REVIEW

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# A guide to practical aspects of measurement of human nasal airflow by rhinomanometry*

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SUMMARY

*The guide is intended for all those interested in measuring human nasal airflow by rhinomanometry, either for clinical or research purposes. The guide is written in non-technical language so that it may be understood by nursing and support staff who may need to make measurements using rhinomanometry. It is not a systematic review of the literature but a personal view based on over 40 years experience of measuring nasal airflow. The guide introduces the basic principles of nasal airflow and pressure and their measurement. The following topics are discussed: anterior and posterior rhinomanometry and their relative problems and benefits, control of errors in measurement, standard operating procedures, calibration of equipment, measurement of the totally obstructed nose, reproducibility and sensitivity of rhinomanometry, hygiene, factors influencing nasal airflow such as rest and exercise, alcohol, medicines, temperature and humidity and diseases such as common cold and allergy.*

*Key words: rhinomanometry, nasal airflow, nasal decongestant*

## INTRODUCTION

This guide is intended for those interested in measuring human nasal airflow either for clinical assessment of nasal obstruction or for research purposes such as studies on the efficacy of nasal decongestant medicines. It is a personal view based on over 40 years experience of nasal research rather than a literature review with cited references. A bibliography of key references will be provided for further information at the end of the guide.

Active rhinomanometry is a functional test of breathing as it measures nasal airflow during normal breathing. Other techniques such as acoustic rhinometry may give an anatomical measure of nasal cross sectional area, and nasal peak inspiratory flow may give a measure of nasal airflow at maximum effort, but only active rhinomanometry can provide a functional, physiological measure of nasal airflow. This guide will discuss the technique of active rhinomanometry during normal breathing, and although there are other techniques that may involve passive nasal airflow or plethysmography, these are restricted in use and will not be discussed. The term rhinomanometry will be used in the guide to mean the active technique during normal breathing.

The principles of rhinomanometry are relatively simple, and the measurements are not technically difficult, yet rhinomanometry is not routinely used in clinical assessments of the nose prior to nasal surgery, and very few research centres are able to conduct clinical trials using rhinomanometry. One of the barriers for the use of rhinomanometry in clinical research is the lack of a simple guide to the principles and techniques. Although manufacturers of rhinomanometry equipment provide instruction manuals on the use of equipment, these manuals are mainly technical and do not provide a basic understanding of the principles and practice of rhinomanometry.

The aim of this guide is to provide a step-by-step guide on the basic principles of rhinomanometry, and instructions on how to measure nasal airflow, for anyone interested in using rhinomanometry equipment. Where possible, technical terms and formula will be discussed in lay language. A range of commercial rhinomanometry equipment is available, and this guide is intended to be useful for all types of rhinomanometry equipment.

## BASIC PRINCIPLES OF NASAL AIRFLOW

### *Nasal resistance to airflow*

Air moves through the nose due to the work performed by respiratory muscles such as the diaphragm which contracts to expand the lungs on inspiration. During normal breathing, the expansion of the lungs on inspiration moves air through the nose into the lungs by creating a lower air pressure in the lungs than the atmospheric pressure at the nostrils. Nasal airflow always occurs along a pressure gradient from a high pressure area to a low pressure area of the airway. On expiration the respiratory muscles relax and the elastic lungs recoil to create a pressure in the lungs that is greater than the atmospheric pressure at the nostrils. Nasal airflow and pressures are illustrated in Figure 1. The technique of rhinomanometry measures the pressure difference and airflows between the posterior and

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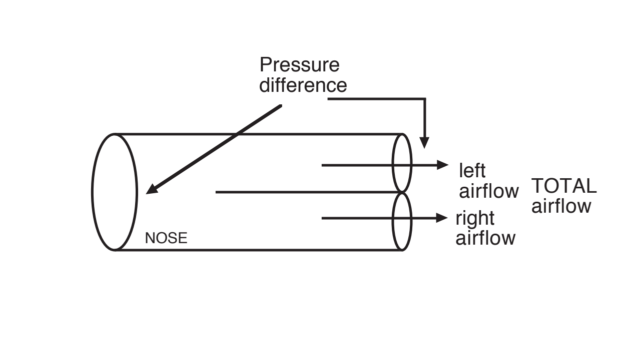


Figure 1. Model of the nose to illustrate measurements needed to calculate nasal resistance to airflow.

anterior parts of the nose during inspiration and expiration.

Nasal resistance to airflow may be calculated from the following equation:

**Nasal resistance = pressure difference across the nose / divided by the nasal airflow**

The nasal pressures are usually measured in Pascals (Pa). The Pascal is a standard international unit (S.I.) and is a very small pressure, as a pressure of 100 Pa equals the pressure created by a column of water only 1 cm in height. Nasal airflow is usually measured in units of cubic centimetres per second. The units of nasal resistance are expressed as a combination of pressure and flow calculated from the formula above and are expressed as Pascals per cubic centimetre per second (Pa / $cm^3$ / sec). Other units may be used to measure nasal pressure and flow such as pressure measured in centimetres of water and flow measured in litres per minute and these will give a measure of resistance expressed as centimetres of water per litre per minute.

