Chapter 4: Rhinomanometry and nasal challenge

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Site of nasal resistance

In adults, the nose contributes two-thirds of the total airway resistance (Ferris, Mead and Opie, 1964; Speizer and Frank, 1964). This nasal resistance can be divided into three components: the nasal vestibule, the nasal valve and the turbinated nasal passage.

The case is presented below that: the nasal vestibule acts as a flow-limiting segment on inspiration and contributes one-third of the nasal resistance; the nasal valve contributes most of the remaining two-thirds of nasal resistance; and the turbinated nasal passage has a minimal contribution to nasal resistance. The three components of nasal resistance are illustrated.

The narrowest point of the nasal passage determines the overall resistance to airflow and this region is often referred to as the 'nasal valve' (Dishoeck, 1965; Bridger, 1970; Haight and Cole, 1983b). However, there is some dispute in the literature as to whether the nasal valve lies in the nasal vestibule or more posteriorly within the bony cavum of the nose.

The site of major resistance to airflow in the nose has been previously described by Dishoeck (1965) as situated at the junction of the upper and lower cartilages (limen nasi), but there is convincing anatomical evidence which indicates that the isthmus nasi at the pyriform aperture is the narrowest region of the nasal airway (Bachman and Legler, 1972).

The change in airway resistance along the nasal passage can be determined by passing a pressure sensing cannula carefully along the passage and determining the pressure-flow relationships during quiet breathing (Bridger and Proctor, 1970). Using this technique, Haight and Cole (1983b) clearly demonstrated that the major site of nasal resistance lies at the anterior end of the inferior turbinate just within the first few millimetres of the bony cavum as shown. The major site of nasal resistance occurs at the entrance of the piriform aperture. This site of maximum airway resistance agrees with the anatomical evidence and places the nasal valve at the isthmus nasi of the piriform aperture.

The nasal valve is the narrowest part of the nasal airway and the aperture is determined by the position of the inferior turbinate which projects forward toward the piriform aperture and the nasal vestibule. The aperture at this nasal valve region is controlled by the state of engorgement of the inferior turbinate which, in its congested state, can cause complete obstruction of the airway. The significance of the erectile properties of the inferior turbinate has been discussed by Haight and Cole (1983b), who found that the anterior end of the turbinate could advance by as much as 5 mm after application of histamine.

The anterior site of the major component of nasal resistance at the isthmus nasi has important surgical implications as it follows that the main turbinated region of the nasal passage offers very little resistance to airflow. Minor corrective surgery, such as the trimming of septal spurs posterior to the nasal valve region, will therefore have little effect on nasal resistance.
The nasal vestibule, because of its compliant walls, is liable to collapse in response to the negative pressure created during inspiration, and in this way the nasal vestibule can limit nasal air flow and act as a flow-limiting segment or Starling resistor. Bridger (1970) described this flow-limiting segment of the nose as lying in the nasal vestibule between the upper lateral cartilages and the septum. Partial collapse of the lateral wall of the nasal vestibule has been shown to occur when ventilation through one nostril reaches around 30 L/min (Bridger and Proctor, 1970; Haight and Cole, 1983b). The flow-limiting effect of the compliant nasal vestibule occurs only on inspiration and expiratory air flows are not limited in this way.

The resistance of the turbinated nasal passage downstream from the nasal vestibule on inspiration does not normally limit peak nasal air flow (Proctor, 1977). This down-stream resistance on inspiration has only a minor contribution to the overall nasal resistance, as can be seen from the slight resistance change over this region.

Control of nasal resistance

In the normal subject, nasal resistance to air flow is primarily regulated by the sympathetic nervous system, as sympathetic activity determines the state of engorgement of the venous erectile tissue. In nasal allergy the effects of local mediators must also be taken into consideration and their significance will be discussed later. The venous erectile tissue is particularly well developed over the anterior ends of the inferior and middle turbinates and along the base of the septum.

The mechanism regulating the swelling of the erectile tissue is poorly understood; Cauna and Cauna (1975) described throttle or cushion veins which may control its filling. Wright (1895) and Burnham (1935) suggested that the close apposition of arteries and veins in the bony canals of the turbinates was significant, as arterial dilation would cause compression of the venous plexus draining the erectile tissue and this would lead to swelling of the erectile tissue.

