentially harmful substances or organisms (assessment covered by P. Rombaux in Chaps. 10 and 30). The measurement of some of the important physiologic components of nasal respiration, warming, humidification, mucociliary clearance, and olfaction, is covered in other chapters in this book as noted above.

As air passes through the nose, comfortable nasal breathing corresponds with a dimension and shape of the nasal airway that in general optimizes the above functions. Rhinomanometry assesses the overall effect of nasal airway dimension and shape on the passage of air through the nose.

> Comfortable nasal breathing corresponds with a dimension and shape of the nasal airway that in general optimizes the multiple functions of the nose.

25.2.2 What Anatomic Elements Are Encountered During Nasal Respiration?

Measurement of the nasal airway assesses the nasal airstream which may be variably affected by the physical dimension of the components of the nasal airway including the vestibule, valve area, turbinates, and sinus openings. The presentation of these anatomic elements as air is *inspired* through the nose is different than the shape of the presenting surfaces as air is *expired*. This may reflect different functions of the two phases.

The first part of inspiration is the passage of air through the vestibule in a curve first superiorly and then toward the nasal valve area. The airstream then passes through a narrower area referred to as the internal valve. This corresponds to the area under the caudal end of the upper lateral cartilages and is clearly seen on casts or volume renderings of the nasal airway (Fig. 25.2). As the airstream leaves the valve area, it is dispersed in a wider distribution, thus providing contact with more surface area of the turbinates than if the airstream had passed unimpeded. The turbinates provide the working surface of the nose. By having protuberant curved surfaces,

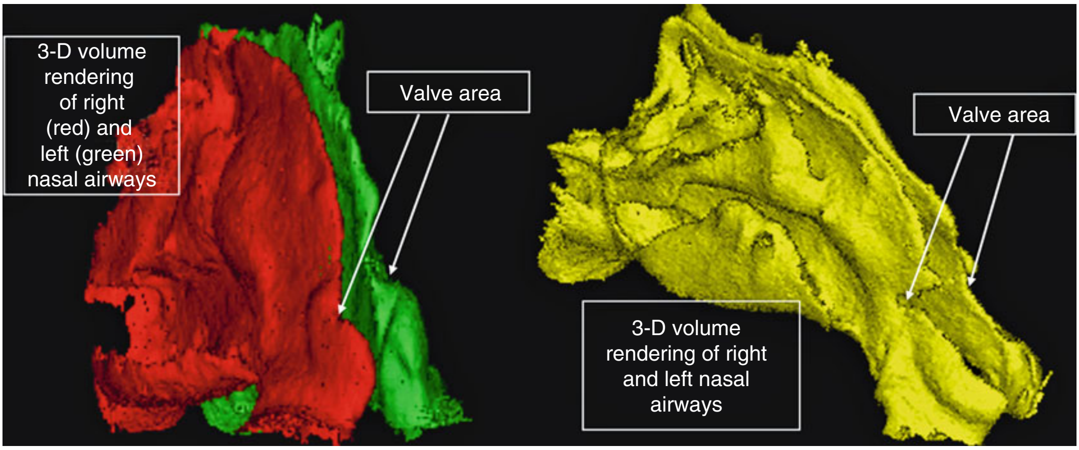


Fig. 25.2 Volume rendering of the nasal airway. Using 3D image analysis software and CT scans, the nasal airway is portrayed. This gives the same image early anatomists accomplished with wax castings. Note the narrow part of the airway at the valve area

they act as flanges in the airstream providing increased surface areas on which to contact the air for humidification, warming, and filtering. The air then passes on to the choana and turns again, this time in the direction of the larynx and tracheobronchial tree.

As the inspired airstream passes the uncinate, the natural os of the maxillary sinus is protected from exposure to the passing airstream. Openings from the frontal sinus, anterior ethmoid cells, and posterior ethmoid cells are similarly sheltered by presenting baffles though maxillary sinus accessory openings and postsurgical openings can present additional openings to the inspired air. Computational fluid dynamics (CFD) studies have suggested only minimal, if any, effect of single maxillary sinus openings on the respiratory airstream in a typical (unoperated) nose, whereas the presence of an accessory os can result in some airflow into the maxillary sinus (Hood et al. 2009; Zhu et al. 2012).

When considering any possible impact of the nasal passage during expiration, retention of heat is usually mentioned. This may be facilitated by having the air pass over the turbinates before encountering the restriction of the valve area. The baffles that sheltered the ostia in the inspiratory direction now may function to catch the expired air. Some associate this phenomenon with nitric oxide from the maxillary sinus serving a regulatory function in respiration (for measurement of nitric oxide, see Chap. 9 by P. Hellings). Computational fluid dynamics (CFD; see below) in 3D models showed an increase in maxillary sinus airflow rate with high expiratory flow rates simulating nose blowing (Zhu et al. 2012).