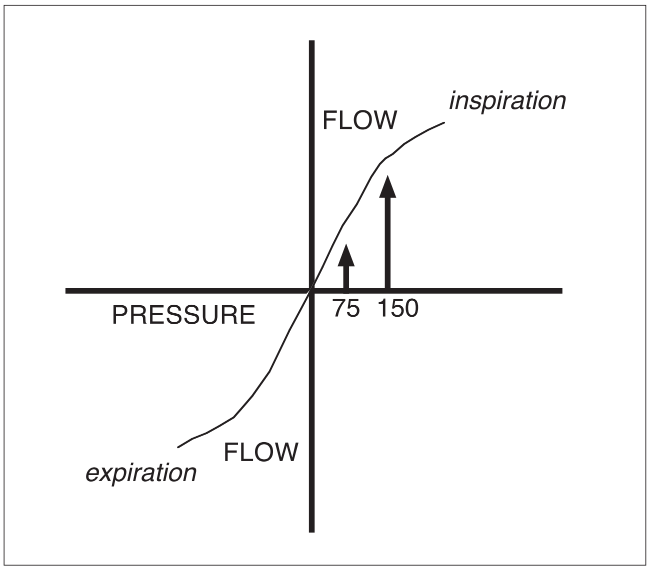


Figure 2. Plot of pressure and flow during normal breathing as displayed on computer screen. Flow is the vertical axis and pressure the horizontal axis. The numbers 75 and 150 refer to sample pressure points that are used in rhinomanometry. The computer cursor moves up and down the screen with inspiration and expiration to form the pressure flow curve.

*Relationship between nasal pressure and airflow*

The relationship between nasal pressure and nasal airflow is usually plotted on a computer screen and a diagram of a typical pressure flow curve is shown in Figure 2. During quiet breathing at low pressures and flows, the relationship between pressure and flow is almost a straight line. But at high pressures and flows the relationship becomes more curved. This means that the relationship between pressure and flow (that is the calculated resistance) is not a constant but differs according to where on the pressure flow curve the resistance is measured. If the breathing pressure was to be increased to very high levels as with a forced maximal inspiratory effort, there would come a point when the flow reached a maximum and any further pressure increase would not cause any further increase in airflow. This is a flow limiting point.

If the relationship between nasal pressure and flow was a straight line, then the resistance would be the slope of the line and it would not matter at which point on the line the resistance was calculated. With a curvilinear relationship of nasal pressure and airflow it is important to standardise the point on the line at which resistance is calculated so that resistance measurements can be standardised between research centres. Most research centres use sample pressure points of 75 or 150 Pa to measure resistance as illustrated in Figure 2.

The relationship between nasal pressure and flow is disturbed at the higher pressures and flows because the airflow becomes turbulent and noisy. The nose is a complicated airway with constrictions and changes in airflow direction and this creates turbulent airflow. The turbulent airflow is good for mixing the nasal airflow and ensuring maximal air conditioning with efficient warming and humidification of the air as it passes through the nose to the lungs.

*Nasal conductance*

Although most rhinomanometers express nasal airflow in terms of nasal resistance there are advantages in expressing results in terms of nasal conductance. A measure of nasal conductance can be calculated from the sample pressure divided by resistance.

**Nasal conductance = pressure difference across the nose/ resistance**

So for a resistance of 0.25 Pa $cm^3$ sec measured at a sample pressure of 75 Pa the conductance would be 75 divided by 0.25, or a flow of 300 $cm^3$ sec. Conductance has some advantages over resistance as; the total conductance of the nose is easily calculated by adding left and right conductance values, whereas for resistance one must use reciprocals as described below. Also, it is impossible to use the resistance of a totally obstructed nose or nasal passage (infinite resistance) in any statistical data

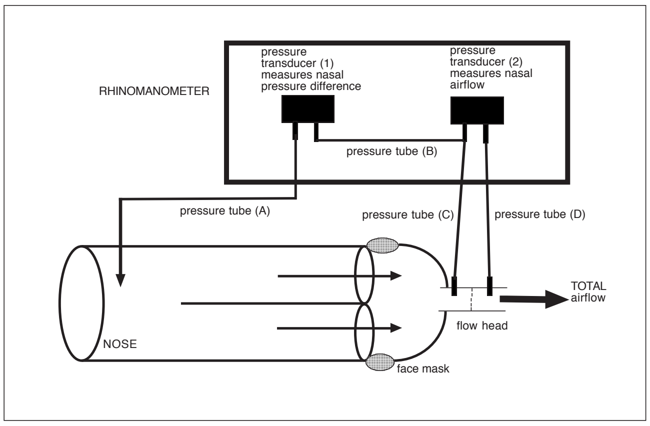


Figure 3. Model of pressure measurements with rhinomanometry. The pressure difference across the nose is measured via transducer (1) and nasal airflow is measured by the pressure difference across the flow head via transducer (2). Pressure tube (B) is inside the frame of the rhinomanometer and samples the pressure inside the face mask at the front of the nose via pressure tube (C).