The venous erectile tissue of the nasal mucosa has a dense adrenergic sympathetic innervation (Dahlstrom and Fuxe, 1965) and electrical stimulation of the sympathetic nerves to the nose causes a pronounced vasoconstriction and a marked decrease in the volume of blood held in the mucosa (Angård and Edwall, 1974; Eccles and Wilson, 1974; Malm, 1977). Under normal conditions, there is a continuous sympathetic vasoconstrictor tone to the nasal venous erectile tissue and section or local anaesthesia of the cervical sympathetic nerves which supply the nasal mucosa causes nasal congestion and an increase in nasal resistance to air flow (Beickert, 1951; Stoksted and Thomsen, 1953; Eccles, 1978b). The sympathetic division of the autonomic nervous system has a major role to play in the regulation of nasal resistance as a final effector pathway in various reflexes which will be discussed later.

The parasympathetic innervation of the nasal mucosa is primarily to glandular tissue and stimulation of parasympathetic nerves causes a watery nasal secretion with little effect on venous erectile tissue and nasal resistance (Eccles and Wilson, 1973, 1974). Section of the parasympathetic nerves to the nose as they pass through the nerve of the pterygoid canal (Vidian nerve) has proved successful as a last resort in the treatment of nasal hypersecretion (Golding-Wood, 1973).
The nasal vestibule is surrounded by cartilages which are attached to muscles controlled by the facial nerve. These muscles are important in facial expression as is apparent in facial palsy caused by interruption of the motor pathways in the facial nerve. Activity of the dilator naris muscle and the movement of the alar cartilage can be used as a test of facial nerve integrity in suspected cases of facial nerve damage or compression (Sasaki and Mann, 1976).

Contraction of the dilator naris muscle causes a dilation or flaring of the nostril but, according to Haight and Cole (1983b), this has little effect on nasal resistance to air flow as the major resistance lies at the isthmus nasi at the entrance of the piriform aperture. However, Strohl, O'Cain and Slutsky (1982) report that voluntary flaring of the nostril can cause a 20% reduction in nasal resistance.

The function of the dilator naris muscle and other muscles around the nasal cartilages is probably to stabilize the nasal vestibule and prevent alar collapse during the high negative pressures developed during deep and rapid inspiration. Upper airway negative pressure in the anaesthetized rabbit has been shown to increase the activity of nasal muscles and this observation supports a stabilizing role for nasal muscles (Mathew, 1984). Nasal air flow has also been shown to enhance the activity of the nasal dilator muscle in the cat and this finding suggests that nasal air flow is an important stimulus in the control of upper airway accessory respiratory muscles (Davies and Eccles, 1984). At peak inspiratory nasal air flows, the pressure within the nasal vestibule falls well below atmospheric pressure and, when this suction effect exceeds the supporting tension of the lateral nasal wall, nasal collapse occurs and flow is limited.

**Measurement of nasal resistance**

**Basic principles**

Nasal resistance to air flow is calculated from two measurements: nasal air flow and trans-nasal pressure as shown. Both these parameters are measured by means of differential pressure transducers and this is why the study of nasal pressure and flow is termed 'rhinomanometry', since manometry involves the measurement of pressure. Nasal air flow can be measured by means of a pneumotachograph which consists of a gauze resistance inside a cone-shaped tube. The pressure difference across the gauze generated by air flow through the tube is used to measure air flow. Transnasal pressure can be measured by relating the pressure at the posterior nares to that at the entrance of the nostril which will normally be atmospheric pressure or nasal mask pressure.

Nasal resistance to air flow may be calculated from the following equation:

\[ R = \frac{P}{V} \]

- **R** = resistance to air flow, in cmH₂O/L per s or Pa/cm³ per s
- **P** = transnasal pressure, in cmH₂O or Pa
- **V** = nasal air flow, in L/s or cm³/s.
This equation is a compromise which has been generally accepted by rhinologists and it does not take into consideration separate components of laminar and turbulent air flow (Clement, 1984).

Rohrer (1915) described an equation which allowed for both components of laminar and turbulent air flow in the respiratory tract, but his conclusions concerning the significance of laminar air flow in the airways have been shown to be in error (Williams, 1972; Hey and Price, 1982). For the greater part of the respiratory cycle, nasal air flow is turbulent and this turbulence aids in mixing the air and facilitates the exchange of heat and moisture. Nasal air flow shows evidence of turbulence when transnasal pressures exceed 40-80 Pa and therefore laminar air flow would only be found when dynamic pressure and flow values are close to zero (Hey and Price, 1982).