> As the airstream leaves the valve area, it is dispersed in a broader distribution, thus providing contact with more surface area of the turbinates than if the airstream had passed unimpeded.

25.2.3 Objective Measurement of Nasal Respiratory Function

Of the various anatomic elements present, measurements of the airstream are primarily influenced by the dimension of the valve and turbinates, by the relative thickness of the mucosal lining, and, at times, by the respiratory effort of the patient.

The objective methods of assessing the nasal respiratory passages include (a) measurement of the dimension of the airway, (b) measurement of the nasal airflow alone, and (c) rhinomanometry, the simultaneous measurement of the transnasal pressure and airflow.

25.2.3.1 Measurement of the Dimension of the Airway

The assessments of the dimensions of the nasal airway are not measurements of the airflow through the nose during respiration. Imaging with CT or MRI and then doing a 3D reconstruction of the airway will demonstrate the airway dimensions in different parts of the nose. This can be helpful especially when used in conjunction with computational fluid dynamics (CFD).

Acoustic rhinometry (see Chap. 26 by E. Hizal and O. Cakmak) also measures the airway dimension by calculations done on sound waves reflected back by intranasal structures. While this is not an assessment of the flow of air through the nose, it can be useful for measuring relative airway dimensions as well as changes with time, treatment, or various interventions (Lal et al. 2006).

Computational fluid dynamics (CFD) uses imaging, typically a CT scan done at one point in time, to generate a 3D model of the airway and then apply fluid dynamic modeling to that airway (Zhao and Dalton 2007). By using different transnasal pressures representing a respiratory cycle, the software can calculate the relative flow velocity in a number of anatomic sites in the nasal airway for various points in time during respiration. This capability offers exciting possibilities for the future study of the impact of various anatomic variations or pathology on the airstream. Those studying nasal physiology will be faced with the task of finding the meaning of the plethora of different flow vectors that result from CFD analysis of the nasal airway. To identify the meaningful parameters derived from the large amount of data is a tantalizing possibility for future study that will be facilitated by ever increasing computer processing speed and data handling (see Chap. 19 by R. Mösges).

25.2.3.2 Measurement of the Nasal Airflow Alone (Peak Flow Measurement)

Measuring only nasal airflow is popular especially with physicians who already use similar equipment to monitor their asthmatic patients by measuring peak lower airway flows. While this has the limitations of some dependence on patient effort, it has been relatively popular because of its simplicity and the ready availability of the equipment (Timperley et al. 2011). It has been demonstrated that physicians would like to have a simple tool for objective assessment of results in allergic rhinitis (Serrano et al. 2007). Since the rate of flow changes throughout the respiratory cycle, taking the measurement at some constant point can help decrease the variability of results and provide a standard for comparison. In this case, the "constant" point is the "peak" airflow reached with maximal effort. Peak nasal inspiratory flow can be measured by modifying the peak flow device for nasal inspiration. The measurements can be affected by valve collapse occurring at higher airflows that may not occur at normal physiologic flows (Barnes and Lipworth 2007). Nonetheless, this method has been popular, and normative values have been collected (Ottaviano et al. 2006; Papachristou et al. 2008; da Cunha Ibiapina et al. 2011; van Spronsen et al. 2012).

Both peak nasal inspiratory flow (PNIF) and peak nasal expiratory flow (PNEF) measurements have been used. There is some debate about the variability of results (Blomgren et al. 2003; Teixeira et al. 2011), but the tests have been shown to be useful, particularly for challenge testing in patients with allergic rhinitis (Wilson et al. 2003).

25.2.3.3 Rhinomanometry: The Simultaneous Measurement of the Transnasal Pressure and Airflow

Collecting simultaneous pressure and flow values allows the calculation of nasal resistance or conductance. Calculation of the ratio of pressure to flow could be done at any one of many simultaneous pressure-flow values along the continuously changing curve during respiration (Fig. 25.3). Using a specific airflow value at which to measure the pressure-flow values is an important element allowing consistent comparisons. Viewing the entire sigmoid pressure-flow curve also allows the observation of the position and amount of curvature that reflects the amount of flow the patient is generating for the range of pressures occurring in the course of their nasal breathing. Rhinomanometry is used (except in rare studies) to assess the pressure and flow across the entire nasal airway, from nasal entrance to nasopharynx.

The use of CFD analyses done from CT images inspires thoughts of using microsensors to inobtrusively detect the pressure and flow changes during respiration for multiple sites in the nasal airway. Just as Lindemann (Lindemann et al. 2006) had actual measurements using tiny thermocouples to validate the corresponding CFD calculations they did for temperature at many sites in the nose, multiple localized pressure and flow measurements could verify the results of CFD analyses that yield multiple differing flow vectors at different anatomic sites in the nasal airway. Such validation of CFD, if combined with actual pressure measurements for a given patient, could move it out of the category of assessing airway dimensions to the category of yielding measured information about nasal airflow.

