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Laser-Doppler blood flowmetry measurement of nasal mucosa blood flow after injection of the greater palatine canal

PAUL GURR, F.R.C.S., VINCENT CALLANAN, F.R.C.S., F.R.C.S.I., DAVID BALDWIN, F.R.C.S.

Abstract
Laser-Doppler blood flowmetry was used to measure the mucosal blood flow of the inferior turbinate before and after injection of the greater palatine canal with 2 ml of a 0.5 per cent bupivicaine hydrochloride solution. Injection of the greater palatine canal is a useful technique in the control of posterior epistaxis. The arterial blood supply to the inferior turbinate is via a single descending branch of the sphenopalatine artery. We conjectured that injection of the pterygopalatine fossa, via the greater palatine canal, would result in a reduction of blood flow to the inferior turbinate. In this study injection of the pterygopalatine fossa caused only a 4.7 per cent decrease in blood flow to the inferior turbinate mucosa ($p = 0.571$). Elevation of the head by an angle of 20 degrees reduced nasal mucosal blood flow by 38.3 per cent ($p<0.0001$). Depression of the head by an angle of 20 degrees increased nasal mucosal blood flow by 74.7 per cent ($p<0.0001$). We conclude that there is an adequate collateral blood circulation to the anterior portion of the inferior turbinate.

Key words: Flowmeters; Turbinates

Introduction

Injection of the greater palatine canal is an effective method of controlling posterior epistaxis (Padrnos, 1968; Bharadwaj and Novotny, 1986; Williams and Ghorayeb, 1990). Greater palatine canal injections are also used to provide anaesthesia for dental procedures, anaesthesia and haemorrhage control during nasal sinus surgery, and to relieve sphenopalatine neuralgia (Stankiewicz, 1988).

The greater palatine foramen opens into the greater palatine canal which leads into the pterygopalatine fossa. The pterygopalatine fossa contains the sphenopalatine artery and the posterior (descending) palatine artery branches from the third portion of the internal maxillary artery, the sphenopalatine ganglion and the maxillary nerve. The sphenopalatine artery supplies virtually all of the posterior nasal area and inferior turbinate except for a small site on the inferolateral wall of the nose supplied by the posterior (descending) palatine artery (Weingarten, 1972).

The arterial blood supply of the inferior turbinate is via a single descending branch of the sphenopalatine artery (arising in the sphenopalatine foramen) which descends on the lateral wall of the nose under cover of the attachment of the middle turbinate to enter the inferior turbinate, 1.0–1.5 cm from its posterior tip. The artery then passes anteriorly in a series of arcades (Burnham, 1935; Padgham and Vaughan-Jones, 1991). We conjectured that measurement of the mucosal blood flow of the anterior portion of the inferior turbinate would reflect flow in its supplying vessel and this would be altered by greater palatine canal injection.

Laser-Doppler flowmetry (LDF) is a reproducible non-invasive technique for measurement of capillary microcirculation which provides real time qualitative assessment of nasal mucosal blood flow (NMBF) (Druce *et al.*, 1984; Olsson *et al.*, 1985; Druce, 1988). The laser-Doppler blood flowmeter produces an output measured in flow units (Perfusion units (PU), also referred to as *flux*. This unit is derived from the amount of light reflected back to the laser Doppler probe from the microcirculation of the nasal mucosa. Flow will vary according to the Doppler principle when the laser shines on red blood cells moving through blood vessels. This reproducible perfusion unit (PU) allows a comparison between different events. Flux is defined as the number of red blood cells multiplied by their mean velocity in a measured volume (Nilsson, 1990).

This study involves the use of an established technique known to control posterior epistaxis. This control is achieved either by a topical pressure effect on the blood vessels crossing the pterygopalatine fossa or by a pharmacological action on the blood vessels or autonomic nervous system via local

From the Department of Otolaryngology, Head and Neck Surgery, Southmead Hospital, Bristol BS10 5NB, UK.
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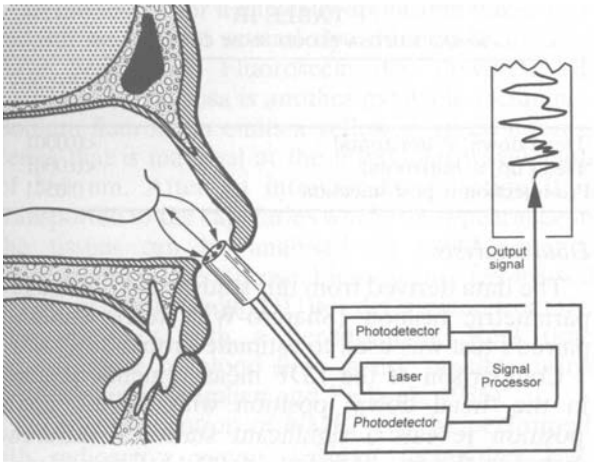

FIG. 1
Schematic illustration of the laser-Doppler flowmeter.

sympathic or parasympathetic nerves (Bharadwaj and Novotny, 1986). We conjectured that injection of the pterygopalatine fossa, via the greater palatine canal, would result in a reduction of blood flow to the inferior turbinate, the changes of NMBF were measured with a laser-Doppler flowmeter.

