Using dynamic analysis of Laser-Doppler blood flowmetry to measure nasal mucosa bloody flow in postural changes*

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Summary

Background: The regulation of nasal mucosa blood flow (NMBF) is affected by multiple factors, such as the autonomic nervous system, medications, temperature, humidity, endocrine, even emotional stress and vision. The effects of postural changes on NMBF have been described in numerous studies. However, the results are far from consistent due to different experimental designs.

Objective: Dynamic analysis of Laser-Doppler blood flowmetry (LDBF) is employed to recognize the effect of postural changes on NMBF.

Methods: NMBF was continuously measured by LDBF in 14 participants with changing postures (sitting and supine). NMBF was measured in Blood Perfusion Unit (BPU), equivalent to the number of red blood cells multiplied by their mean velocity in a measured volume.

Results: NMBF increases significantly in a supine posture compared with that in a sitting posture.
Conclusion: Our study demonstrates that NMBF is significantly influenced after initial postural change, suggesting that changes in posture may be regarded as an important factor regulating NMBF.

Key words: blood flow, nasal mucosa, dynamic analysis, body posture, Laser Doppler blood flowmetry

Introduction

The main physiological functions of nasal mucosa include cleaning inhaled air, maintaining nasal humidity, and adjusting inhaled air temperature. Nasal mucosa is supplied by rich vessel beds composed mainly of arteriovenous anastomosis (AVA) and venous sinusoid (VS)[(1)]. VS offers good compliance and is effective in storing nasal mucosa blood. There are two main mechanisms influencing nasal mucosa capacitance, including hydrostatic pressure of blood and autonomic nervous system [(2-6)]. The change in hydrostatic pressure affects the filling pressure of vessel beds, and the VS content expands with increase in filling pressure. The autonomic nervous system, comprising mainly sympathetic nerve fibers, controls the smooth muscle of ANA, which regulates NMBF by adjusting smooth muscle tone [(3,5-6)]. The regulation of NMBF is affected by multiple factors, such as the autonomic nervous system, medications, temperature, humidity and endocrine, even emotional stress and vision [2-10]. Postural changes induce variations of filling pressure, but the relationship between postural changes and NMBF remained obscure. The aim of our study is to investigate the correlation between NMBF and postural changes.

Methods

Subjects

The study was performed with 14 healthy participants, (6 women and 8 men, aged 22 to 38 years, mean age 31 years). The participants were healthy young adults without medical history of heart disease, hypertension, and nasal allergy. They were not on medication before the study and underwent a normal rhinoscopic examination. All participants had neither symptoms of the common cold nor those of allergic nasal disease. They restrained themselves from any physical activity for 10 minutes before each test.

Blood flow measurement

Measurements were made with the participants in two postures including upright sitting position and supine position. Laser-Doppler blood flowmetry (LDBF) (Periflux 4001, Perimed, Sweden) with the standard probe was applied at a right angle to the anterior part of the inferior turbinate mucosa. The LDBF measured blood flow in Blood Perfusion Unit (BPU), equivalent to the number of red blood cells multiplied by their mean velocity in a measured volume. Gentle placement of the probe without pressure is important to avoid compression of the superficial blood vessels. The probe was held immobile and in position by attachment to a head mirror modified with stationary metal bars. The participants were asked to sit quietly and breathe normally through the nose exclusively in an upright sitting position.

Stable nasal mucosa blood flow

Each subject performed one course of position change, and the change of nasal blood flow was measured. Each measured data was judged by relative standard deviation (RSD) to increase the reliability. We defined "stable nasal mucosa blood flow (SNMBF)" as RSD < 20% and maintained for at least 30 seconds. After detecting and recording SNMBF in sitting position, the participants changed to a supine position. SNMBF in supine position was also recorded. Each subject repeated the test several times until we measured stable nasal flow in both positions. The mean value of each period's SNMBF was calculated and compared (Figure 1).

Statistical analysis

NMBF results were expressed as mean ± SEM in all subjects. Student's paired t-test was used for statistical evaluation. The difference was assumed to be significant at $p < 0.01$.

Results

All 14 participants underwent the test smoothly without any difficulty. Although there were some variations between each participant, the NMBF in upright sitting position was less than that in supine position for each individual (Table 1). The average NMBF in supine position was 450.5 ± 55.5 (BPU); and the average NMBF in upright sitting position was 159.0 ± 22.7 (BPU). The NMBF in supine position was significantly increased when compared with that in upright sitting position ($p < 0.00001$) (Figure 2).