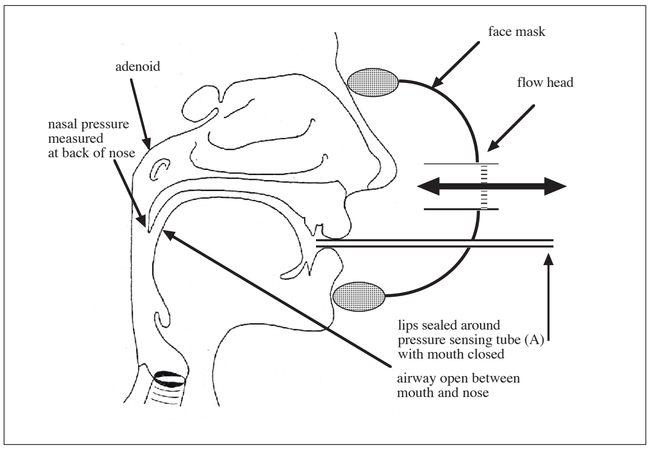


Figure 4. Diagram of technique of posterior rhinomanometry. The pressure sensing tube (A) is placed in the mouth and senses the pressure at the back of the nose.

whereas the conductance of a totally obstructed nose (zero conductance) is easily dealt with in statistical data.

*Rhinomanometry*

The word rhinomanometry means 'rhino' for nose and 'manometry' for measurement of pressure. The earliest measurements of nasal resistance at the start of the twentieth century involved the measurement of nasal pressure from one nasal passage with a water manometer, whilst the subject breathed through the other nasal passage, and therefore the term 'rhinomanometer' was introduced for instruments measuring nasal resistance. A modern rhinomanometer consists of two pressure transducers (one to measure nasal pressure differences and the other to measure nasal airflow) as illustrated in Figure 3. Pressure transducer (1) in Figure 3 measures the nasal pressure difference via tubes (A - B) and pressure transducer (2) is connected to either side of a flow head that measures airflow by measuring the pressure difference across a gauze resistance in the flow head via tubes (C - D). The greater the flow through the flow head the greater the pressure difference measured at transducer (2).

Pressure tube (A) is the pressure tube that is placed in the mouth for posterior rhinomanometry or taped to the nostril for anterior rhinomanometry. Pressure tube (B) is contained within the rhinomanometer and connected to pressure tube (C) via a 'T' junction so that it measures the pressure at the front of the nose in order to provide the pressure difference across the nose for transducer (1). This arrangement of pressure tubes is typical for rhinomanometers such as the GM Instruments rhinomanometer. Only three pressure tubes exit the rhinomanometer and this is often a source of confusion for those expecting to see four pressure tubes (two for each pressure transducer). The third pressure tube (B) is hidden inside the rhinomanometer casing.

The electrical signals from the two pressure transducers are connected to a computer to provide the pressure flow plot on the computer screen as illustrated in Figure 2.

*Anterior and posterior rhinomanometry*

Rhinomanometry is usually divided into posterior and anterior techniques. Although these terms may be confusing as they refer to the positioning of the pressure sensing tube that measures the pressure at the back of the nose. With anterior rhinomanometry the pressure sensing tube is taped to one nostril whereas with posterior rhinomanometry the tube is placed in the mouth. Both anterior and posterior rhinomanometry measure the pressure at the back of the nose via tube (A) illustrated in Figure 3. In both anterior and posterior rhinomanometry it is important to ensure that the face mask is sealed completely against the contours of the face. Face masks usually have a soft inflatable cushion interface with the face to ensure a seal. The most common source of any air leak around the mask is around the bridge of the nose. The subject should place the mask with sufficient pressure on the face to seal leaks but not with so much pressure that it distorts the face and nose and alters nasal airflow. Any air leak around the mask will cause an error of higher resistance measurement than the true resistance, as at any given nasal pressure not all of the airflow will pass through the flow head.

*Posterior rhinomanometry*

The technique of posterior rhinomanometry requires some training of the subject to ensure they have an airway open between the mouth and nose at the level of the soft palate as illustrated in Figure 4. The pressure sensing tube (A) is placed in the mouth and the lips are gently placed around the tube to provide an airtight seal as the tube rests between the incisor teeth that are held gently apart to accommodate the tube resting on the surface of the tongue. The mouth end of the tube is cut at an angle to prevent the soft tissue of the tongue or cheek from sealing the end of the tube. During normal nasal breathing the tongue tends to seal the back of the mouth and prevent any sensing of nasal pressure, this is why the subject needs some training to position the tongue to make an airway at the back of the mouth. The training is achieved by asking the subject to

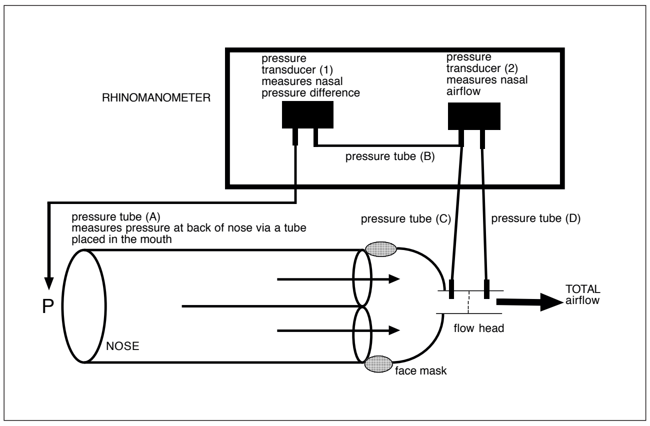


Figure 5. Diagram of method of posterior rhinomanometry. The nasal pressure is measured via an oral cannula that detects the pressure P illustrated on the diagram at the level of the posterior nares. Posterior rhinomanometry measures total nasal airflow and therefore total nasal resistance. If one nostril at a time is sealed with surgical adhesive tape posterior rhinomanometry can be used to measure unilateral nasal resistance.

