Roles of the Facial, Glossopharyngeal and Vagus Nerves in Velopharyngeal Movement

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The present study was designed to clarify the role of the motor nerves in velopharyngeal movements. Experiments were carried out on 15 anesthetized rhesus monkeys on the assumption that their velopharyngeal structures are similar to those of human beings. The pattern and degree of velopharyngeal movements with stimulation to the facial, glossopharyngeal, and vagus nerves in the petrosal area were analyzed by means of fiberscopic observations. The results obtained were as follows:

1. Velopharyngeal movements were most active with stimulation to the vagus, then the glossopharyngeal, and finally, the facial nerve.
2. Complete closure by unilateral stimulation was elicited only by the vagus nerve and not the facial or glossopharyngeal nerves.
3. The pattern of velopharyngeal movements observed when stimulating the facial nerve was quite different from those seen when the glossopharyngeal or the vagus nerve was stimulated. That is, movements in a plane at the upper part of the nasopharynx were observed on stimulating the facial nerve while upward movements from all of the velopharyngeal structures were seen when the glossopharyngeal or vagus nerve was stimulated.
4. Combined stimulation to the nerves sometimes resulted in additive effects on velopharyngeal movements, but these could be recognized in only a few cases.

This study reveals that the motor nerves innervating the velopharyngeal muscles play different roles in velopharyngeal movements.

Introduction

Knowledge concerning the physiological mechanisms of velopharyngeal movements is important to the management of velopharyngeal incompetence. Although these mechanisms have not yet been fully explained, certain findings of interest have been reported.

Ashley, et al. (1961), Bloomer (1953), Calnan (1953), and Matsuya, et al., (1974), have noted that velopharyngeal movements during swallowing appear to be quite different from those seen during phonation. In addition, Yamaoka, et
al., (in press) have reported that many repaired cleft palate patients who show velopharyngeal incompetence during phonation have the ability to close completely during swallowing. These observations suggest that both the motor nerves and the muscles participating in velopharyngeal closure differ in swallowing and phonation.

In a previous study of evoked EMG, Nishio, et al., (1976) reported that muscles related to velopharyngeal closure were innervated by the facial, glossopharyngeal and vagus nerves. Learning more about the role of each of these nerves would provide an important key to understanding the velopharyngeal valving mechanism. The present study utilized fiberoptic observations to explore the roles of these nerves in the velopharyngeal movements of rhesus monkeys.

Methods

The experiments were carried out, as shown in Figure 1, on 15 rhesus monkeys lightly anesthetized with Nembutal. Descriptions of the dissection and electrical stimulation of the facial, glossopharyngeal and vagus nerves were provided in detail in the previous paper (Nishio, et al., 1976). In addition to the above procedures, the nasopharyngeal fibroscope (NPF) was used to observe velopharyngeal movements on stimulating the distal stumps of the dissected nerves. The fiberscope was inserted into the upper part of the nasopharynx through a nostril, and the tip of the scope was fixed so that the epiglottis could be seen at the center of the velopharynx view. This procedure was previously described by Miyazaki, et al., (1975).

Observations were made to determine:
1. The effects of isolated electrical stimulation on the facial, glossopharyngeal, and vagus nerves

FIGURE 1. Diagram of equipment used.
a) The influence of frequency with constant intensity
b) The influence on intensity with constant frequency

2. The effects of combined stimulation of two of the three nerves.

In all cases, duration of square wave pulse was maintained at 0.5 msec. Still photographs were made of the velopharynx at rest and during stimulation of the nerves. Velopharyngeal movements during nerve stimulation were evaluated by comparing orifice size at rest with orifice size during movement. Orifice size was subsequently judged and classified as “complete closure”, “marked movement”, “moderate movement”, and “slight movement”, as shown in Table 1 and Figure 2.

Results

1. Velopharyngeal movements associated with electrical stimulation to the facial nerve

In order to examine the effects of various frequencies (1-80 Hz) upon velopharyngeal movements, intensity was first maintained at the level of 10v. Figure 3 shows the fibrescope findings. At low frequencies (1-10 Hz), mere

<table>
<thead>
<tr>
<th>Degree</th>
<th>Velopharyngeal orifice size</th>
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<tbody>
<tr>
<td>0%</td>
<td>Complete closure</td>
</tr>
<tr>
<td>40%</td>
<td>Marked movement</td>
</tr>
<tr>
<td>70%</td>
<td>Moderate movement</td>
</tr>
<tr>
<td>100%</td>
<td>Slight movement</td>
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TABLE 1. Interpretation of descriptive terms used in describing velopharyngeal movements.

FIGURE 2. Descriptive terms used in describing velopharyngeal movements.
twitch-like movements of the velopharynx were evoked synchronously with the rate of stimulation on the unilateral facial nerve. With gradual increase in frequency, the movements became more active, and stimulation at 20Hz provoked “slight movement” of the velopharynx. Further narrowing of the velopharyngeal area was induced with increasing frequencies, and maximal movement was recognized at frequencies between 70 and 80Hz. However, “complete closure” could not be evoked by stimulating only the unilateral facial nerve. On the other hand, bilateral stimulation of the facial nerve produced velopharyngeal movements that were more active than those which occurred with unilateral stimulation (Figure 3-B). Bilateral nerve stimulation at frequencies of 70 to 80Hz produced “marked movement” of the velopharynx in most cases with “complete closure” occurring occasionally.