Discussion

NMBF was affected by multiple factors, such as medication, autonomic nervous system, medication, temperature, humidity and endocrine, even emotional stress and vision [2-10]. During nasal allergic reactions, histamine causes vasodilatation and stimulates fluid outflow causing allergic symptoms such as rhinorrhea and congestion. Antihistamines and intranasal corticosteroids were used to relieve allergic symptoms. Several studies using the LDBF method to measure effects of medication on NMBF have been presented. Juliusson illustrated that H1-antagonists influenced NMBF and inhibited allergic symptoms, while H2-antagonists did not [9]. In Cervin's study, a single dose of intranasal corticosteroid had no acute effects on NMBF [10]. Differential postures affect the hydrostatic blood pressure, which also influences the filling pressure of nasal mucosa vessel beds. The increase in filling pressure synchronizes with a head position change from upright to trendelenburg [3]. Theoretically, this mechanism might result in expansion in VS content and increase in NMBF. The effects of postural changes on NMBF have been described in numerous studies. However, the results are far from consistent due to different experimental designs. Bende used a Xenon washout method to measure NMBF and reported that NMBF decreased significantly with change in posture from supine to sitting position [11]. In Riechelmann's study, changes in posture did not alter nasal blood flow, which was measured by LDBF [3]. Gurr presented that patients under general anesthesia changing position from the horizontal to the head tilting at an angle of ± 20 degrees resulted in significant changes of NMBF [8]. The inconsistent results obtained may be attributed to the differences between instruments used, duration of examination, examination interval, patient conscious condition, and analysis duration of NMBF. According to our experience, NMBF kept changing even in the same posture. We did not average the results of each subject over several trials. Nasal mucosa blood flow was under the influence of multiple factors, and even with the same subject, the different temporal data varied. We calculated the RSD for each test to increase the precision, and excluded the test data RSD > 20%, which indicated variation is obvious. We considered that a smooth and short-term test procedure had the advantage of avoiding both exercise and environmental ef-

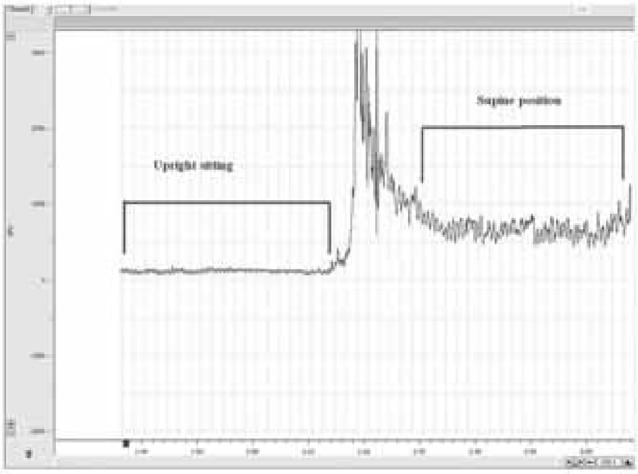

Figure 1. A dynamic record of NMBF from one participant. Stable NMBF was recorded in both postures.

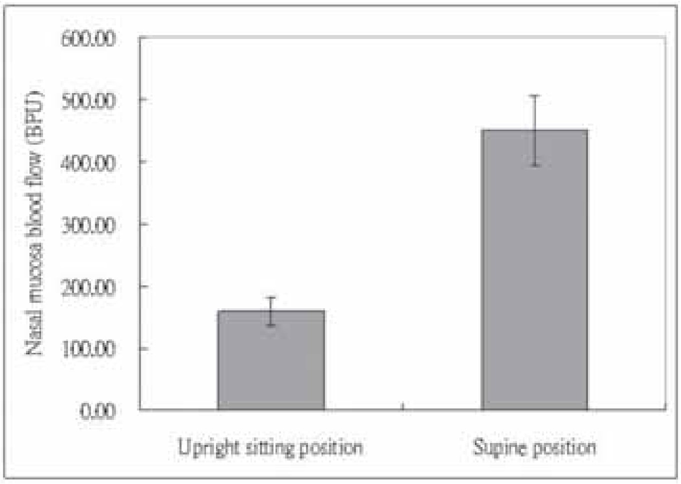

Figure 2. The average of nasal mucosa blood flow in different posture measured by laser-Doppler flowmeter.
Each point represents mean ± SEM (n = 14). The difference between the means is statistically significant.

fects, thus yielding credible and low-variation data on the effect of postural changes on NMBF.