The plot of pressure and flow during inspiration and expiration yields a sigmoid curve that is closer to the *x*-axis (pressure axis) when nasal obstruction is greater.

25.2.4 Rhinomanometry for Measurement of Nasal Respiratory Function

As noted in the introduction, when rhinomanometry is performed, continuous measurement of transnasal pressure shows a rising and falling curve in the positive and then negative direction throughout each respiratory cycle (Fig. 25.1). As the changing pressure drives an accelerating and then decelerating flow of air, a plot of airflow shows a similar positive and negative excursion. Plotting pressure (*x*-axis) versus flow (*y*-axis) during inspiration and expiration yields a sigmoid curve that is closer to the *x*-axis when obstruction is greater (Figs. 25.3 and 25.4). Vogt

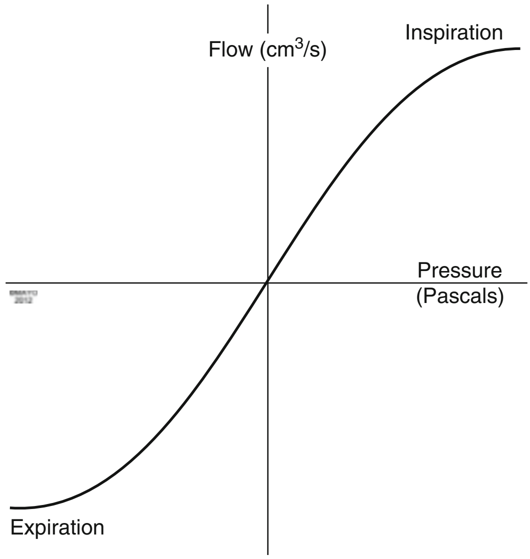


Fig. 25.3 The plot of pressure versus flow. Each point represents the simultaneous measurement of pressure and the corresponding flow value. Pressure values are on the *x*-axis and flow values on the *y*-axis. The sigmoid shape of the curve shows that in general there is a gradual increase in the pressure to flow ratio as one goes further out the curve toward the maximum values reached in normal respiration. Thus, for a given patient, the resistance value reported can vary depending on the point on the curve that is selected for calculating the result

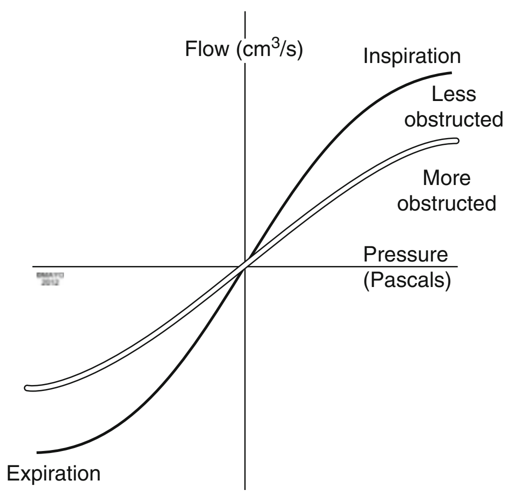


Fig. 25.4 The sigmoid pressure-flow curves for two different patients. The curve that is closer to the *x*-axis (pressure) represents the more obstructed nasal airway with higher resistance values

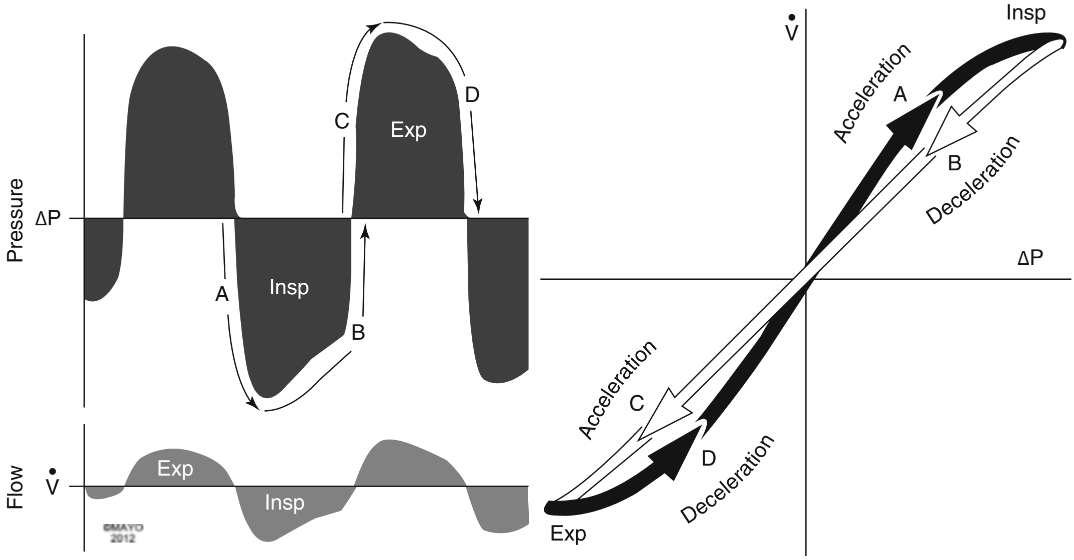


Fig. 25.5 The path of the pressure-flow curve away from the origin during inspiration (the accelerating limb, *A*) does not follow the same curve on the path back to the origin (decelerating phase, *B*). The same is true for the expiratory limb (*C*, *D*)

