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# Nasopharyngeal pressure gradients during non-phonetic activities of the velopharyngeal valve. Part II

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**Abstract**

The subject of our study is the non-phonetic activities of the velopharyngeal valve (VPV). The VPVs of 10 patients were assessed by nasendoscopic examinations. The nasopharyngeal pressure fluctuations were recorded by catheters placed into the nasopharynx. Simultaneous pressure created in the oral cavity was measured as well. In Part I we discussed the swallowing activities and here we describe sucking and blowing activities. The pressure wave tracings and measurement with the nasendoscopic examination provide us with new information which permits a further study of the non-phonetic activity of the VPV and a correlation with its abnormal speech activity.

## Introduction

The sphincteric mechanism of the velopharyngeal valve (VPV) which is the coupling gate between naso- and oropharynx, and the tongue palatal valve [10] which disconnects the oropharynx from the oral cavity necessitates an harmonic function of the pharyngeal muscles. This harmony is important for pneumatic activity, using the lungs as a source of energy, in a form of pressured air, such as speech. Harmonic function of the pharyngeal muscles is essential for non-phonetic

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activities as blowing and for sucking. Sucking and swallowing are not pneumatic activities and for accomplishing swallowing we must stop breathing.

As the pharynx is a common passage for various activities, there are also other facts to be noted. In speech the pharyngeal muscles function in the necessary harmony under the control of the left cerebral hemisphere [1]. In the non-phonetic activities the coordinated muscle function probably depends on the control of dorsal reticular formation of the medulla, ventral to the solitary nucleus [9]. As these centers differ from evolutionary point of view, these activities as well appear in different developmental phases. The fetus swallows the amniotic fluid and sucking in the perinatal period is very important [4,14]. The phonetic activity of the VPV develops later on as speech is developed [7,11,18]. The precise mechanism of the VPV has been in dispute since the time of Passavant [12,13] in the nineteenth century, and is still not fully understood.

In Part I of our work, we stated our concept that for evaluation and treatment of patients suffering from VPV insufficiency in speech, additional information about the non-phonetic activity of the VPV would have a potential importance. The diagnosis of "organic" velopharyngeal insufficiency is more strongly confirmed if there are concomitant non-phonetic disturbances. The value of non-phonetic exercises is still in dispute and will be clarified.

Until now, the major effort has been concentrated on the study of the phonetic activity in cases of VPV insufficiency. A further study of the non-phonetic activity of the VPV and its correlation with the phonetic activity in cases of VPV insufficiency is necessary.

In the present study, by measuring pressure gradients within the nasopharynx and oral cavity during forced sucking and blowing, we want to establish the basis for development of an objective aeromechanical system for evaluation of the non-phonetic activity of the VPV.

## Patients and Methods

We have fully described in Part I of the present study the patients' profile and the methods used. The investigation was carried out in 10 patients who have undergone nasal septal surgery.

Before surgery, E.N.T. examination with special attention to oral cavity and nasendoscopy of the VPV were performed. During the nasendoscopic examination, after performing the same swallowing activities as described in Part I, the patients performed:

(1) Forced sucking and swallowing: forcedly sucking by the mouth for 2.5 s through a No. 16 Nelaton catheter connected to a special device (Fig. 1, right, top). The device consists of plastic tubing adapted from a No. 16 Nelaton catheter inserted in a bottle (D) full of water. At its exit there is a laboratory compression screw (F) which partially clamps the tube. Proximally there is a T system (E) connected to a negative pressure manometer with pressure ranges of 0 to $-100$ mm