Materials and methods

A cohort of 14 healthy volunteers who were to undergo routine nasal surgery was recruited to this study. Their age ranged from 28–52 years.

Subjects were excluded from the study if they suffered from sinusitis, rhinitis or nasal polyposis. Subjects were also excluded if they were taking any medication or were smokers. Ethical committee approval was obtained. This study was performed while patients were under general anaesthesia. A standard anaesthetic regimen using propofol induction and halothane maintenance was used. Hypotensive agents were not used. No topical anaesthesia or decongestants were given prior to the measurements.

Laser-Doppler blood flow measurements

Nasal mucosa blood flow measurements were obtained with a Periflux PF3 laser-Doppler perfusion meter using a 2 mW helium-neon laser with a wave length of 632.8 nm and a Gaussian beam width of 0.8 mm. A mounted laser-Doppler probe was held in position against the inferior turbinate, using a modified head-light retaining strap. The probe includes three optical fibres, one to conduct the light from the laser to the tissue and two to carry a portion of the scattered light back to two photodetectors (Nilsson, 1990), (See Figure 1.)

The laser-Doppler blood flow meter was set to 3 second averaging, at 4 Hz with the gain set at 3. All results were recorded using a chart recorder set at 1 cm per min. An initial period of 15 minutes observation was allowed for equilibration of the output of the flowmeter, i.e. in order to stabilize the baseline (horizontal place) measurement (Perimed, UK).

The study was performed with the patients at first lying supine in the horizontal plane. The patients were then placed 'head up' at an angle of 20 degrees to the horizontal and subsequently returned to the horizontal position. The patients were next placed in the 'head down' position at an angle of 20 degrees to the horizontal before again being returned to the horizontal plane (now the 'pre-injection' position). This manoeuvre was chosen to confirm that the laser-Doppler blood flowmeter was correctly recording the expected changes in perfusion associated with alterations of the patient's posture. Following the changes in the patient's posture the baseline was allowed to re-establish, the greater palatine canal was injected and the output of the flowmeter measured for a further 15 minutes. Flow measurements were made at each stage described (Table I, and Table II).

Injection technique of the greater palatine foramen

Injection of the greater palatine foramen was standardized for all patients. A 25 gauge dental

TABLE I
FLOW MEASUREMENTS RECORDED BEFORE AND AFTER CHANGES IN PATIENT POSITION

	Flow measurements (Perfusion units)					
Subject no.	Horizontal	Head up	Change (per cent)	Horizontal	Head down	Change (percent)
1	6.4	4.5	−29.6	6.3	10.2	61.9
2	4.4	2.0	−53.9	4.5	8.0	78.1
3	5.1	3.7	−27.4	5.2	10.6	103.0
4	4.1	3.7	−9.8	4.2	8.4	102.0
5	4.8	3.5	−27.5	5.0	9.4	89.0
6	4.3	2.8	−34.8	4.4	8.4	91.6
7	4.6	3.2	−30.4	4.7	7.9	68.7
8	5.4	3.4	−37.0	5.4	9.3	73.1
9	4.3	2.9	−33.3	4.3	8.5	97.7
10	6.8	2.9	−57.3	6.0	9.7	61.7
11	5.6	2.0	−63.6	5.8	8.8	50.4
12	5.6	3.9	−30.3	5.8	10.3	77.6
13	6.3	3.1	−50.8	6.7	9.7	45.5
14	5.8	2.9	−50.0	6.1	8.9	45.9
Mean average	5.3	3.2	−38.3	5.3	9.1	74.7
Standard deviation	0.8	0.7	−14.7	0.8	0.9	20.1

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TABLE II

FLOW MEASUREMENTS RECORDED BEFORE AND AFTER INJECTION OF THE GREATER PALATINE CANAL WITH 2.0 ML OF A 0.5 PER CENT BUPIVICAINE HYDROCHLORIDE SOLUTION

	Flow measurements (Perfusion units)		
Subject no.	Pre-injection	Post-injection	Change (per cent)
1	6.3	5.9	−6.3
2	4.5	4.4	−1.1
3	5.2	5.5	4.8
4	4.2	4.0	−3.1
5	4.9	5.3	7.8
6	4.5	3.0	−34.4
7	4.7	4.8	2.8
8	5.4	4.5	−16.3
9	4.3	4.0	−4.7
10	6.0	5.1	−14.5
11	5.9	5.6	−5.4
12	5.5	5.7	3.2
13	6.6	6.4	−3.0
14	6.0	5.6	−6.6
Mean average	5.3	5.0	−4.7
Standard deviation	0.8	0.9	11.1

syringe needle was bent to an angle of 45 degrees, thus making access to the greater palatine canal easier by allowing an active needle length of 25 mm. The greater palatine foramen was identified using two tongue depressors to demonstrate the edge of the hard palate and by taking a perpendicular line anterior from the quarter point of the hard palate to a point opposite the last molar tooth (wisdom tooth) or, if absent, the medial posterior alveolus (Stankiewicz, 1988).