watch the computer screen and using this as a positive feedback system to indicate when the pressure flow curve follows the 's' shape illustrated in Figure 2. If the computer trace shows an irregular pattern unrelated to the breathing pattern of the subject this indicates that the tongue is sealing the back of the mouth and pressure changes due to tongue movements are recorded rather than the pressure at the back of the nose during breathing. If the subject does not achieve a satisfactory curvilinear pressure flow curve then they can be asked to re-position the mask and oral tube a few times and also to re-position the tongue at the side of the cheek. On some occasions a curvilinear pressure flow curve may be obtained which does not pass through the origin of the graph, and this indicates that the pressure signal is in error and the measurement should be rejected.

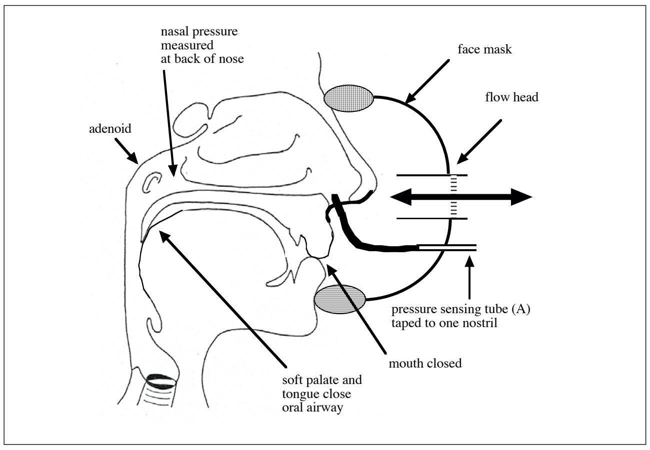


Figure 6. Diagram of method of anterior rhinomanometry. The nasal pressure is measured via a tube taped to one nostril that detects the pressure P illustrated on the diagram at the level of the posterior end of the nasal septum. The resistance of each nasal passage is measured separately and total resistance must be calculated rather than measured directly.

Up to 10% of subjects may fail to be trained to perform posterior rhinomanometry but despite this issue it is the standard method used at our centre because of some advantages over anterior rhinomanometry that will be discussed below.

A diagram of the pressure and flow measurements associated with posterior rhinomanometry is illustrated in Figure 5. The pressure tube A is the oral cannula that detects the nasal pressure (P) at the level of the posterior nares.

*Anterior rhinomanometry*

The technique of anterior rhinomanometry does not require training of the subject. The nasal pressure sensing tube (A) is taped to one nasal passage as shown in Figure 6 using a special connector and surgical adhesive tape, whilst the other nasal passage remains open. It is important to get an airtight seal around the nostril and this is often not possible in male subjects with a moustache. The pressure sensing tube (A) measures the pressure at the back of the nose, as the sealed nasal passage acts as an extension of the nasal tube as there is no airflow through this tube. All nasal airflow occurs through the open nasal passage and this is measured by the flow head. Anterior rhinomanometry measures the resistance of one nasal passage at a time and the tape and pressure sensing tube are sealed around the other nasal passage to complete the two measurements.

A diagram of the pressure and flow measurements associated with anterior rhinomanometry is illustrated in Figure 7. The pressure tube A is taped to one nostril and detects the nasal pressure (P) at the level of the posterior end of the nasal septum.

Surgical tape is the most common method of sealing the nostril in order to perform anterior rhinomanometry but other methods of sealing the nostril such as plastic foam inserts of different sizes may be used. The plastic foam inserts have the disadvantage that on insertion they may distort and irritate the nostril compared with adhesive tape that is placed external to the nostril.

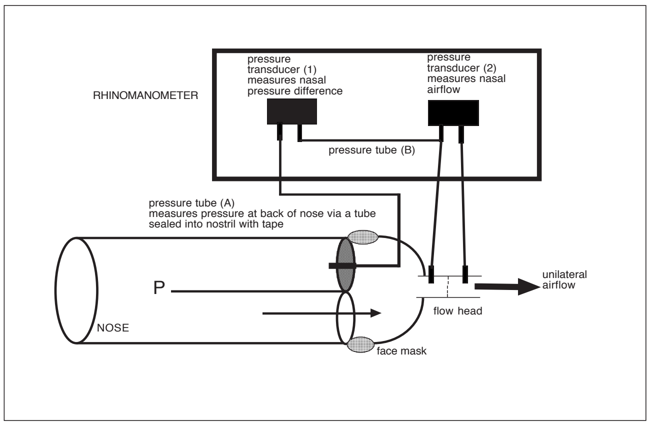


Figure 7. Diagram of method of anterior rhinomanometry. The nasal pressure is measured via a tube taped to one nostril that detects the pressure P illustrated on the diagram at the level of the posterior end of the nasal septum. Nasal airflow is measured from one nasal passage at a time. Measurements cannot be made if one nasal passage is obstructed.