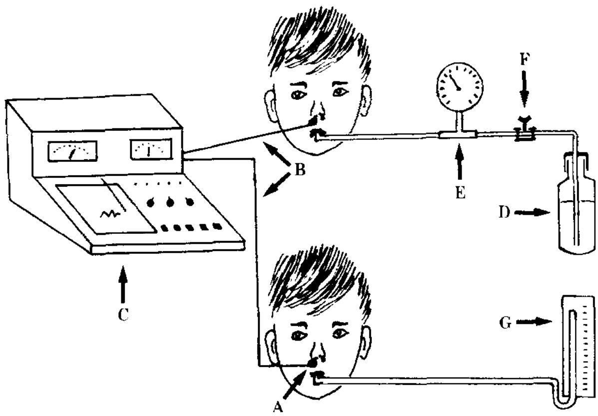


Fig. 1. Manometric measurements of pressure gradients developing within the nasopharynx and oral cavity: during forced sucking (top), and during forced blowing (bottom): A: the probe is applied to the funnel connector of the catheter. B: the electrical cord to the pressure transducer (C). D: the water bottle from which the patient is sucking water through an elastic tube. E: negative pressure manometer connected by a T system. F: laboratory compression screw. G: blood pressure sphygmomanometer.

Hg (1 mm Hg = 13 mm $H_2O$). The negative pressure built up in the oral cavity during the sucking is measured by this device.

(2) Forced blowing: blowing using the lungs (not only by puffing cheeks) into a No. 16 Nelaton catheter (Fig. 1, right, bottom). The catheter is connected to a blood pressure sphygmomanometer (G) from which the rubber bag and pump were removed. With this device we measured the positive pressure building in the oral cavity and oropharynx below the closed VPV.

The patients have undergone septal surgery and at the end of the operation we inserted a No. 16 Nelaton catheter between the layers of one of the nasal packs. The internal end was obliquely cut and placed within the nasopharynx. The funnel connector of the catheter remained just outside the nose.

A 'Grason-Stadler' 1723 middle ear analyzer (Fig. 1C) was used to record the pressure gradients within the nasopharynx as fully described in Part I.

The measurements were made in the first and second postoperative days. The recordings were made in a sitting position. The probe of the transducer was applied to the funnel connector of the catheter (Fig. 1A) after patency of the intranasal catheter was assured.

The patients were instructed to repeat the same tasks as were done before surgery during the nasendoscopic examination.

## Results

Patients' data, nasendoscopic findings and manometric measurements are presented in Table I.

TABLE I

*Patients data, nasendoscopic findings and manometric measurements*

| *Patient No.* | *F/M* | *Age* | *Closure pattern* | *Forced sucking Oral cavity (mm $H_2O$)* | *Forced sucking Nasopharynx (mm $H_2O$)* | *Forced blowing Oral cavity (mm $H_2O$)* | *Forced blowing Nasopharynx (mm $H_2O$)* | *Closure Level* |
|---|---|---|---|---|---|---|---|---|
| 1 | M | 56 | Coronal | −117 | −140 | +910– +1040 | +300 | Middle 1/3 |
| 2 | M | 57 | Coronal | −130 | −30– +30 | +1300 | +250 | Superior 1/3 |
| 3 | M | 22 | Coronal | −143 | −50 | +1430 | +200 | Middle 1/3 |
| 4 | M | 28 | Circular and Passavant | −130 | +50 | +910 | +130 | Inferior 1/3 |
| 5 | M | 58 | Circular | −130 | +170 | +780 | +300 | Middle 1/3 |
| 6 | M | 24 | Coronal | −130 | No | +910 | +200 | Superior 1/3 |
| 7 | M | 25 | Circular and Passavant | −130 | No | +1105 | +300 | Superior 1/3 |
| 8 | M | 34 | Coronal | −104 | −40 | +650 | ≈ +250 | Middle 1/3 |
| 9 | M | 25 | Circular | −117 | +40 | +780 | +220 | Middle 1/3 |
| 10 | F | 30 | Coronal | −78 | No | +780 | +170 | Superior 1/3 |