Confirmation of successful entry into the pterygo-palatine fossa was achieved by passage of the needle to a depth of 25 mm, and was followed by aspirating the needle. Incorrect placement of the needle was shown by either the presence of blood, indicating entry into a blood vessel or by the presence of air bubbles indicating that the needle was in the nasopharynx. In either case the needle was withdrawn and repositioned (Bharadwaj and Novotny, 1986).

The greater palatine canal was injected with 2 ml of a 0.5 per cent bupivicaine hydrochloride solution in order to cause compression of the descending branch of the sphenopalatine artery.

Results

Baseline (i.e. horizontal) laser-Doppler blood flowmetry measurements were recorded after 15 minutes in the horizontal position. The baseline LDF measurements did not vary on average by more than 1.2 per cent while replacing the patients from the 'head up' and 'head down' positions to the horizontal plane. Altering patient position from the horizontal plane to the 'head-up' position resulted in a diminution of NMBF by 38.3 per cent. Conversely, altering patient position from the horizontal plane to the 'head-down' position resulted in an increase of NMBF by 74.7 per cent. Comparison of the data obtained pre-injection and post-injection of the greater palatine canal shows a mean cohort NMBF decrease of only 4.7 per cent (Table I).

TABLE III

NASAL MUCOSA BLOOD FLOW COMPARISONS

	Probability value
'Head down' *v.* horizontal	<0.0001
'Head up' *v.* horizontal	<0.0001
Pre-injection *v.* post-injection	0.0571

Data analysis

The data derived from this study is distributed in a parametric fashion (Shapiro-Wilk test). Student's paired *t*-test was used to estimate probability values.

Comparison of the LDF measurements obtained in the 'head down' position with the horizontal position reveals a significant statistical difference between the two groups ($p<0.0001$). Comparison of the LDF measurements obtained in the 'head up' position with the horizontal position also shows a significant statistical difference ($p<0.0001$).

These probability values indicate that changing the patient's position significantly alters NMBF. This also confirms that the system is working correctly and behaving predictably. The NMBF decrease observed after greater palatine canal injection is not statistically significant ($p=0.0571$) (Table III).

Analgesia

We chose to inject a 0.5 per cent bupivicaine hydrochloride solution in an attempt to try and reduce post-operative pain. Pain levels in the early post-operative period were assessed by asking patients to complete a visual linear analogue scale, with zero indicating no pain and ten representing the worst pain. This was unsuccessful because it was not possible for recovering patients to distinguish the injected from the non-injected side of their nose.

Discussion

Measurements of NMBF were originally developed to separate out the components of nasal airway obstruction for independent study and is of interest to nasal physiologists and allergists alike. Techniques used to investigate nasal microcirculation have evolved from simple observations of nasal mucosa colour. In animals invasive studies are applicable but these are less feasible to humans. At present, techniques involving Fluoroscein dye flowmetry, radioactive xenon washout and laser-Doppler blood flowmetry are available for use in man (Table IV), (Druce, 1990).

TABLE IV

TECHNIQUES FOR MEASUREMENT OF NASAL MICROCIRCULATION

Direct observation
Colorimetry
Fluoroscein dye flowmetry
Thermal conductivity
Cannulation (animals)
Radioactive microspheres (animals)
Hydrogen clearance
^{133}Xe washout
Laser-Doppler flowmeter

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In the search for a clinically applicable blood flow measuring method several dye dilution techniques have been used. Fluoroscein dye flowmetry in human nasal mucosa is another available technique. Sodium fluoroscein emits a yellowish-green fluorescence that is maximal at the ultraviolet wavelength of 360 nm. After an intravascular injection it is transported to the capillaries where its appearance in the tissues can be analysed by rapid-sequence photography of the mucosa. Fluorescence (expressed in optical density units (DU)) is determined from the film negatives with a densitometer. Real time measurement of blood flow is not possible using this technique (Kumlien and Perbeck, 1986).