Next, the effects of various intensities (2-18v) in association with a constant frequency (40Hz) were examined. Figure 4 indicates the fiberoscopic findings. With unilateral stimulation, “slight movements” were recognized between 2 and 4v. Maximum movement occurred at higher intensities (about 16v), but “complete closure” was never seen. Bilateral stimulation evoked more active movements than did unilateral stimulation. “Marked movements” were evoked as the maximal response to bilateral stimulation in most cases. Figure 5 summarizes these findings.

The characteristic response of the velopharynx to stimulation of the facial nerve is described as movement in a plane.

2. Velopharyngeal movements associated with electrical stimulation to the glossopharyngeal nerve
At low frequencies (1–10 Hz), an intensity of 10 V produced twich-like movements of the velopharynx synchronously with the rate of the unilateral nerve stimulation. The movements became more active with gradual increases in frequency, and "marked movements" were observed between frequencies of approximately 60 to 70 Hz. With unilateral stimulation of the glossopharyngeal
nerve, however, “complete closure” of the velopharynx was not elicited. Movements with bilateral stimulation were more active than with unilateral. Figure 6 shows the fibrescopic findings.

Next, the effects of various intensity levels (2–18v) at a constant frequency (40Hz) were examined. With unilateral stimulation, at intensities between 2 and 4v, “slight movements” were observed. With increases in intensity level, narrowing of the velopharynx occurred, and “marked movements” were elicited at about 16v. With bilateral stimulation at 16v, the velopharynx was closed completely. This information is illustrated in Figures 7 and 8.

The characteristic response to stimulation of the glossopharyngeal nerve as seen through the fibrescope was upward movement of the velopharyngeal structures.

3. Velopharyngeal movements associated with electrical stimulation to the vagus nerve

The effects of various frequencies (1–80Hz) upon velopharyngeal movements were examined at the intensity level of 10v. At low frequencies (1–10Hz), active, twitch-like movements of velopharynx were elicited by unilateral stimulation of the vagus nerve. With increases in frequency, movements became more marked, and the velopharynx was closed completely even by unilateral stimulation. (See Figure 9-A) Bilateral stimulation made velopharyngeal movements more active and induced “complete closures” at frequencies between 30 and 40Hz. (See Figure 9-B).

At the fixed frequency of 40Hz, “complete closure” was evoked by unilateral

stimulation at the level of 12v and at the level of 8v when stimulation was bilateral. (See Figures 10 and 11).

The characteristic response of stimulation to the vagus nerve as seen through the fiberscope was active, upward movement of the velopharyngeal structures.
FIGURE 9. Velopharyngeal movements with stimulation of the vagus nerve at a constant intensity level of 10v. A: Unilateral stimulation. B: Bilateral stimulation. (The velopharyngeal structures are marked by white lines.)


4. Comparison of velopharyngeal movements elicited by stimulation of the three nerves

Figure 12 shows that velopharyngeal movements were most active with stimulation of the vagus and least active with stimulation of the facial nerve.
FIGURE 11. The influence of intensity of vagus nerve stimulation upon velopharyngeal movements at a constant frequency of 40 Hz. ■—■ Unilateral stimulation. □—□ Bilateral stimulation.

FIGURE 12. The influence of frequency of each unilateral nerve stimulation upon velopharyngeal movements with a constant intensity level of 10 V. □—□ Stimulation of the vagus nerve. ●—● Stimulation of the glossopharyngeal nerve. ○—○ Stimulation of the facial nerve.

Response to stimulation of the glossopharyngeal fell between the vagus and facial nerves. "Complete closure" by unilateral stimulation was seen only with stimulation of the vagus nerve.

Movements in a plane in the upper part of the nasopharynx were observed
when the facial nerve was stimulated, but upward movements of the velopharyngeal structures were noted when the vagus and/or glossopharyngeal nerves were stimulated. Thus, movement patterns elicited by stimulation of the facial nerve were different from those seen when either the vagus or glossopharyngeal nerve was stimulated.

5. Effects of stimulation on two nerves simultaneously

Combined stimulation of the facial and glossopharyngeal nerves was carried out. Stimulation to the glossopharyngeal nerve was held constant (50 Hz, 6v) while various levels of stimulation were provided to the facial nerve. As shown in Figure 13, the velopharynx closed in the double-fold form. Results indicate a difference in the site of movements when the facial and glossopharyngeal nerves are stimulated simultaneously. That is, movements were produced at a higher level in the velopharynx than was true when the glossopharyngeal nerve alone was stimulated. However, there was evidence of additive effects upon movement only in a few cases. (See Figure 15.)