*(A) Forced sucking*

On nasendoscopic examination the VPV during the sucking phase (SP) remained open permitting observation of the pharyngeal walls. In patients No. 1, 3 and 8 the velum was anteriorly invaginated into the oropharyngeal isthmus forming the lingual palatal valve [10]. In these patients during SP the measurements of nasopharyngeal pressure negative deflections of $-30$ to $-140$ mm $H_2O$ were recorded (Figs. 2A and 3A, arrows). In patients No. 4 and 7 the Passavant ridge appeared exactly as in swallowing but more clearly because the VPV remained open and was uncovered by the anterior and lateral pharyngeal walls. In these patients the nasopharyngeal pressure recordings during SP showed positive deflections of $+50$ to $+70$ mm $H_2O$ (Fig. 3A, bottom, arrow). In patients No. 5 and 9 on nasendoscopy, medial-oriented movement of the lateral pharyngeal walls was observed at the level of the VPV closure during SP. The nasopharyngeal recordings showed positive deflections of up to $+170$ mm $H_2O$ (Fig. 4A, top, arrow). In patients No. 2, 6 and 9 (Fig. 4A, bottom) no movement of the pharyngeal walls was observed and the tracing of nasopharyngeal pressure remained near to the zero line. Patients No. 2 and 6 closed their VPV during SP. Simultaneous chest auscultation by stethoscope confirmed that instead of sucking they aspirated the water. After further instructions, they could aspirate or suck on command. The nasopharyngeal pressure recordings showed during the aspiration phase (AP) a marked negative deflection down to $-230$ mm $H_2O$ (patient No. 2, Fig. 5A, AP; patient No. 6, Fig. 5C, AP).

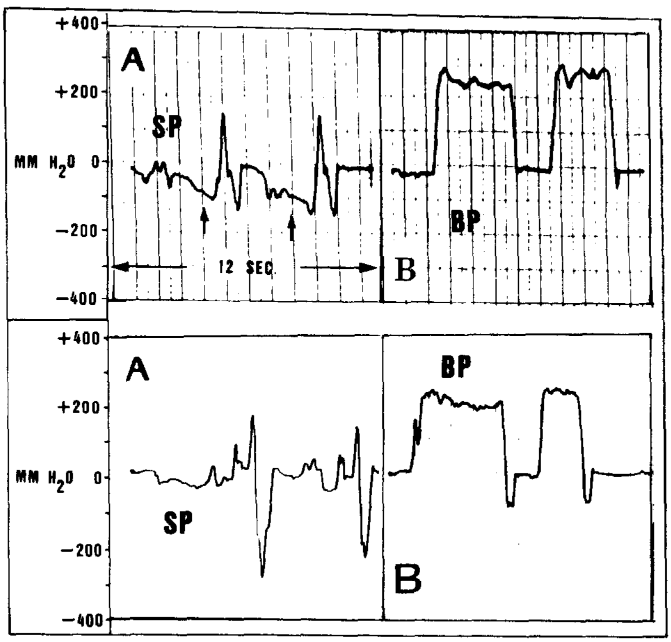


Fig. 2. Nasopharyngeal pressure recordings during: (A) forced sucking and immediate deglutition, arrows note the negative deflection; (B) forced blowing (patient No. 1, top; patient No. 2, bottom).

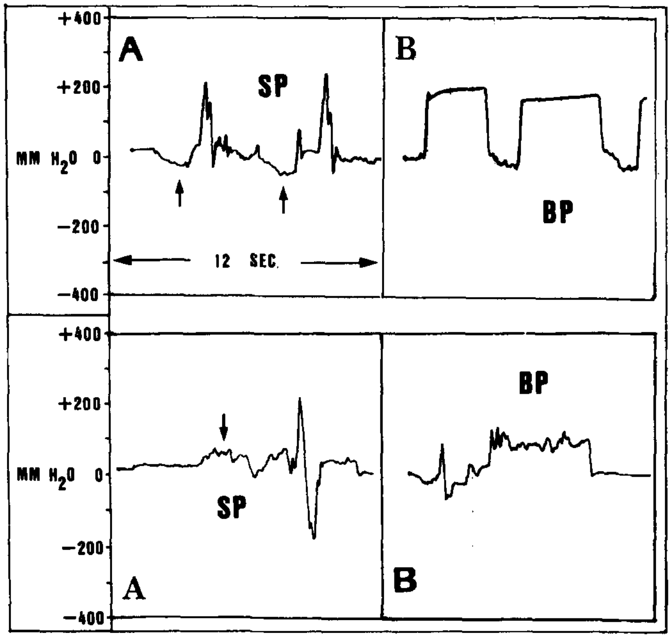


Fig. 3. Nasopharyngeal pressure recordings during: (A) forced sucking and immediate deglutition, arrows note the negative or positive deflections; (B) forced blowing (patient No. 3, top; patient No. 4 bottom).