A plot of the dynamic relations of transnasal pressure and flow on an x/y plotter shows a curvilinear relationship as illustrated. Nasal air flow rises with increase of transnasal pressure, but at the higher pressures there is a limitation of flow due to the increased frictional effects of turbulent air flow. The flow-limiting effect of nasal alar collapse is only apparent during rapid or close to maximum inspiratory manoeuvres.

The curvilinear relationship between transnasal pressure and flow means that one cannot simply determine nasal resistance from the slope of the graph, as would be the case with a straight line relationship. The slope of the P/V plot varies along its length and, therefore, it is not possible to describe the curve with a single numerical value for resistance. It is, however, possible to define the resistance at any given sample point along the curve and this has been the solution recommended for a standardized measurement of nasal resistance (Clement, 1984).

The positive or negative pressure at the posterior nares results in air flow through both nasal passages. The right and left nasal air flows are normally asymmetrical due to the nasal cycle (see below) and therefore a single pressure value may relate to two different air flows. It is, therefore, sensible to standardize nasal resistance by measuring both nasal air flows at the same sample pressure point rather than by measuring transnasal pressures at the same sample flow point.

Unilateral nasal air flow measured at a sample pressure point of 150 Pa and bilateral nasal air flow measured at 75 Pa have been recommended as universal standards (Clement, 1984). However, the Asian population cannot always achieve these pressures during normal quiet breathing and the lower sample pressures of 100 and 50 Pa, respectively, are generally accepted for nasal resistance measurements in Japan.

It seems likely that, for clinical determination of nasal resistance, measurement of nasal air flow at a sample pressure will become the standard, as nasal resistance meters produced commercially are already adopting this system. Sample pressure points of 150 Pa and 100 Pa for unilateral resistance determination will probably be used by the majority of rhinologists in Europe and Japan.
Total nasal resistance to air flow can be either determined directly using the posterior method of rhinomanometry (see below) or it can be calculated by combining the two separate values of nasal resistance for the two nasal passages as shown in the formula below:

\[
\frac{1}{R(\text{total})} = \frac{1}{r(\text{left})} + \frac{1}{r(\text{right})}
\]

where the reciprocal of total resistance is equal to the sum of the reciprocals of left and right resistance.

Total resistance can also be directly calculated from the separate nasal airflows obtained at a sample pressure, e.g., at 150 Pa:

\[
R_t = \frac{P(150 \text{ Pa})}{V_r + V_l}
\]

\(R_t\) = total nasal resistance  
\(P\) = transnasal pressure at sample point (150 Pa in this example)  
\(V_r\) = right nasal air flow  
\(V_l\) = left nasal air flow.

When quoting values for total nasal resistance it should be stated whether the value was obtained by measurement of total nasal air flow using posterior rhinomanometry, or whether the air flows of the nasal passages have been measured separately.

The use of a sample pressure point to determine nasal resistance is a compromise, as the single numerical value calculated as nasal resistance only described one point on the P/V respiratory curve.

It is possible to sample the curve at numerous points and obtain an average resistance value with the aid of a microprocessor, and this technique has particular advantages when comparing the resistance values of different segments of the respiration tract (Cole, Fastag and Niinima, 1980).

Another approach to defining the P/V curve has been described by Broms, Jonson and Lamm (1979) who found that curves from a large sample of subjects could be arranged in radial order and that the curves only rarely crossed each other. From this arrangement of the curves, it was possible to define nasal resistance in terms of a polar coordinate system. This particular system of determining nasal resistance is now commonly used in Sweden.

**Techniques of rhinomanometry**

The determination of nasal resistance involves the measurement of nasal pressure and flow as described above. Active rhinomanometry involves the generation of nasal air flow and pressure with normal breathing. Passive rhinomanometry involves the generation of nasal air flow and pressure from an external source, such as a fan or pump, to drive air into the nose.

Active rhinomanometry can be divided into anterior and posterior methods according to the siting of the pressure-sensing tube.
In active anterior rhinomanometry, the pressure-sensing tube is normally taped to one nasal passage as shown. The sealed nasal passage acts as an extension of the pressure-sensing tube to measure pressure in the posterior nares. With this method, nasal air flow is measured from one nostril at a time and the pressure-sensing tube is swapped from one side to the other. Therefore, the P/V curves and nasal resistance are determined separately for each nasal passage and the total resistance is then calculated by summing the values as shown in the formulae above.