pointed out that the path of the pressure-flow curve away from the origin during inspiration (the accelerating limb) often does not follow the exact same curve on the path back to the origin (decelerating phase). The same is true for the expiratory limb (Fig. 25.5).

25.3 How Is the Measurement Done with Rhinomanometry?

25.3.1 Different Techniques: Most Common Method

The most commonly employed method of doing rhinomanometry is called anterior masked rhinomanometry. The different methods of rhinomanometry are distinguished by the location of the pressure detection and the apparatus for flow measurement. Table 25.1 lists the different types (methods) of rhinomanometry and the methods of pressure and flow detection that define them.

For measurement of the nasal airway of a patient with a nasal septal perforation, only the total airway is measured because the septal perforation would cause an error in unilateral pressure assessment. Anterior rhinomanometry thus is not used in patients with nasal septal perforations. Since the total airway is not measured when the anterior method is used, it is necessary to derive the total airway values by adding the right and left flow values for each corresponding pressure value along the pressure-flow curve (Fig. 25.6).

25.3.2 Transnasal Flow Measurement: Anterior or Posterior Method

Flow through the nasal airway is most commonly measured by attaching a flowmeter at the outlet of the mask which is sealed tightly on the patient's face. The usual flowmeter consists of pressure detection on either side of a resistive element. Originally nozzles were used to measure the flow through each nostril. When using a mask (or body plethysmograph), unilateral measurements can be done by occluding the opposite nostril with tape.

Since the total airway is not measured when the anterior method is used, it is necessary to derive the total airway values by adding the right and left flow values for each corresponding pressure value along the pressure-flow curve (Fig. 25.6).

Table 25.1 The different types of rhinomanometry. Anterior masked rhinomanometry is the type most commonly employed

Type of rhinomanometry	Flow detection	Pressure detection	Side(s) that can be directly measured
Anterior masked with full face mask	Device on outlet of full face mask	Catheter with sealed connection to non-measured nostril	Unilateral
Anterior masked with partial face mask	Device on outlet of partial face mask	Catheter with sealed connection to non-measured nostril	Unilateral
Anterior with nozzle	Device connected to nozzle held to nostril opening	Nozzle held to non-measured nostril	Unilateral
Posterior with full face mask	Device on outlet of full face mask	Catheter by nasopharynx – either transoral or transnasal	Total or unilateral
Posterior with partial face mask	Device on outlet of partial face mask	Catheter by nasopharynx – either transoral or transnasal	Total or unilateral
Body plethysmograph	Movement of chest inside body plethysmograph	Posterior catheter by nasopharynx – either transoral or transnasal or anterior catheter to non-measured nostril	Total or unilateral

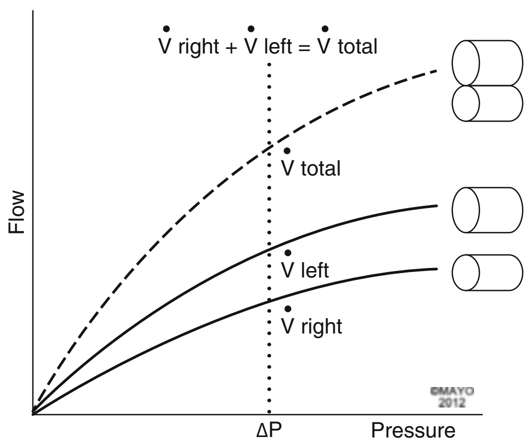


Fig. 25.6 For a given pressure value, the total flow is equal to the right-sided flow plus the left-sided flow, both measured at that pressure value. Flows are only additive if measured at the same pressure. This is analogous to two electrical currents being additive at the same voltages

25.3.3 Transnasal Pressure Measurement for Posterior Rhinomanometry

Measurement of transnasal pressure requires pressure detection in two sites, outside the nose and in the nasopharynx. Measurement of pressure outside the nose is easily done when the patient is wearing a mask by measuring the pressure inside the mask. Measurement in the nasopharynx can be done in several ways. As shown in Table 25.1, in anterior rhinomanometry, the nasopharyngeal pressure is detected using a tube sealed over the opposite nostril, turning the unmeasured nasal passage into an extension of the tube (Fig. 25.7). In posterior rhinomanometry, the nasopharyngeal pressure is measured by a catheter that is held in the back of the oropharynx with the lips sealed or by a tube passed to the nasopharynx along the floor of the nose (Fig. 25.8). The first of these methods can take extra time to learn for some patients.