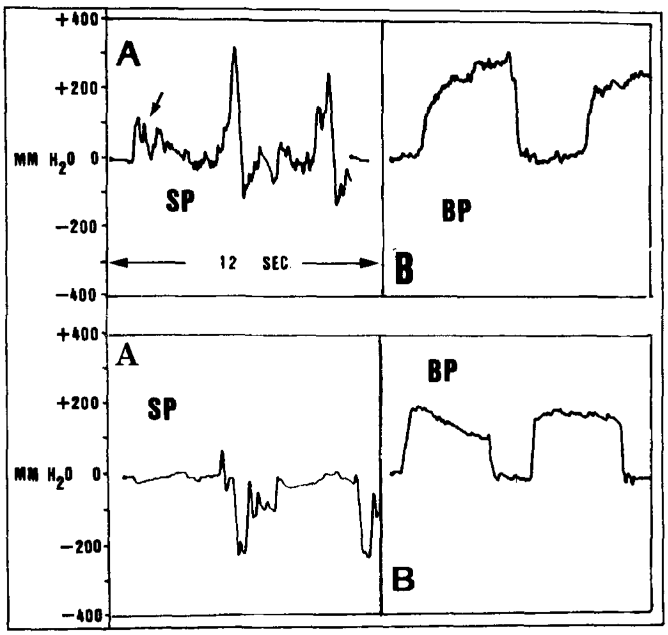


Fig. 4. Nasopharyngeal pressure recordings during: (A) forced sucking and immediate deglutition; (B) forced blowing (patient No. 5, top; patient No. 6, bottom).

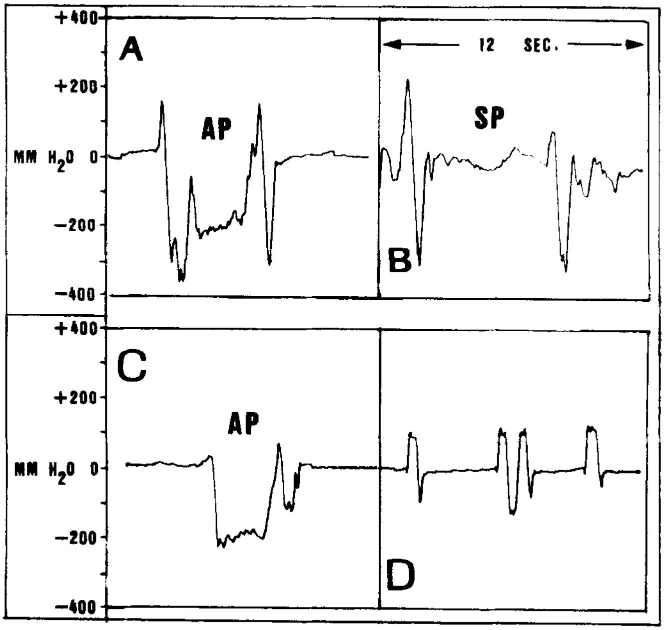


Fig. 5. Nasopharyngeal pressure recordings during: (A) aspiration; and (B) forced sucking and immediate deglutition (patient No. 4); (C) aspiration; (D) deglutition and in the center an 'unsuccessful' deglutition (patient No. 9).

During sucking this deflection disappeared (Fig. 5B, top). All the patients were instructed to suck strongly with maximal effort and to hold this negative pressure for 2.5 s, and to swallow the sucked water immediately at the end of the SP. The closure pattern of their VPVs was demonstrated by this maneuver. The classification of the closure patterns to coronal, circular and circular with Passavant ridge was described in Part I and is shown in Table I.