In active posterior rhinomanometry, the pressure-sensing tube is held in the mouth and detects the posterior nares pressure when the soft palate allows an airway to the mouth as shown. Total nasal air flow can be measured from both nasal passages, or by taping off one nostril; the right and left nasal air flows can be measured separately. Total nasal resistance can be determined directly from the total nasal air flow and transnasal pressure with this method. A disadvantage of this method, when compared with the anterior method, is that not all subjects can obtain an airway around the soft palate into the mouth. With some training of subjects using feedback from a P/V plot on an oscilloscope or monitor, it is possible to obtain satisfactory results from about 80% of subjects. The use of a P/V plot is necessary when performing posterior rhinomanometry as this method is more prone to artefacts than anterior rhinomanometry because of pressure changes in the mouth due to tongue movements. The use of a small cone-shaped oral cannula made from a plastic disposable auroscope cone often helps subjects to obtain an airway to the mouth and also helps prevent blockage of the cannula with the tongue.

Passive rhinomanometry involves the direction of an external flow of air through the nose and out of the mouth as shown. The method may involve either measurement of the driving pressure at a constant flow or measurement of the flow at a constant pressure. Passive rhinomanometry is particularly useful if it is necessary to separate the upper and lower airways for experimental work (Bundgaard, Sybbalo and Widdicombe, 1983; 1984).

Active anterior rhinomanometry, using surgical tape to seal a pressure sensing tube into the nasal passage, is one of the most commonly used methods for clinical determination of nasal resistance (Solow and Greve, 1980) and it will probably become the clinical standard for studies on nasal disease.

The following precautions are recommended when determining nasal resistance to air flow.

(1) The use of a face mask is recommended rather than nasal cannulae as the insertion of a cannula into the nostril is likely to cause distortion of the airway and irritation. The face mask should form a soft airtight seal and should not pull on the cheek as this can distort the nasal vestibule and disturb nasal resistance.

(2) Equipment should be routinely calibrated for pressure and flow measurement. A sloping manometer filled with light paraffin can be used to calibrate the pressure and a rotameter and air cylinder to calibrate flow as shown.

(3) A single determination of nasal resistance is unreliable because of possible air leaks around the mask etc. It is, therefore, more satisfactory to take two sets of, say five, readings
with a change in mask position between the sets. If the two sets of readings are similar then an air leak is unlikely and the mean value of resistance can be calculated.

Nasal resistance meters are now produced commercially and some of the more modern equipment incorporates a microcomputer to process and store the information from the P/V curves as shown.

**Factors influencing nasal resistance**

Nasal resistance to air flow is primarily determined by the state of congestion of the inferior turbinate and the septal wall at the level of the isthmus nasi. The filling of the venous erectile tissue in the mucosa of the turbinate is controlled by the sympathetic innervation and by the presence of local mediators such as histamine. Apart from this nervous and local mediator control, nasal resistance may be influenced by other complicating factors such as a deviated nasal septum or the presence of nasal polyps.

What is the normal range of nasal resistance in healthy subjects? This question has not been properly answered in the literature because of the confusion regarding methodology and standardization of rhinomanometry. However a total nasal resistance of 2-3 cm H$_2$O/L per s is generally accepted for the adult with the resistance of each nasal passage varying between 2 and 8 cmH$_2$O/L per s. Nasal resistance is inversely related to age with maximum values in the infant at around 12 cmH$_2$O/L per s total resistance (Polgar and Kong, 1965) which declines to the adult value at around 16 years of age and then shows only a slow further decline with increasing age (Saito and Nishihata, 1981; Syballo et al, 1986). Unlike other respiratory parameters, such as vital capacity etc, there is no correlation between total nasal resistance and age, sex or height (Saito and Nishihata, 1981).

**Nasal cycle**

The air flow through the nasal passages is normally asymmetrical and most normal subjects show a regular cyclic change in nasal air flow as shown. A nasal cycle is found in 80% of the population, yet most subjects are completely unaware of any changes in nasal air flow because the total resistance to air flow remains relatively constant due to a reciprocal relationship between the nasal passages (Heetderks, 1927; Stoksted, 1953; Eccles, 1978a, 1982; Hasegawa and Kern, 1978b).

Since the nasal cycle was first described in the scientific literature by Kayser (1895), there have been numerous other studies repeating his observations and extending our understanding of this unusual asymmetry of nasal air flow. However, the functional significance of the nasal cycle is still obscure, apart from the fact that the alteration of nasal air flow allows a rest period from the damaging effects of nasal air flow.