*Advantages and disadvantages of posterior and anterior techniques of rhinomanometry*

Posterior rhinomanometry has the advantage that it measures the total resistance of the nose by measuring total nasal airflow as illustrated in Figure 5.

Anterior rhinomanometry has the disadvantage that it can only measure the resistance of one nasal passage at a time and the total resistance must be calculated from the formula.

$$\frac{1}{R} = \frac{1}{r\ \text{left}} + \frac{1}{r\ \text{right}}$$

The calculation of total resistance may be in error if there is a significant delay between the measurement of the left and right nasal resistances.

If one nasal passage is completely obstructed perhaps due to congestion or a deviated nasal septum then it is not possible to obtain any resistance measurements using the technique of anterior rhinomanometry as each nasal passage must be patent for unilateral measurements of pressure and flow. Unilateral nasal obstruction is not a problem when using posterior rhinomanometry, and this is a major advantage, as clinical studies often involve subjects with unilateral nasal obstruction due to congestion or deviated nasal septum. Unilateral nasal obstruction is a common finding in patients with common cold and allergy, and in clinical studies on nasal decongestants or on the effects of nasal surgery it is important to include this type of patient in the study population.

Posterior rhinomanometry can be used to measure unilateral resistance even if one side of the nose is completely obstructed.

With anterior rhinomanometry the nasal passages are alternately sealed with adhesive surgical tape. When performing a single measure of resistance, nasal irritation on application of adhesive tape is not a problem, but with multiple measurements of nasal resistance at intervals of an hour or less, such as may be needed in clinical trials, frequent taping of the nostrils results in damage to the nasal skin and nasal irritation and sneezing, which may result in nasal congestion and confound the study. This type of nasal irritation associated with taping the nostril does not occur with posterior rhinomanometry.

The site of measurement of nasal pressure at the back of the nose varies between anterior and posterior rhinomanometry. With anterior rhinomanometry the pressure is measured at the level of the posterior end of the nasal septum in the nasopharynx as illustrated in Figures 6 and 7. With posterior rhinomanometry the nasal pressure is measured at the posterior end of the nasopharynx as shown in Figures 4 and 5. This means that posterior rhinomanometry gives a resistance value for the whole of the nasal passages, including any contribution from the adenoids (pharyngeal tonsils) whereas anterior rhinomanometry will gives a measure of nasal resistance of the anterior nasal passages from the posterior end of the nasal septum and does not include any contribution from the adenoids.

With anterior rhinomanometry, it is necessary to ensure that the adhesive tape applied to the nostril forms an airtight seal. This is in addition to the airtight seal required for the face mask. In subjects with high nasal resistance the nasal pressure may reach high values and push out the nasal tape and create air leaks. An air leak is also more likely when the nasal skin is oily or when there is much nasal secretion, as these factors may decrease the adhesive properties of the nasal tape. The problems of an air tight seal around the nasal passage associated with anterior rhinomanometry do not occur with posterior rhinomanometry when measuring total nasal resistance.

With anterior rhinomanometry, it is necessary to seal a pressure tube into the adhesive tape used to seal the nostril and the junction between the tube and tape may be a source of air leaks. The pressure tube used in anterior rhinomanometry is usually of a narrow calibre to allow some flexibility when it is manipulated within the mask, and sufficient length of tubing is needed to allow easy fixation to the inside of the mask. The narrow calibre and length of pressure tubing may cause some distortion of the pressure signal compared with posterior rhinomanometry where a short length of large calibre tubing may be used as an oral cannula. Instead of a compact pressure flow curve as illustrated in Figure 2 distortion of the pressure signal may cause hysteresis of the curve making it difficult to calculate any resistance. Use of a larger diameter pressure sensing tube taped to the cheek can be used to overcome any distortion of the pressure signal.

*Control of errors in measurement*

Assuming the equipment is correctly calibrated, the major source of errors in rhinomanometry are air leaks around the mask. The operator must be careful to ensure that the face mask is gently pressed against the face and makes an air tight seal. Air leaks may also occur around the adhesive tape used to seal the nose in anterior rhinomanometry and this seal should be tested by asking the subject to close the contralateral nostril with a finger and gently breathe out to apply a little pressure to the tape seal to test for leaks.

The operating system on most rhinomanometers can be set so that a series of four breaths are taken to obtain a mean measure of resistance. This controls for any differences in breathing pattern between breaths. In order to control for air leaks around the mask it is advisable to take a mean measure of resistance and then ask the subject to re-position the face mask and repeat the measurement. The two series of measurements can then be compared to calculate the co-efficient of variance (C.V.) between the measurements, as a measure of the variability between measurements. If the C.V. is greater than 10% then there may be a problem between the measurements such as an air leak at the mask interface. The measurements can be repeated until the C.V. is equal to or less than 10%. Repositioning the mask between measurements helps to control for air leaks, as if the mask is sealed around the face it is unlikely that the C.V. between measurements will be greater than 10%, but if a leak occurs this will increase the C.V. between measurements. This type of protocol for measurements can be included in a standard operating procedure (SOP).

