An Electromyographic Study of the Musculus Uvulae

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The musculus uvulae and the levator veli palatini muscle were studied with electromyography (EMG) in three normal young adult subjects. Patterns of EMG activity for the musculus uvulae were similar to those of the levator veli palatini for all three subjects. When differences in EMG activity between the two muscles were found, the tasks did not involve speech. The presence of the musculus uvulae along the nasal aspect of the velum may be important in filling the space between the elevated velum and the posterior pharyngeal wall. In addition, the musculus uvulae may function to modify stiffness of the tissue adjacent to the insertion of the levator veli palatini and to produce extension of the velum.

From anatomic evidence it is generally acknowledged that the levator veli palatini muscle is of a size and alignment to play a primary role in velopharyngeal closing movements (Kuehn, 1979). This view has been supported by electromyographic (EMG) data showing this muscle is active consistently in relation to velar closing movements (Fritzell, 1969; Bell-Berti, 1976). However, other muscles of the velopharyngeal complex, specifically the palatoglossus, the palatopharyngeus, and the superior pharyngeal constrictor, also show activity related to velopharyngeal movements and may be involved in positioning the velum during speech (Seaver and Kuehn, 1980; Kuehn et al, 1982). In contrast, the tensor veli palatini does not have an anatomic alignment that is advantageous in velar movements and its lack of involvement in speech is supported by EMG evidence (Fritzell, 1969).

Relatively little information exists concerning the function of the musculus uvulae. The musculus uvulae is a paired muscle, with the two bundles adjacent to each other and running along the midline near the nasal surface of the velum. In normal adults, the most cohesive portion of the muscle is superficial and perpendicular to the levator sling (Azzam and Kuehn, 1977). The musculus uvulae does not have a lengthy tendinous origin or insertion, and it does not connect to any tissue external to the velum. As such, forces from the musculus uvulae have not been considered as contributing to velopharyngeal closing movements.

Historically, the function usually ascribed to the musculus uvulae is that of elevating the uvula or shortening the velum (Hollinshead, 1954; Sicher and DuBrul, 1975). The significance of this action for speech is unclear. Logically, however, shortening the velum might oppose velopharyngeal closing movements. In contrast, the endoscopic descriptions (originally those of Pigott, 1969) of the nasal surface of the velum have been used to suggest that the bulging on the nasal surface, presumably produced by contraction of the musculus uvulae, aids velopharyngeal closure. The bulge on the nasal surface of the velum would extend this surface further toward the posterior pharyngeal wall. In this regard, the musculus uvulae could be considered to be a space-occupying structure positioned dorsally along the velum and moved by other muscles acting on the velum in which the musculus uvulae is embedded.

The space-occupying function of the muscu-

Presented at the 41st Annual Meeting of the American Cleft Palate Association, Seattle WA, 1984.

This study was supported in part by PHS Research Grants DE 05837 from the National Institute of Dental Research, and NS-07555 from the National Institute of Neurological and Communicative Disorders and Stroke.

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lus uvulae is supported by gross anatomic as well as endoscopic observations. Azzam and Kuehn (1977) found that in adult cadavers the musculus uvulae bundle measured an average of 3 mm in diameter in a region overlying the sling of the levator veli palatini. Thus, if one assumes that the muscles are roughly cylindrical, and adjusting for 10% shrinkage of muscle as a result of fixation, the cross-sectional area of both musculus uvulae bundles in the living adult would be about 16 mm^2. It would appear that in the absence of a structure of that size and not replacing it with other material, such a void may lead to, or exacerbate, already existing velopharyngeal closing difficulties. Endoscopic observations have revealed that in individuals diagnosed as having occult submucous cleft palate, there often is a midline trough instead of a bulge along the nasal surface of the velum. It has been suggested that this trough, presumably caused by hypoplasia of the musculus uvulae, is related to hypernasal speech (Pigott et al, 1969; Croft et al, 1978; Lewin et al, 1980).

If the musculus uvulae does function as a space-occupying structure, a question remains as to whether the *activated* muscle might increase its diameter in the region overlying the levator sling, thereby possibly becoming even more effective in filling the space between the velum and posterior pharyngeal wall. In this regard, the muscle may function as a variably active space-modifying structure and not just a passive space-filling material. A test of this possibility would be to determine whether the musculus uvulae changes its diameter during speech or other activities. Unfortunately, given current methodology, it is not possible to measure muscle diameters in situ without removing surrounding tissue, which is not possible in live human subjects. However, because the musculus uvulae is so near the mucosal surface of the velum, one might make inferences about the underlying muscle configuration based on observations of the external surface.