Nasal mucosa vessels can be divided into resistance vessels and capacitance vessels [6]. The resistance vessels of nasal mucosa include small arteries, veins and AVA. AVA is composed of a rich smooth muscle layer, which is controlled by the autonomic nervous system. The system comprises mainly sympatic nerve fibers and regulates NMBF by alternating smooth muscle tone [1,3,5,6]. The primary capacitance vessels in nasal mucosa are VS, whose content is mainly affected by NMBF and filling pressure. With changes in posture from upright sitting position to supine position, the filling pressure of nasal mucosa vessel beds increases rapidly under the effect of gravity. The volume of nasal mucosa blood affects nasal resistance, and VS overload can result in nasal congestion and even obstruction [2,4,13]. In this study, we demonstrated that NMBF increased as the posture changed from upright sitting to supine, which we regarded as a rapid response to a change in the vessel filling pressure. The increased NMBF at supine posture may facilitate nasal decongestion because it also leads to a greater outflow from VS that prevents VS overload. Thus, postural changes may be regarded as an important factor for NMBF regulation. In clinical management of epistaxis, increase in NMBF poses problems to the procedure, prolongs bleeding time and increases blood loss. In our opinion, a persistent upright sitting position is the optimal posture for management of epistaxis.

The role of the nervous system in response to postural changes has been discussed in several studies, and Riechelmann pre-

No.	Gender	Age	Upright sitting position (BPU)	Supine position (BPU)	Difference
1	F	25	124	681	557
2	M	23	136	686	550
3	F	36	251	670	419
4	F	31	296	705	409
5	F	31	87	451	364
6	M	25	168	512	344
7	M	29	152	488	336
8	M	28	328	654	326
9	M	34	65	233	168
10	M	32	85	240	155
11	F	29	135	289	154
12	F	27	231	365	134
13	M	28	90	222	132
14	F	33	78	109	31

Table 1. The gender, age, nasal mucosa blood flow (NMBF) in upright sitting position and supine position, and the differences of NMBF between the 14 subjects.

sented that an increase in filling pressure led to an increase in NMBF, thus regulating contraction of the nasal mucosa smooth muscle layer to prevent VS overload by alpha-1 adrenergic mechanisms [3,5-6,8]. The experience of body haemodynamic change during different postures also offered suitable explanation. As body posture changes, the hemodynamic regulation triggered by baroreceptor relaxation and sympatic stimulation lead to changes in heart rate, catecholamine excretion, vascular smooth muscle tone and cardiac output to maintain blood pressure in a stable condition. In our previous study, we found that the response of NMBF to cold air is similar to that of the body surface [14]. Therefore, we consider that the regulations of postural changes in nasal microcirculation might have a similar purpose; that is, to maintain homeostasis. In Kobayashi's research, nasal mucosa stimulation inhibits baroreflex vagal bradycardia identified in rats, and this result implies that nasal mucosa might serve as a sensor of barometric pressure [15]. It remains unclear whether there exists an independent baroreceptor-like structure specially for regulating the reflex arc of NMBF, or whether such regulation is controlled simultaneously by the baroreceptor reflex.

There are two common instruments for measuring the NMBF: the radioactive Xenon washout method and LDBF [3,4,7-12]. This radioactive 133Xenon in isotonic sodium chloride solution has been used for evaluating tissue blood flow and was first described for measuring NMBF in Bende's study [11]. The injection of Xenon tracer into the nasal mucosa was an invasive procedure, which may cause pain in participants, activate the sympatic nervous system and lead to unwanted vasoconstriction in the nasal mucosa, which might affect data accuracy. Moreover, the radioactive Xenon has a long half-life, and the participants have to receive additional radiation doses after the experiment. LDBF ameliorates the disadvantages of the Xenon washout method. LDBF uses non-contact probe-emitted laser light, thus avoiding local nasal mucosa stimuli. The detector distinguishes the reflex waves of different wavelengths by the "Doppler effect", where wavelengths will fluctuate when the laser light hits upon mobile red blood cells but remain unchanged when coming in contact with motionless objects, such as soft tissue. LDBF being non-radioactive and non-invasive can provide a safe and accurate impression of NMBF. In Ehnhage's report, LDBF could evaluate possible changes in nasal mucosal swelling and microcirculation very well [16]. Furthermore, in this study, LDBF offers dynamic and stable data, that facilitate detailed observation of changes in NMBF within a short period. In our opinion, a longer period of stable NMBF recorded in each position and a shorter interval between posture changes can shed light on the effect of postural changes on NMBF.