Direct investigation of NMBF can be performed with radioactive xenon washout techniques and laser-Doppler flowmetry. The xenon washout technique requires an injection of fluid directly into the nasal mucosa that may, itself, affect the local response and alter the recorded measurement. The technique of xenon washout has not been verified for nasal tissue, as the partition coefficient for xenon between blood and mucosa has not been accurately determined for nasal tissue (Druce, 1988).

Olsson (1985) demonstrated that when feet were exposed to cold water there was a drop in NMBF after 15 seconds. Calculated as a percentage of the starting values it corresponds to a decrease in blood flow of 24 per cent. The maximum effect occurred 33 seconds after the cold water was applied, and thereafter the blood flow gradually returned to its starting value after five minutes. The decrease in blood flow was associated with a drop in mucosal temperature and the authors drew the conclusion that LDF is a useful tool for estimation of changes in nasal mucosal microcirculation.

The best known applications of the Doppler technique principle in biology and medicine are a series of different techniques for assessing blood flow from the Doppler shift, that sound waves experience when they travel through blood flowing in large blood vessels, thereby producing images of the heart and major blood vessels. However it is impractical to use Doppler ultrasound to measure changes in the capillary microcirculation. Laser-Doppler blood flowmetry utilizes the short wavelength or extremely high frequencies of visible and infra-red light to measure tissue perfusion by exploiting the Doppler shifts that moving red blood cells impart to light. LDF is a versatile tool which is used to measure blood flow in the cochlea, retina, kidney, bone, brain, skin and gastrointestinal tract (Shepherd, 1990).

Laser-Doppler blood flowmetry requires no injection of the mucosa, gives a continuous tracing and requires no changes in the patient's posture; however, bodily movement leads to artefacts with the measurements especially over a protracted time period. This did not pose a difficulty in our study as the patients were under general anaesthesia and therefore immobile. LDF also allows the measurement of pulsatility which results from systolic and diastolic variations and may be relevant in the studies of tissue perfusion. Nasal LDF can be used to provide a stable measurement of NMBF which reflects tissue perfusion. This depends on blood flow into the inferior turbinate via the artery to the inferior turbinate (Druce, 1988).

The technique of injection of the pterygopalatine fossa via the greater palatine canal is effective in controlling posterior epistaxis. Bharadwaj and Novotny (1986) injected a solution of 1 per cent Xylocaine or sterile water, Williams (1990) injected a solution of 1 per cent Xylocaine and adrenaline and Weingarten (1972) used glycerine injections. As plain Xylocaine, water or glycerine are effective on their own, we chose to inject a plain 0.5 per cent bupivicaine hydrochloride solution to reduce NMBF and augment post-operative analgesia.

There is no common pharmacological pathway by which these diverse agents could cause vasoconstriction and hence affect nasal mucosal blood flow. The fact that these agents control posterior epistaxis when injected into the greater palatine canal leads us to the conclusion that the reduced mucosal blood flow may be either a pressure effect on the vascular contents of the pterygopalatine fossa or (perhaps more likely) physical irritation of the descending branch of the sphenopalatine artery causes reflex vasoconstriction.

No significant change (either reduction or increase) in NMBF can be demonstrated either before or after greater palatine canal injection whilst measuring at the anterior portion of the inferior turbinate. This contrasts with a 38.3 per cent decrease in NMBF achieved by elevating the patient's head and a 74.7 per cent increase on depressing the patient's head. There are no previously reported studies in the literature investigating the link between posture and NMBF objectively measured by laser Doppler flowmetry.

This finding complements the findings of Porter *et al.* (1991) who showed that five per cent cocaine solution reduced NMBF by 61.2 per cent and when mixed with adrenaline (1:1000) reduced NMBF by 76.7 per cent. The patients in their study were in the supine position.

Therefore nasal surgery as traditionally performed in the 'head up position' combined with the use of topical nasal mucosa decongestants leads to the maximal reduction in NMBF.

Conclusion

We conclude that, either the scientific basis of injection of the greater palatine canal in the management of epistaxis is flawed, or else sufficient collateral blood supply exists explaining why no demonstrable effect on NMBF at the anterior part of the inferior turbinate is observed after injection of the greater palatine canal. The latter thesis is in keeping with the observation of Padgham and Vaughan-Jones (1991) who describe an increasing diameter of the main arterial trunk in the anterior part of the inferior turbinate as the artery passes forward. They postulated that a possible anastomosis with the facial artery augments this region's blood

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supply. This study lends support to that view. If it is accepted that the technique of injection of the greater palatine canal does control posterior epistaxis then this study shows that the blood supply of the inferior turbinate is augmented by an undefined anastomosis. The vascular anatomy of the lateral wall of the nose needs further study.

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Address for correspondence:
Mr Paul Gurr, F.R.C.S.,
Clinical Lecturer,
Royal National Throat Nose and Ear Hospital,
Grays Inn Road,
London WC1X 8DA.

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