It is also possible to measure a segment of transnasal pressure using a double catheter with the two openings on each side of the segment to be measured or by passing a catheter only partially along the floor of the nose. This methodology has only been employed in research but could potentially assess resistance at particular areas of the anatomic dimension of the airway, e.g., at a site suspected to be causing the symptom of nasal obstruction. This calculation uses the approximation of assuming a constant flow along the length of the nasal airway. Haight and Cole passed a catheter progressively further along the nasal airway while measuring the pressure at its tip and found that the greatest change in pressure and resistance occurred at the nasal valve (Haight and Cole 1983).

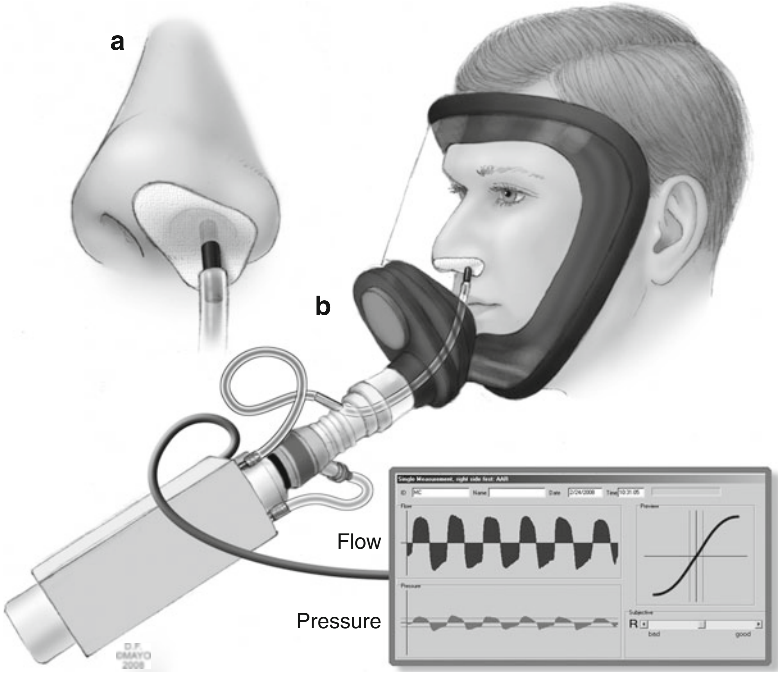


Fig. 25.7 Depiction of anterior masked rhinomanometry. A full face mask (**b**) is being used to avoid any distortion by the nasal alae. The pressure detection for the nasopharyngeal pressure is done with the tube that is sealed to the left nostril (**a**)

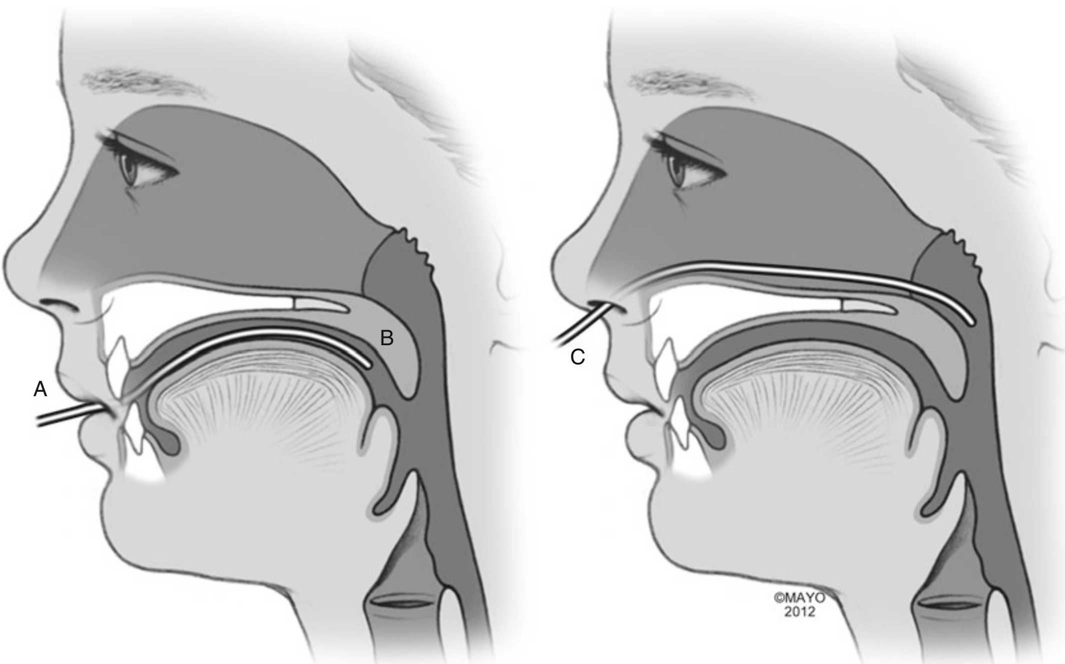


Fig. 25.8 Two methods of measuring the nasopharyngeal pressure in posterior rhinomanometry. The figure on the *left* shows the pressure detection tube being held in the oropharynx with the lips sealed (*A*) and the patient holding the soft palate open (*B*). The figure on the *right* shows the pressure catheter (*C*) passing along the floor of one of the nasal passages back to the nasopharynx. The small dimension of the tube is considered to have negligible effect on the airflow measurement on that side