In subjects with rhinitis, excessive nasal mucus may influence the resistance measurements and it is therefore advisable to ask

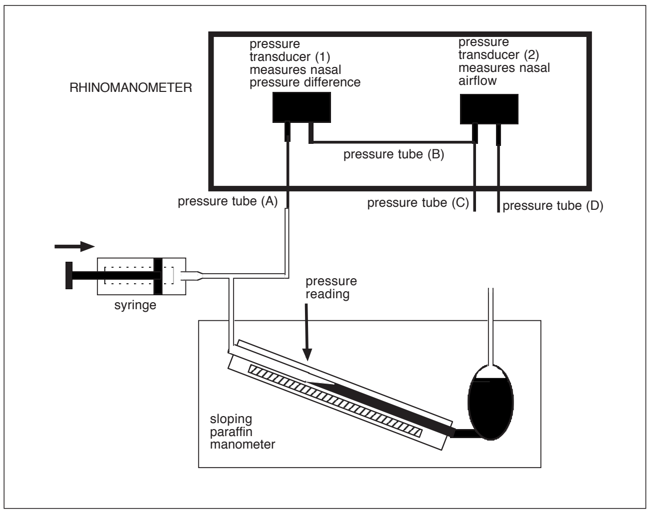


Figure 8. Diagram of use of a sloping paraffin manometer to calibrate the nasal pressure measurements on a rhinomanometer. The pressure in the paraffin manometer is varied by means of a syringe and the pressure is applied to the pressure transducer via pressure tube (A).

the subjects to gently blow their nose to remove mucus before every measurement. Other factors that may influence nasal airflow and confound measurement of resistance are discussed below.

*Standard operating procedures*

Standard operating procedures are written by the operator of the equipment and consist of a step-by-step practical guide to using the equipment and obtaining measurements. The SOP is a written document that is essential for reliable and reproducible measurements. If the practical steps in obtaining measurements are carefully documented then it is possible to train staff to follow the SOP carefully, and this helps in the standardisation of measurements. If the measurements are not conducted in a standard way then it is likely that different staff will have different ways of using the equipment and obtaining measurements. This will inevitably lead to greater variability in the data for any study if several staff are involved in taking measurements. Without an agreed SOP it is not possible to control and standardise measurements. The act of writing the SOP focuses the mind on any likely issues that may confound the measurements and allows standardisation between staff and between research centres using the same equipment. A well written SOP is the foundation of any scientific measurement. Inevitably the SOP will need to be regularly updated as equipment and software changes or to allow for any improvements in procedures that become apparent.

*Calibration of equipment*

Rhinomanometry equipment should be calibrated each day before the start of any measurements. It is possible to quickly check the status of the calibration by use of a standard resistance or model nose. However, it is more reliable to calibrate pressure and air flow separately.

*Pressure*

The pressure channel on the rhinomanometer can be calibrated by use of a sloping paraffin manometer as illustrated in Figure 8. The calibration manometer uses paraffin as it is lighter than water, and therefore the pressure scale is extended compared to a water manometer. The calibration scale is also extended by using a sloping scale rather than a vertical scale. A pressure scale of 5 cm $H_2O$ is extended along a sloping scale of around 25 cm. The pressure in the paraffin manometer is altered by pumping air into a side arm by means of a syringe. The pressure tube of the manometer is connected to pressure tube (A) of the rhinomanometer in order to calibrate pressure transducer (1) as illustrated in Figure 8. The pressure transducer can be calibrated at the sample pressures used for posterior and anterior rhinomanometry e.g. at 75 Pa and 150 Pa.

*Airflow*

The airflow measured by the rhinomanometer can be calibrated by moving a known rate of airflow through the rhinomanometer flow head. Flow meters or ‘rotameters’ are produced commercially for industrial use. A rotameter consists of a calibrated vertical glass tube with an air float inside that moves up the tube according to the flow rate. The glass tube is narrower at the bottom than the top, so it requires an increasingly greater airflow to move the air float as it moves towards the top of the glass tube. The airflow is generated by an electric air pump similar to those used in a vacuum cleaner and the rate of airflow through the rotameter can be adjusted by varying the electric voltage to the pump by means of a transformer. Calibration of the rhinomanometer flow head with a rotameter is illustrated in Figure 9. The flow head can be calibrated at airflows that are achieved during normal breathing e.g. at 200 and 300 $cm^3$ sec.

*Grouping flow heads for measurements on a group of subjects in one day*

Calibration of a single flow head will allow measurements for only one patient, as the flow head will need to be cleaned and disinfected before use on another patient, and cleaning may alter the airflow characteristics of the flow head. In clinical trials on a number of patients it may be necessary to use several flow heads in one day, and in order to avoid having to calibrate the rhinomanometer each time a different flow head is used, it is possible to use a group of flow heads with similar calibration parameters so that the rhinomanometer calibration is closely matched to the group of flow heads. In order to match the rinomanometer to a group of flow heads it is necessary to first measure the airflows recorded on a group of say 12 flow heads when the rotameter is set at a standard flow of 300 $cm^3$ sec. Then to choose the flow head with airflow in the middle of the range of measured airflows as the standard flow head. The rhinomanometer airflow is then calibrated with the standard flow head for an airflow of 300 $cm^3$ sec. The remaining flow heads can then be attached one at a time to the rhinomanometer with the rotameter set at a flow of 300 $cm^3$ sec and the measured airflow recorded. All the flow heads with a measured airflow within the range of 295 – 305 $cm^3$ sec (± 1.6%) can be used as