The regular changes in nasal resistance are regulated by changes in sympathetic tone to the nasal venous erectile tissue, with the low resistance side having the greatest sympathetic vasoconstrictor tone (Stoksted and Thomsen, 1953; Eccles, 1978b).

There is some experimental evidence from animal studies that the regular oscillations in sympathetic tone are controlled from the respiratory areas of the brainstem with the control
of nasal resistance being closely integrated with respiratory activity (Bamford and Eccles, 1982; Eccles, 1983).

The regular oscillations in nasal resistance associated with the nasal cycle are not disturbed by the congestion or decongestion of a nasal passage or by occluding one nasal passage (Haight and Cole, 1983a; Bende, 1985). Thus it seems that local stimuli such as air flow in the nasal passage do not influence the central rhythm of the nasal cycle.

**Exercise**

Exercise causes a decrease in nasal resistance to air flow which is directly related to the workload for values between 30 and 120 watts (Richerson and Seebohm, 1968; Dallimore and Eccles, 1977; Hasegawa and Kern, 1978a). The typical effects of exercise on nasal resistance are illustrated. As a means of decongesting the nose, exercise is more potent than topically applied nasal vasoconstrictors as it decongests those areas of the nose which may not be accessible to a nasal spray. The reduction in nasal resistance is probably caused by an increase of sympathetic tone to the nasal erectile tissue, as the response is abolished during blockage of the stellate ganglion. Since exercise can cause a decrease in resistance, it is important that subjects are rested prior to nasal resistance readings.

**Respiration**

An increase in arterial carbon dioxide due to rebreathing or asphyxia causes a pronounced nasal vasoconstriction and a reduction in nasal resistance to air flow. These responses are mediated via the cervical sympathetic nerve and are probably initiated by the stimulatory effects of carbon dioxide on central and peripheral chemoreceptors which initiate a reflex increase in sympathetic tone to the nasal blood vessels (Tatum, 1923; Dallimore and Eccles, 1977; Hasegawa and Kern, 1978a).

A decrease in arterial carbon dioxide due to hyperventilation causes nasal vasodilation and an increase in nasal resistance to air flow, probably by the same arterial chemoreceptor reflex as described above (Tatum, 1927; Dallimore and Eccles, 1977; Hasegawa and Kern, 1978a; Babatola and Eccles, 1986).

Oscillations in nasal resistance with a respiratory rhythm have been described in anaesthetized animals, with a slight decrease in resistance during inspiration (Bamford and Eccles, 1982; Lung et al, 1984).

The regulation of respiration and the control of nasal resistance are closely integrated and studies of anaesthetized cats indicate that the vasomotor control area which regulates nasal resistance is situated within the respiratory areas of the brainstem region (Bamford and Eccles, 1982).

**Posture**

Changes in posture can cause marked changes in nasal resistance due to changes in jugular venous pressure and reflex changes in sympathetic tone to the nose.
The change from erect to supine posture causes an increase in total resistance to air flow which may be explained by an increase in jugular venous pressure (Rundcrantz, 1969; Hasegawa, 1982).

On adoption of the lateral recumbent posture, reflex changes in nasal resistance occur so that the dependent nasal passage congests and the upper nasal passage decongests. This partitioning of nasal air flow ensures that the upper nasal passage is responsible for the major component of the nasal air flow. The changes in nasal air flow are caused by a pressure stimulus to the skin, with the axillary region being the most sensitive area for the initiation of the reflex (Rao and Potdar, 1970; Haight and Cole, 1984; Davies and Eccles, 1985).

Reciprocal changes in nasal resistance may be obtained in the lateral recumbent subject by alternatively lying on one side and then the other, as shown. This postural reflex change in nasal resistance overrides any asymmetry in nasal resistance due to the nasal cycle.

These effects of changes in posture must be taken into consideration when measuring nasal resistance in any posture other than the normal seated upright posture.

**Nasal reflexes**

Mild mechanical or chemical stimulation of the nasal mucosa causes sneezing usually associated with nasal secretion and congestion. The afferent limb of this reflex is the trigeminal nerve with the efferent components including respiratory muscles and the autonomic innervation of the nose (Richardson and Peatfield, 1981). The sneeze has not been studied in as much detail as other respiratory reflexes and there is some controversy as to the efficiency of a sneeze in clearing the nose as in many subjects most of the air flow passes through the mouth (Birch, 1959).