25.3.4 Nasal Resistance or Conductance

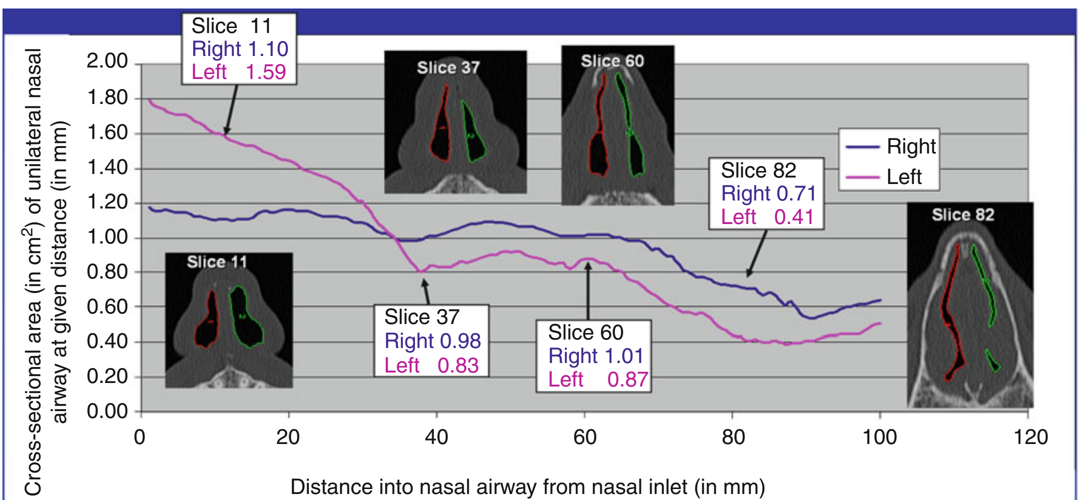
Resistance at a given point during the cycle of pressure and flow values can be obtained by dividing pressure by the corresponding flow at that point. Conductance is used by some and is the ratio of flow over pressure, the inverse of resistance. Typically resistance (or conductance) values are taken from inspiration, though some devices also report expiratory values.

Since rhinomanometry measures the simultaneous flow and pressure for the entire length of the nasal airway, it is generally thought that it primarily reflects the minimal effective cross-sectional airway. Figure 25.9 shows an example in which the cross-sectional area of an airway is smallest posteriorly rather than in the valve area. In this example, the right valve area has a smaller cross section than the left valve area, but the cross sections further posteriorly are smaller still with the left being the least. In this patient, the left side, which had the smallest overall cross section, is the same side that has the higher measured resistance and the same side where the patient felt the greatest obstruction.

25.4 Rhinomanometry Has Been Instrumental in Understanding Elements of Nasal Physiology

25.4.1 Measuring Changes That Occur in the Passage of Air Through the Nose with Growth and with Age

Children have smaller nasal passages and thus higher average nasal resistance. Nasal resistance has been shown to decrease as children grow to adulthood. Interestingly, Thulesius found nasal resistance to decrease as adults aged (Thulesius et al. 2009).



	Flow 150	Res150	Reff Ins	VR Rvert Ins	Sx side	Sxs subj
Right	526	0.29	0.33	0.37		50
Left	404	0.37	0.45	0.50	left worst	36

Fig. 25.9 The plot of the cross-sectional area of right (*blue*) and left (*pink*) nasal airway as one goes further back (along the *x*-axis in mm's) in the nasal airway. A 3D reconstruction was done from high-resolution CT scans, and successive cross-sectional areas were calculated perpendicular to the center vector of airflow through the nasal airway. Note that at the valve area (30 mm in) the right-sided cross-sectional area is smaller, but that (at 80–90 mm) the smallest overall cross-sectional area occurs posteriorly on the opposite (*left*) side of the nose

25.4.2 Measuring the Nasal Cycle

Unilateral nasal resistance measurements have been used to document the periodicity of the nasal cycle. One side of the nose is put at rest as the other is open and doing the work of humidifying, warming, and filtering the air. In some patients, it was found to be fairly regular, and in others, it was shown to be rather irregular (Hasegawa et al. 1979; Hasegawa and Kern 1990).