Combined stimulation of the facial-vagus and the vagus-glossopharyngeal nerves was carried out in the same way as described above. A difference in the site of movements as compared to stimulation to each nerve singly was observed as is shown in Figure 14. These latter findings were recognized in most cases, but additive effects of velopharyngeal movements by combined stimulation could be evoked in only a few cases. (See Figure 16.)

Discussion

In the present investigation, the rhesus monkey was chosen as the experimental animal. Bosma and Flecher (1961) reported similarity in the basic

![FIGURE 13. Velopharyngeal movements with combined stimulation to the facial-glossopharyngeal nerves. (Additive effects could not be elicited in most cases.)](image)
FIGURE 14. Velopharyngeal movements with combined stimulation to the: A: Facial-vagus nerves. B: Vagus-glossopharyngeal nerves. (Additive effects could not be elicited in most cases.)

FIGURE 15. Velopharyngeal movements by combined stimulation to the facial-glossopharyngeal additive effects (elicited in only a few cases.)

arrangement of the pharynx in the cat, the dog and the monkey with all of these animals having a relatively spacious pharynx. However, they also noted that the craniovertebral angle was less obtuse in the monkey than in the other animals. Therefore, velopharyngeal movement patterns in dogs or cats would probably
differ more markedly from those seen in human beings than would the movement patterns of the monkey.

In this study, velopharyngeal movement was most active with stimulation to the vagus, then the glossopharyngeal, and finally, the facial nerve. These findings correspond to the order of response previously reported by Nishio, et al., (1976) on the basis on an EMG study.

The pattern of velopharyngeal movement observed with stimulation to the facial nerve was quite different from that seen with stimulation to either the glossopharyngeal or the vagus nerve. Considering the degree and pattern of movements seen, it is assumed that the facial nerve controls finer movements of the velopharyngeal muscles than do the glossopharyngeal or the vagus nerve.

Matsuya, et al., (1974) observed velopharyngeal movements during various activities in normal subjects by use of the fiberscope and reported that, during swallowing, closure was constrictive and that the entire pharyngeal wall and surrounding structures moved toward the midline.

On the other hand, during phonation and blowing, there was a point of contact or an osculating plane between the velum and the lateral and posterior pharyngeal walls. Calnan (1953) and Bloomer (1953) have noted that the sphincteric closure occurring during swallowing is quite different from the closure seen during speech. The present study shows that the movements seen when stimulating the vagus or glossopharyngeal nerve are similar to those seen in swallowing in human beings. On the other hand, the patterns occurring with stimulation to the facial nerve resemble those of phonation. Podvinec (1952) suggested that coordination of the muscles of the pharynx, palate and esophagus for swallowing was controlled by the glossopharyngeal and vagus nerves.

FIGURE 16. Velopharyngeal movements with combined stimulation to the: A: The facial-vagus. B: The vagus-glossopharyngeal. (Additive effects could be elicited in only a few cases.)
However, for speech, he thought that the facial nerve might take the lead in coordinating the movements of the palatal, pharyngeal and facial muscles. In this study, on the other hand, complete velopharyngeal closure could hardly be elicited by bilateral stimulation of the facial nerve. Therefore, it can not be concluded that velopharyngeal movements during phonation are elicited only via the facial nerve. Considering the movements associated with each of the nerves, it seems that impulses via the vagus and glossopharyngeal nerves might take the lead in velopharyngeal movements for phonation and that the facial nerve controls finer adjunctive movements of the velopharynx. However, this question needs to be addressed more precisely in future investigations.

By combined stimulation to the nerves, additive effects of velopharyngeal movements could be elicited in only a few cases. Where there were no additive effects, a double-fold valve was formed. This finding indicates differences in the sites of movement with stimulation of the nerves. That is, the site was lowest when the facial nerve was stimulated, slightly higher with stimulation to the glossopharyngeal, and highest with stimulation to the vagus nerve. Generally, the velopharynx is said to be formed of structures derived from the 1st to 4th branchial arches in embryonic life (Thomas, 1968). Therefore, the differences in the movement sites may be related to the position of the branchial arches in the early stages of development.

As noted in the previous paper (Nishio, et al., 1976), there has been a great deal of disagreement concerning the nature of velar disability in patients with facial paralysis. Mann (1904) and Moritz (1934) both pointed out that some patients with facial paralysis also had velar paralysis. On the contrary, Eichhorn (1917), Falk (1963), and Turner (1889) all reported that velar paralysis had not been recognized in all cases of facial nerve lesions. As shown in the present study, movements elicited by stimulation to the facial nerve were less pronounced than were those associated with stimulation of the vagus or the glossopharyngeal nerve. Therefore, velar disability with facial paralysis will probably be less severe than with lesions of the vagus or glossopharyngeal nerve. Thus, some of the above mentioned investigators may have misjudged velar deficits since velar paralysis associated with facial paralysis can be reasonably explained on the basis of the present study.

The results of this study should prove helpful in understanding certain of the physiological mechanisms involved in velopharyngeal closure and, ultimately, in treating patients with velopharyngeal incompetence such as cleft palate or velar paralysis.

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