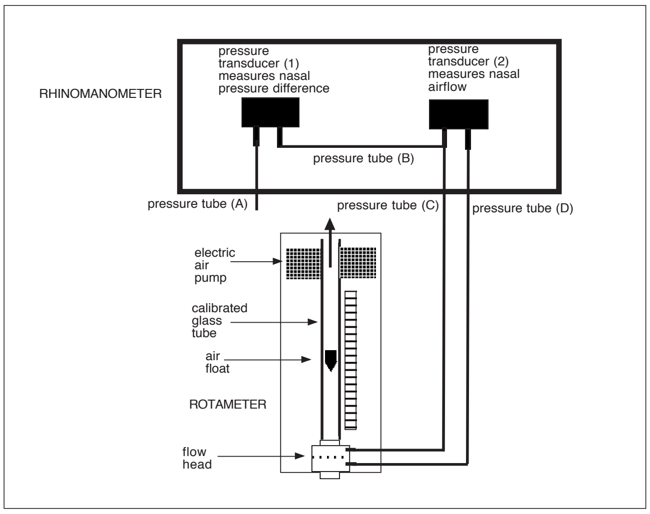


Figure 9. Diagram of use of a rotameter to calibrate the flow head and airflow measurements of a rhinomanometer. The flow through the calibrated glass tube on the rotameter is varied by means of an electric air pump and the airflow is drawn through the flow head.

part of the group of flow heads matched to the rhinomanometer for that day.

*Measurement of the totally obstructed nose*

Unilateral nasal obstruction is a common finding with rhinitis. Total nasal obstruction is also found in 1% of subjects recruited with common cold, and a higher percentage of subjects recruited for surgical studies such as those with a severely deviated nasal septum. It is not possible to measure nasal airway resistance when the nose is completely obstructed and also when the nose is severely obstructed. In these cases the nasal airflow tends towards a value of zero and therefore the nasal resistance value becomes unstable and tends towards infinity. When the subject has great difficulty breathing through the nose and measurement of nasal resistance is not possible it is possible to still obtain useful data. In these cases the subject is asked to try and breathe though the nose and if breathing is laboured and noisy due to obstruction then the nose can be recorded as totally obstructed, and a conductance value of zero can be assumed. Although it is not possible to describe the totally obstructed nose or unilateral nasal obstruction in terms of nasal resistance it is possible to allocate a value of zero conductance and this value can still be used in statistical analysis (as described above). The inclusion of totally obstructed subjects in any clinical trial ensures that all of the population may enter the study and these subjects are important in any study as they may exhibit the best response to nasal decongestants or surgical procedures that increase nasal airflow.

*Reproducibility and sensitivity of rhinomanometry*

Rhinomanometers are tested and validated by the manufacturers to provide stable measurements of nasal pressure and flow in laboratory and clinical use. The equipment stability will be related to the characteristics of the pressure transducers and fluctuations in temperature or humidity in the laboratory, and usually this is not a problem for the repeatability of measurements.

The reproducibility and the sensitivity of rhinomanometry can be demonstrated in the results of clinical trials on nasal decongestant medicines. Reproducibility is demonstrated by the consistency of the mean nasal conductance values in a group of subjects suffering from common cold who received a placebo nasal spray in a clinical trial on a topical nasal decongestant as illustrated in Figure 10. The mean nasal conductance values in the placebo treated group show a maximum variation of 11% over a 12 hours recording period and for most of the recording period the variation between measurements is less than 5%. This variation is most likely due to real variations in nasal conductance in the study population, as spontaneous fluctuations in nasal conductance are to be expected in a population suffering from acute rhinitis due to common cold. The sensitivity of rhinomanometry is demonstrated in the same study as the results clearly show in Figure 10 the significant increase in nasal conductance caused by application of the topical decongestant that is maintained for a period of 10 hours.

The sensitivity of rhinomanometry in detecting relatively small changes in nasal conductance has been shown in studies on the efficacy of oral decongestants such as pseudoephedrine and further studies on the effects of nasal surgery that are listed in the bibliography.

*Hygiene*

The face masks and flow heads used for rhinomanometry are often not suitable for steam sterilisation, and alcohol may harden the soft plastic seal of the mask. Low temperature sterilisation using ethylene oxide is time consuming and this procedure is not always available at research centres performing rhinomanometry. Because of the fear of litigation, face