In no case was a sagittal pattern observed. On the recordings of the nasopharyngeal pressure, the biphasic curve of the swallowing signals the end of SP and follows it in to the beginning of the new SP. In Fig. 5D between two normal biphasic pressure curves, a recording of an unsuccessful swallowing act is seen, named by us as 'Bigeminy'.

The negative pressure measured in the oral cavity ranged from 78 mm $H_2O$ (= −6 mm Hg) to 143 mm $H_2O$ (= −11 mm Hg), as shown in Table I.

*(B) Forced blowing.*

The nasendoscopic examination revealed that the level of the VPV closure was much higher generally than during swallowing. In patients No. 2, 6, 7 and 10 the closure level was at the upper third of the torus tubari near the roof of the nasopharynx. The distribution of the closure level of the VPV is shown in Table I. The nasopharyngeal pressure recordings during the blowing phase (BP) showed positive deflections which range from +130 mm $H_2O$ (patient No. 6, Fig. 4B, bottom) up to +300 mm $H_2O$ (patient No. 5, Fig. 3B, top). The positive pressure measured in the oral cavity ranged from 650 mm $H_2O$ (= +50 mm Hg) up to 1430 mm $H_2O$ (= +110 mm Hg) as shown in Table I. In all cases the VPV closure resisted the maximal major pressure created in the oropharynx during the maximal forced blowing.

## Discussion

In the adult the liquids are sucked into the oral cavity after the lips close around the tube. The negative pressure is built up by the movement of the tongue. The dorsum of the tongue is raised and the soft palate descends, the forced attachment of them forming the tongue-palatal valve which disconnects the oral cavity from the oropharynx behind [10]. The most important muscle in this activity is the palatoglossus as was shown by the electromyographic investigation of Fritzell [5]. While the VPV remains open, the floor of the mouth, the mandible and the tongue descend for completion of the first phase of the sucking or deglutition [10]. During sucking the VPV remains open as has been shown by Moll [10]. To the best of our knowledge, observations and measurements of the movements of the pharyngeal wall during the forced sucking were not previously reported. The observation that Passavant's ridge can be formed during forced sucking is of great interest. Glaser et al. [6] have shown that there are variations in the appearance of the Passavant ridge relative to the velum. The ridge can be formed at the level of the velar eminence, the uvula, or below the uvula. Since the ridge can be formed under the plane where the soft palate contacts the posterior pharyngeal wall, it can remain unseen during the nasendoscopy. Karnell and Morris [8] have shown that the nasendoscopic examination of the VPV may cause misinterpretation of the contribution of the posterior wall in some cases and mis-seeing the Passavant ridge altogether. Therefore, they recommend a routine use in tandem oral and nasal endoscopy. In practice, we know that the results of oral endoscopy of the VPV, especially because of patient's discomfort and the interference with speech and non-speech movements, are not clear. Another point of controversy is which muscle produces the Passavant ridge. Von Luschka [16] and many others attribute the formation of the Passavant ridge to the palatopharyngeus muscle. Passavant [12,13] and later also Calnan [3] related it to the upper portion of the superior constrictor. The formation of Passavant's ridge during forced sucking while the VPV remains open probably permits further study of the muscle which creates the ridge.

In the routine nasendoscopy we introduced the Forced Sucking Test (FST) by instructing the patient to suck powerfully from an obstructed catheter for 2–4 s. The examiner then observed the movement of the pharyngeal wall with special attention to the posterior and the lateral walls.

The positive pressure measured within the nasopharynx during the formation of Passavant's ridge or during medial movement of the lateral pharyngeal walls suggests an active muscular activity rather than a passive medial collapse of the mucosa.