25.4.3 Discovering the Cause of Downside Obstruction When Lying on One's Side (or with Pressure Application in Yoga)

When asked why the downside of the nose becomes more obstructed when lying on one's side, many will say it is due to "gravity." Rhinomanometry was used to demonstrate that this is not the case. Haight (Haight and Cole 1986, 1989) mapped the pressure receptors on the side of the body that when activated cause relative congestion of the tissues on that side of the nose. This phenomenon is also known to Yoga practitioners who apply pressure with a hand placed in the axilla to enhance the breathing through the opposite nostril.

> In the nasal cycle, one side of the nose is put at rest as the other is open and is doing the work of humidifying, warming, and filtering the air.

25.4.4 Quantitating Airway Change with Recumbency

Hasagawa has used rhinomanometry to demonstrate the significant increase in nasal resistance that can occur with recumbency (Hasegawa 1982). Just as our cardiovascular system has to make appreciable adjustments to maintain the same blood flow to our brain and extremities when we change to recumbency, the same regulatory parasympathetic/sympathetic pathways affect the relative congestion of the nasal tissues, particularly in certain individuals, resulting in increased nasal resistance and obstruction in the recumbent position.

25.4.5 Assessing Nasal Airway Change with Exercise and CO_2

Studies using rhinomanometry have shown the opening of the nose with exercise (Cole et al. 1983). Measurements of nasal resistance revealed the increase in nasal obstruction occurring as increased amounts of CO_2 is delivered in the inspired air (McCaffrey and Kern 1979b).

25.4.6 Finding the Normal Range and Abnormal Range of Nasal Resistance Values

If nasal resistance is measured in a standardized fashion for a large group of people, it is possible to show the distribution of "normal" resistance values for that population. This has been done for the sides of the nose as well as the total nose. By then comparing the nasal resistance of a patient against this distribution of normal values, one can determine if the patient has nasal resistance that is far outside the normal range (Pallanch et al. 1985).

25.4.7 Measuring Disturbance in Nasal Respiratory Function

By measuring a large group of patients who complained of the symptom of nasal obstruction, it was possible to describe the range of resistance values that are "abnormal" (McCaffrey and Kern 1979a). The significance of an abnormal unilateral resistance value must be considered in the light of the variation that occurs with the nasal cycle in the non-decongested nasal airway. Measuring the unilateral nasal airway after thorough decongestion can eliminate a major portion of the contribution of the nasal cycle in many individuals, but it will also change the overall range of "normal" and "abnormal" values to lower resistance ranges (Pallanch et al. 1985). The total resistance of the nasal airway is relatively constant (Hasegawa 1982) through the course of the nasal cycle in the non-decongested nose. Some investigators have therefore suggested the use of total resistance as a value to measure the degree of nasal obstruction.

> Pressure receptors on the downside of the body cause the downside nasal airway to have higher resistance.

25.4.7.1 When Is Disturbance in the Nasal Airstream Significant?

If an abnormal value of nasal resistance is measured, is this always of significance? By "significance" in patients, we usually mean that they are experiencing a symptom or condition that warrants treatment. Like an abnormal audiogram, it is the patient's choice as to whether any condition confirmed or found by a test is treated. Like any test, it is possible to have an abnormal result, but for a patient not to feel that they have sufficient symptoms to be treated.

25.4.7.2 Studying the Correlation of Elevated Resistance with the Symptom of Nasal Obstruction

There continues to be active debate about whether objective measurements of the nasal airway correlate with the symptom of nasal obstruction (Andre et al. 2009; Barnes et al. 2010; Eccles et al. 2010; Hopkins 2010; Hopkins et al. 2010; Williams et al. 2010; Nivatvongs et al. 2011) (see also G. Mylinski Chaps. 20 and 27). There has also been interesting work about the sensation of nasal obstruction being related to cold receptors that are stimulated by menthol-like compounds (Eccles et al. 1990). If there is more resistance to airflow, then is it the narrower airway causing less flow and thus less cold receptor stimulation that causes the sensation of obstruction?

Elevated values of nasal resistance have been shown to correlate with the symptom of nasal obstruction (McCaffrey and Kern 1979a; Pallanch 1995; Vogt et al. 2010). Several studies have looked at which parameter derived from the pressure-flow curve data obtained by rhinomanometry would best correlate with symptoms. Two studies (Pallanch 1995; Vogt and Zhang 2012) found the maximal resistance during normal respiration to be a parameter that correlated with symptoms better than other parameters. Phillip Cole (personal communication) explained this best, noting that the greatest time during the respiratory cycle (Fig. 25.1) was spent at the extremes of the pressure and flow curves; thus, it would follow that a parameter from this location would have the greatest correlation with patient's symptoms.

> In general, recumbency increases nasal resistance.