In this study, NMBF was measured in 14 healthy participants, and we succeeded in investigating the response of NMBF to postural changes. We designed only one postural change to avoid both environmental and exercise effects on participants. Our study demonstrated NMBF was significantly influenced within the short period after initial postural change, which we regarded as a rapid regulation in response to an increase in vessel filling pressure. The long-term effect of postural change on NMBF was not examined in our study, but merits further exploration.

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Conflict of interest

There was no conflict of interest for all the authors.

Author contribution

K-KT: conducted the experiment and wrote the paper.
C-FY: revised the paper.
Y-HC: helped with the experiment.
H-WW: designed the experiment and helped the paper writing.

References

1. Nagai M, Nagai T, Tono T. Scanning electron microscopy of arteriovenous anastomosis in nasal respiratory mucosa. Arch Otorhinolaryngol. 1983; 238: 115-122.
2. Wang HW. Effects of Posture on Nasal Resistance. J Med Sci. 2002; 22: 161-164.
3. Riechelmann H, Krause W. Autonomic regulation of nasal vessels during changes in body position. Eur Arch Otorhinolaryngol. 1994; 251: 210-213.
4. Kurita N, Hasegawa M, Ohki M, Watanabe I. Nasal resistance and nasal blood flow in postural changes. Acta Otolaryngol. 1988; 106: 448-452.
5. Klaassen AB, van Megen YJ, Kuijpers W, van den Broek P. Autonomic innervation of the nasal mucosa. ORL J Otorhinolaryngol Relat Spec. 1988; 50: 32-41.
6. Malm L. Sympathetic influence on the nasal mucosa. Acta Otolaryngol. 1977; 83: 20-21.
7. Chu YH, Wu CC, Kao CH, Wang HW. Low temperature decreased tension in isolated hypertrophic human nasal mucosa. Am J Rhinol. 2006; 20: 84-86.
8. Gurr P, Callanan V, Baldwin D. Laser-Doppler blood flowmetry measurement of nasal mucosa blood flow after injection of the greater palatine canal. J Laryngol Otol. 1996; 110: 124-128.
9. Juliusson S, Bende M. Effect of systemically administered H1- and H2-receptor antagonists on nasal blood flow as measured with laser Doppler flowmetry in a provoked allergic reaction. Rhinology. 1996; 34: 24-27.
10. Cervin A, Akerlund A, Greiff L, Andersson M. The effect of intranasal budesonide spray on mucosal blood flow measured with laser Doppler flowmetry. Rhinology. 2001; 39: 13-16.
11. Bende M. Blood flow with 133Xe in human nasal mucosa in relation to age, sex and body position. Acta Otolaryngol. 1983; 96: 175-179.
12. Olsson P. A comparison between the 133Xe washout and laser Doppler techniques for estimation of nasal mucosal blood flow in humans. Acta Otolaryngol. 1986; 102: 106-112.
13. Stroud RH, Wright ST, Calhoun KH. Nocturnal nasal congestion and nasal resistance. Laryngoscope. 1999; 109: 1450-1453.
14. Chu YH, Lu DW, Wang HW. Ambient cold air decreased nasal mucosa blood flow measured by laser Doppler flowmeter. Rhinology. 2010; 48: 160-162.
15. Kobayashi M, Cheng ZB, Nosaka S. Inhibition of baroreflex vagal bradycardia by nasal stimulation in rats. Am J Physiol. 1999; 276: H176-184.
16. Ehnhage A, Kolbeck KG, Juto JE, Dahlen B, Stjarne P. Evaluation of nasal mucosal swelling and microcirculation throughout nasal and bronchial provocation tests with lysine-aspirin in asthmatics with nasal polyposis. Rhinology. 2010; 48: 216-223.

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