**Air and skin temperature**

Warming or cooling of the skin surface can induce reflex changes in nasal mucosal blood flow and there are several detailed studies on this area which indicate that the nasal mucosa responds in the same way as the skin (Cole, 1954, 1982; Drettner, 1961). Cooling of the skin causes a decrease in nasal mucosal blood flow and warming an increase. Therefore the nasal mucosa has a thermoregulatory role and body heat is conserved or lost to the expired air in order to maintain body homeothermy. In this respect the nasal mucosa responds to body cooling or warming in the same way as the skin.

Although the effects of changes in skin temperature on nasal blood flow are well documented, the effects of changes in the temperature of inspired air on nasal blood flow have not been studied in as much detail and the results of these studies are inconclusive (Drettner, 1961; Cole, 1982).

The temperature of the inspired air may vary independently from skin temperature, for example on a cold day the inspired air may be below freezing point but the skin of a warmly clad person may be near body temperature. In these conditions, the cold inspired air causes congestion of nasal venous erectile tissue and an increase in nasal resistance to air flow (Holmes et al, 1950; Takagi, Proctor and Evering, 1969; Cole, Forsyth and Haight, 1983).
However, the effects of cold inspired air on nasal blood flow are uncertain. The nasal congestion associated with cold inspired air can be overcome by the decongestant effects of exercise and this indicates that it is a vascular congestion rather than oedema which causes the increased resistance to air flow (Cole, Forsyth and Haight, 1983).

The increase in nasal resistance to air flow on inspiration of cold air is caused primarily by nasal congestion, rather than an accumulation of nasal secretion. Nasal hypersecretion may accompany the nasal congestion (Holmes et al, 1950) and this secretory response may be accompanied by the condensation of water from the saturated expired air in the nasal cavity.

**Emotional and psychological responses**

The effects of various emotional and psychological disturbances on nasal function have been studied in detail by Holmes et al (1950). In general, acute and chronic emotional disturbances may result in nasal congestion sometimes associated with hypersecretion. An acute decrease in nasal resistance would be found with any stressful stimuli which caused an increase in sympathetic vasoconstrictor tone or an increased release of adrenaline from the adrenal medulla.

**Sensation of nasal air flow**

The subjective sensation of nasal air flow is very important as regards patient comfort, but it is a parameter which is often overlooked by clinicians treating nasal obstruction. In some patients the objective measurement of nasal resistance determined by rhinomanometry may indicate a normal airway, but the subjective impression of the patient is one of nasal obstruction. In these cases there may be some loss of nasal sensation of air flow, perhaps due to nasal pathology or damage to sensory pathways.

Nasal air-flow sensory receptors have been proposed by several groups (McBride and Whitelaw, 1981; Burrow, Eccles and Jones, 1983), and there is evidence that anaesthesia of these air-flow receptors can lead to disturbance of respiration during sleep (White et al, 1985). Experiments on anaesthetized animals indicate that nasal air-flow receptors are present in the nasal vestibule and that the sensory pathway is via branches of the infraorbital branch of the trigeminal nerve (Davies and Eccles, 1984).

The sensation of nasal air flow is markedly enhanced by aromatics, such as menthol, which are frequently incorporated in preparations used to treat nasal obstruction associated with the common cold; these have a marked effect on the subjective sensation of nasal air flow but do not have any decongestant action (Burrow, Eccles and Jones, 1983). The sensitization or stimulation of nasal air-flow receptors by menthol has been shown to enhance the activity of upper airway accessory respiratory muscles and this action may help to prevent upper airway collapse especially during sleep (Davies and Eccles, 1985).

**Nasal challenge**

Nasal challenge or nasal provocation tests involve the administration of suspected allergens directly into the nose in order to determine the nasal sensitivity of a subject to test
substances. In cases where there is some doubt over the results of skin or blood tests for allergen sensitivity, then nasal challenge may provide valuable diagnostic evidence of sensitivity (Mygind, 1978; Davies et al, 1985; Weeke, Davies and Okuda, 1985).