Speech, blowing and whistling are all pneumatic activities of the VPV [2,15] using the pressurized air derived from the lungs as a source of energy. Bloomer [2] stated that the VPV activity during blowing resembles that of speech. Warren and Hofmann [17] found in this activity greater velar movements than during deglutition. Moll [10] has shown that velar elevation during blowing is approximately 2 or 3 mm greater than in speech. This difference could be explained by the greater air pressure developing in the oral cavity and the oropharynx during blowing which forces the velum to a higher level [10]. Fritzell [5] in his electromyographic study has shown that during blowing the main consistent muscle activity is of the levator veli palatini and the superior constrictor.

Positive pressure in the oral cavity can be produced by utilizing the tongue palatal valve. We examined blowing using the VPV. The VPV resists the maximal pressured air during the forced blowing. The measurements of the pressure created by the VPV closure within the nasopharynx merit further investigations. A new method of measuring nasopharyngeal pressure gradients without introduction of catheters is now under primary investigation.

In conclusion, the simultaneous measurement of the pressure developed within the nasopharynx and within the oral cavity gives us a new, basic, valid information which in the future, after a concomitant radiological investigation, could provide more data on the non-phonetic activities of the VPV.

Our results show that there are typical swallow curves in individuals and there are also typical individual sucking and blowing patterns.

## References


1 Best and Taylor's Physiological Basis of Medical Practice, West, J.B. (Ed.), 11th edn., Williams and Wilkins, Baltimore, 1985, pp. 643.

2 Bloomer, H.H., Observations on palatopharyngeal movements in speech and deglutition, J. Speech Hear. Dis., 18 (1953) 230–246.

3 Calnan, J., Modern views on Passavant ridge, Br. J. Plast. Surg., 10 (1958) 89–113.

4 English, G., Otolaryngology, 13th edn., Harper and Row, Philadelphia, 1985, 2–19.

5 Fritzell, B., The velopharyngeal muscles in speech, Acta Otolaryngol., Suppl 250 (1969) 1–77.

6 Glaser, E.R., Skolnick, M.L., McWilliams, B.J. and Shprintzen, R.J., The dynamics of Passavant's ridge in subjects with and without velopharyngeal insufficiency—a multi-view videofluoroscopic study, Cleft Palate J., 16 (1979) 24–33.

7 Irwin, O.C., Development of speech during infancy: curve of phonemic frequencies, J. Exp. Psychol., 37 (1947) 187–193.

8 Karnell, M.P. and Morris, H.L, Multiview videoendoscopic evaluation of velopharyngeal physiology in 15 normal speakers, Ann. Otol. Rhinol. Laryngol., 94 (1985) 361–365.

9 Miller, A.J., Characteristics of the swallow reflex induced by peripheral nerve brain stem stimulation, Exp. Neurol., 34 (1972) 210–222.

10 Moll, K.L., A cineradiographic study of the velopharyngeal function in normals during various activities, Cleft Palate, J., 2 (1965) 112–122.

11 Muriel, E. and Morley, D., The development and disorders of speech in children, 2nd edn., Williams and Wilkins, Baltimore, 1967, pp. 314–315.

12 Passavant, G., Uber die Verschliessung des Schlunders beim Sprechen, Virch. Arch. Pathol. Anat., 46 (1869) 1–81.

13 Passavant, G., Concerning the improvement in speech after operation on the palate, Arch. Klin. Chir., 23 (1879) 771.
14 Peiper, A., Cerebral Function in Infancy and Childhood, Consultants Bureau, New York, 1963.
15 Shprintzen, R.J., Lencione, R.M., McCall, G.N. and Skolnick, M.L.A., A three dimensional cinefluoroscopic analysis of velopharyngeal closure during speech and non-speech activities in normals, Cleft Palate J., 11 (1974) 412–428.
16 Von Luschka, B, Die Anatomie des Menschen Halses, Vol. 1, 1870, p.101.
17 Warren, D.W., and Hofmann, F.A., A cineradiographic study of velopharyngeal closure, Plast. Reconstr. Surg., 28 (1961) 656–659.
18 Winitz, H., Articulatory Acquisition and Behaviour, Appleton–Century–Crofts, New York, 1969.