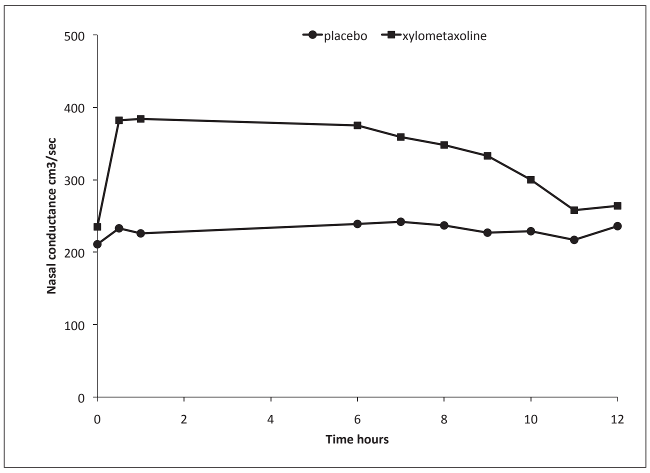


Figure 10. Effects of xylometazoline and placebo nasal sprays on nasal conductance in subjects with nasal congestion associated with common cold. The Figure demonstrates the reproducibility of the nasal conductance measurements over a 12 hours period in the placebo treatment group. The sensitivity of rhinomanometry is demonstrated by the significant increase in nasal conductance over 10 hours after treatment with xylometazoline. The data are taken from Eccles et al. (2008) [18].

masks and sometimes flow-heads that may be safely re-used after cleaning and disinfection may be labelled by the supplier as for single use by a patient. The infection control procedure that has been used for many years at this centre is to clean and disinfect face masks and flow heads. Face masks are first washed in warm water with non fragrant washing up liquid and then washed with disinfectant (Virkon®) and then rinsed with cold water. The flow heads are sonicated in a disinfectant solution (Virkon®), rinsed in cold water and dried using warm air. Virkon® is virucidal, bactericidal, fungicidal and tuberculocidal. Facemasks and flow heads are cleaned and disinfected after use by each patient. Cross infection is considered low-risk, and cleaning and disinfecting the face mask and flow head for each patient should reduce the risk of infection to extremely low levels.

Antiviral filters for single patient use are sometimes recommended to be placed between the face mask and the flow head. However, the filter adds a significant resistance to the measurements (around 0.1 Pa $cm^3$ sec) and this resistance may not always be known in the measurements. Another issue is that the filter does not have the same linear characteristics as the flow head and even if its resistance is included in the calibration of the flow head the resistance will vary in an unknown way during measurements.

*Factors influencing nasal airflow*

When measuring nasal airway resistance it is important to control for factors that may confound the measurements.

*Rest and exercise*

Exercise has been shown to cause a reduction in nasal airway resistance and therefore it is important that patients are rested for up to 30 minutes before any rhinomanometry. This time period should be sufficient to allow the nasal resistance to stabilise to normal levels after the mild exercise undergone in reaching the clinic. If it is suspected that the patient has undergone more strenuous exercise immediately before arrival at the clinic then a longer period of rest (up to one hour) may be necessary before the nasal resistance reaches normal levels.

*Alcohol*

Ingestion of alcohol has been shown to cause an increase in nasal airway resistance and patients for rhinomanometry should not have consumed any alcoholic drinks in the six hour period prior to measurements. In the case of excessive alcohol consumption this wash-out period may need to be extended to 24 hours.

*Medicines*

Medicines such as topical and oral nasal decongestants will obviously alter nasal resistance and a wash out period will be needed according to the dose and pharmacokinetics of the medicine, before any rhinomanometry. Analgesics such aspirin and topical corticosteroids may also influence nasal airway resistance and use before rhinomanometry will need to be restricted. Menthol will alter the perception of nasal breathing but there is no evidence that menthol containing products such as confectionery and chewing gum influence nasal airway resistance.

*Temperature and humidity*

Changes in the temperature and humidity of the inspired air may cause changes in nasal airway resistance. Inspiration of cold air has been shown to cause nasal congestion, but changes in humidity do not have any consistent effect on the nose. Moving from a very cold outdoor environment to a warm clinic environment may cause changes in nasal resistance and patients should be allowed time to acclimatise to the clinic environment. The length of the acclimatisation period will vary according to the climate, with winter climates having an outdoor temperature of below freezing it may be necessary to acclimatise patients to the clinic environment for up to an hour but with milder conditions a period of 30 minutes may be adequate. Similarly, moving from a hot humid outdoor environment to a cold dry air-conditioned environment may cause changes in nasal airway resistance but there are no studies to indicate how the resistance is affected and how long an acclimatisation period is needed to stabilise airway resistance.

With such a range of indoor and outdoor climates and little research in this area it is not possible to recommend clear guidelines for acclimatisation apart from the 30 minute period of rest that is recommended to control for the effects of any exercise.

*Disease*

Infection and allergy of the nose can cause congestion of the nose and nasal obstruction. Much research involving rhinomanometry is concerned with studying the effects of surgical and medical treatments for nasal obstruction and in these studies the nature of any disease of the nose is normally investigated as part of the research. However, acute diseases such as common cold and flu can cause nasal obstruction for several weeks and it is important to question the participants in any research study about the history of any acute upper airway infections and to exclude those subjects who may have had a recent in infection. It is not possible to determine accurately the recovery period needed to exclude any effects of cold and flu on the nose but a period of at least one week after cessation of symptoms associated with cold and flu is reasonable. In the winter period a large proportion of the population may suffer from on or two bouts of cold and flu and if this issue is not taken into consideration in screening subjects for any research on nasal airflow it may confound the measurements of nasal airflow. Other factors such as the presence of severe nasal septal deviation or a previous history of nasal surgery are common problems to take into consideration when screening subjects for research on nasal airflow and they should form part of the exclusion criteria for any research project, apart from any current nasal disease.

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