Although nasal challenge tests have often been used for research purposes in the past, their use is not firmly established in clinical practice because they are time consuming and always carry the risk of an anaphylactic reaction. Nasal challenge can be useful, however, to confirm that a positive skin or blood test is clinically relevant, as a control in immunotherapy, and when bronchial challenge of asthma patients is contraindicated (Mygind, 1978). It has been claimed that allergy can be localized exclusively to the nose and be demonstrated by nasal challenge, but not by skin tests (Huggins and Brostoff, 1975); however, Mygind and Lowenstein (1982) state that nasal challenge in patients with negative skin tests has no place in clinical practice, except perhaps for occupational allergy. The usefulness of nasal challenge and rhinomanometry in studying occupational allergy is supported by the results of other researchers who have found nasal challenge useful in the identification of occupational allergens (Okuda et al, 1982; Gervais, Ghaem and Eloit, 1985).

Bronchial challenge can be readily quantified by measuring forced expiratory volume, FEV₁, and a 20% fall in FEV₁, is generally accepted as a positive response. Unfortunately there is no similar standard for nasal challenge.

**Local and reflex effects**

The tickling sensation, sneezing and hypersecretion caused by allergen challenge are due to stimulation of sensory nerve endings in the nasal mucosa. There is now evidence that histamine is the mediator responsible for these responses as they can be reduced by H₁ antagonists, such as chlorpheniramine. From this evidence it has been proposed that there are histamine H₁-receptors on the sensory nerves supplying the nasal mucosa (Kirkegaard, Secher and Mygind, 1983).

The nasal congestion and increase in nasal resistance caused by allergen challenge is due mainly to the local effects of mediators released from mast cells acting directly on nasal blood vessels. Unilateral antigen challenge causes unilateral nasal congestion without any contralateral congestion (Konno, Togawa and Nishihiara, 1982; Haight and Cole, 1983a). Thus, the vascular response to mediators can be explained by their local action, whereas the secretory response depends on a reflex activation of parasympathetic nerves to nasal glands, as shown.

Histamine, when administered into the circulation or applied topically, causes nasal vasodilation and an increase in nasal resistance and there is evidence for both histamine H₁- and H₂-receptors on nasal blood vessels (Hiley, Wilson and Yates, 1978).

Histamine sprayed into the nasal cavity induces symptoms which are very similar to those caused by administration of allergen in the sensitive subject, and this, together with the presence of histamine in the basophilic cells of the nasal mucosa, has implicated histamine as an important mediator of nasal allergy (Mygind, 1982). However, there are important differences between the histamine and allergen provocation tests which indicate that histamine is not the sole mediator of nasal allergy. First, provocation with allergen, but not histamine,
gives rise to local eosinophilia, which can be demonstrated in a nasal smear from 1-3 hours to 1-3 days after provocation, and second allergen provocation, but not histamine, increases nasal reactivity (Connel, 1968).

The allergic response is dependent on a complex soup of mediators whose time course of release and activation varies widely; however, the time course of response can often be divided into early and late phases. The response to allergen challenge in the lungs is often an immediate response occurring in a matter of minutes and a late response occurring after several hours; however, this separation of responses has not been conclusively shown in the nose (Richardson, Rajtora and Penick, 1979; Davies et al, 1985).

**Standardization of nasal challenge**

At the time of writing, there is no generally accepted procedure for nasal challenge and, before any progress can be made in this field, the following variables need to be standardized.

The actual allergen preparation itself can be a source of much variability. Purification of pollen extracts may give a more consistent product, but many active substances may be removed. The initial material itself can vary according to how and when and from where it is collected. The final concentration of allergen on the mucosa and the area of mucosa over which it is spread can also determine the level of allergic response (Mygind, 1978).

The method of administering the allergen varies from one centre to another with nasal drops, nebulized droplets, powders and allergen-soaked filter paper discs all being used (Wihl and Mygind, 1977; Konno, Togawa and Nishihiara, 1982; Weeke, Davies and Okuda, 1985). It is difficult to compare responses when such different methods are used.

The severity of the allergic response to nasal challenge may be measured in terms of sneezes, secretion, a change in nasal resistance, the levels of mediators in secretion or by measuring the concentration of albumin in secretion as a marker for changes in mucosal permeability (Borum et al, 1983).

Measurement of nasal resistance to air flow alone does not always provide a comprehensive measure of the allergic response but use of a simple instrument such as an inspiratory peak flow meter can give clinically meaningful results (Weeke, Davies and Okuda, 1985).

Once there is some generally agreed standardization of nasal challenge, then it may provide useful diagnostic information in the clinic, but at present it is still very much a laboratory-based procedure.