The variability of the nasal cycle and "subjective" symptoms introduces some noise in demonstrating this correlation. It is most easily shown for larger values of unilateral obstruction and in patients who are experiencing symptoms (as opposed to studies on patients who had no symptoms of nasal obstruction). When studies have been done looking for a correlation with the sensation of obstruction in subjects who are not experiencing obstruction, there is more "noise" (variation) making the correlation less clear (Clarke et al. 1995). Most subjects with nasal obstruction are able to distinguish the side with the higher resistance and to give a grading of their obstruction that correlates with other patients who are experiencing obstruction of their nose (Pallanch 1995). This ability to perceive the side of highest resistance has been quantitated and found to be best when there is more than a slight difference in resistance between the sides of the nose at the time of the test (Thulesius et al. 2012).

25.4.7.3 Providing Objective Assessment When Crusting and Dysfunction of Nasal Lining Occur Due to Disturbance in the Airstream

When considering the symptoms of nasal obstruction, the question arises as to whether a patient can have a nasal airway that is too open and a corresponding measure of nasal resistance that is too low. While this is not a common scenario in the measurement of nasal resistance, patients with noses that appear widely patent, dry, and crusty can be shown to have lower resistance. This would suggest that a surgeon's goal of lowering resistance when treating the nasal airway needs to be tempered in this case by maintaining the normal physiologic range of nasal resistance for the unilateral and total nasal airways. This is consistent with the avoidance of disrupting nasal physiology by such procedures as the total removal of turbinate tissues.

Another interesting application of rhinomanometry that can be applied in this context is the measurement of nasal resistance in a patient who complains of symptoms suggesting the type of nasal dysfunction found in patients with the "empty nose syndrome" (see also Chap. 36 by E. Kern), but in whom the exam looks reasonable. Normal measured nasal resistance in this context would support looking for other explanations for the patients' symptoms.

25.4.8 Studying the Airflow in Conditions of Varying Temperature and Humidity

Rhinomanometry has shown that nasal resistance increases when a patient breathes colder than normal air (Cole et al. 1983).

By measuring nasal resistance, studies have looked for whether breathing air of different humidities resulted in any change in amount of nasal obstruction. Ivarsson and Malm found no significant difference in breathing air of different percent humidities (Ivarsson and Malm 1990).

> Exercise resulting in a higher pulse rate decreases nasal resistance.

25.5 Clinical Applications of Rhinomanometry

25.5.1 When Things Do Not Add Up During Clinical Assessment

We have all been confronted with the cases in which a patient complains bitterly about nasal obstruction, but we are not able to see pathology that would account for the symptoms. Furthermore, some patients who have only minimal symptoms have what appears to be dramatic anatomic obstruction. It is in these cases that objective testing can be particularly helpful in being the "tiebreaker." In the first example, if airway testing demonstrates a significant nasal restriction, it agrees with the patient's complaints and makes us look further for the cause. If the airway testing shows a widely patent airway, it supports our exam observations and cautions that a procedure to increase the dimension of the airway to try to help this patient's feeling of obstruction would be ill advised.

This use of the test results relies on the knowledge that there is a correlation between measured airway restriction and the symptom of nasal obstruction for many patients, giving us an objective basis for comparison to use with the patient who seems to have contradictory findings. Further clinical examples have been described (McCaffrey 1997).

25.5.2 For Assessment of Surgical Candidate's Chances of Optimal Outcome

Studies have been done showing the value of rhinomanometric results in optimizing the selection of patients who will be helped by nasal airway surgery (Sipila 1992; Suonpaa 1993).

25.5.3 To Analyze Changes in Patients Who Do Not Have Symptomatic Improvement with Surgery

We all want to learn from our patients who continue to have symptoms despite our surgical intervention for their airway. Rhinomanometry, applied as noted in Sect. 25.5.1 above, can suggest whether it is the still unhappy patient's symptoms that are exceptional (patients with an unusually high resistance threshold for comfort) or whether there is still some measureable obstruction in the airway.

25.5.4 Challenge Testing

Some patients may have reactions to airborne antigens yet have negative skin testing. In these cases, a more direct method of identifying allergens and degree of allergic response can be done with challenge testing (Schumacher and Pain 1979; Bachmann 1987; Fireman 1988; Doyle et al. 1995; Wang and Clement 1995). Rhinomanometry is done first. Then the patient inhales the challenging antigen. Subsequent rhinomanometry can detect significant change in nasal obstruction caused by the antigen in an allergic patient.

25.6 Summary/Conclusion

The observation has been made that viewing the nasal airway will not by itself tell us about the *function* of the nasal airway. Measuring the transnasal pressure and flow using rhinomanometry has provided a greater understanding and insight into the physiologic function of the nasal airway.

Understanding normal physiology comes first. Next comes understanding what is different when patients have disturbance in function that causes symptoms. To fully learn what can be changed to yield improvement in function, we seek measurements of function that correlate with improvement. Rhinomanometry has played a significant role in the ongoing search for these answers so that we can optimize our ability to help our patients.

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