Boorman and Sommerlad (1985b) simulated velar elevation without manipulating the musculus uvulae in fresh adult cadavers. They were able to produce the convexity typically attributed to the musculus uvulae bulging along the nasal velar surface with bilateral traction of the levator muscle alone. The authors also used a nerve block procedure to determine the effects of the musculus uvulae on speech and on the appearance of the nasal surface of the velum. The lesser palatine nerve, which presumably innervates the musculus uvulae (Broomhead, 1951), was anesthetized. During speech, no visible difference was observed in the "nasal convexity" or "ridging" of the velum compared with the control condition without nerve block. The findings of Boorman and Sommerlad suggest that the musculus uvulae may not change its diameter markedly in association with velar movements.

If the musculus uvulae is important as a space-occupying structure but its diameter does not vary appreciably during speech, might the muscle serve other temporally dependent functions? Electromyographic data may be important in helping to answer this question. Although a number of investigators have studied velopharyngeal muscles electromyographically (Kuehn et al, 1982), we know of no EMG data obtained from the musculus uvulae. Therefore, the purpose of this study was to record EMG activity from the musculus uvulae obtained during a variety of gestures involving velopharyngeal movements to answer the following questions:

1. Is the musculus uvulae active during speech?
2. If the musculus uvulae is active during speech, is such activity related in a systematic way to activity of the major muscle of velar elevation, the levator veli palatini?

METHOD

Subjects

The subjects were three young adults, two male and one female. None of the subjects reported a history of speech, language, hearing, or craniofacial disorders.

Procedures

Electromyographic activity was recorded from the musculus uvulae and the levator veli palatini during a series of speech and nonspeech tasks. All of the EMG procedures and all of the tasks were repeated for two of the subjects in a second session that took place at a later date. This resulted in a total of five experimental sessions for three subjects. High-speed lateral-view cineradiography also was used to monitor velar movements during the first experimental sessions for all subjects. However, the cineradiographic data are not included in this report.

Tasks

The speech sample included the sounds [i], [a], [u], and [s] produced in isolation and sustained for about 1 second; the words [mam],

[pap], and [ɪŋk]; and the sentence "No man pampered the puppy." Five tokens of each speech sample were produced by each subject in each session. The nonspeech tasks included sniffing, yawning, and blowing. Three tokens of each were produced in each session. The speech and nonspeech tasks were randomized, and a different sequence was used for each subject. Spontaneous swallowing and laughing also were noted on the cineradiographic films and EMG signals.

Electrode Placement

A specially designed needle transport system described by Kuehn et al (1982) was used to insert hooked-wire electrodes into the musculus uvulae. The insertion end of the transport was a 30-gauge hypodermic needle. A 100 μm Teflon-coated stainless steel wire was threaded through the needle and transport tube. The Teflon was removed 1 mm from the end of the wire, and the tip of the wire was bent to form a hook.

The nasal cavities were anesthetized using cocaine. Care was taken to restrict the application of the anesthesia to the nasal passage and to refrain from applying it within the velopharyngeal region. At least 15 minutes elapsed between the application of the anesthesia and the recording session.

Following anesthetization of the subject, the transport tube was inserted into one nasal cavity. When the tube was beyond the posterior nasal spine, it could be viewed with a Hopkins rod (rigid endoscope) that had been inserted through the other nasal cavity. The subject was instructed to sustain an [s]. The tip of the needle was inserted into the bulge of the musculus uvulae on one side through the nasal mucosa to a depth of approximately 2 mm. The needle and transport were then removed, leaving the wire inserted within the muscle tissue. An attempt was made to align the needle with the long axis of the musculus uvulae at a point overlying the levator sling. The second wire of the differential electrode pair was inserted to a similar depth but about 4 mm more posteriorly than the point of entry for the first electrode.

Hooked-wire electrodes intended to measure levator veli palatini activity were inserted perorally. The same size stainless steel wire was threaded into 1-inch 30-gauge needles. The ends were stripped and bent in the same manner. The needles were inserted into the dimple in the region of the velar knee to a depth of approximately 10 mm. An attempt was made to place the wires approximately 4 to 5 mm apart.

Instrumentation

The electrode wires were connected to Grass HIP511 high-impedance probes and Grass P511 alternating current (AC) amplifiers. The amplified signals were high-pass filtered at 30 Hz and recorded on a Hewlett-Packard 3968A FM tape recorder with the audio signal from a Sennheizer close-talk microphone. At a later time, the recorded signals were displayed on a Honeywell 1858 Visicorder. Prior to display, the EMG signals were rectified and smoothed with a time constant of 200 ms for the isolated sustained sounds and 30 ms for all other speech and nonspeech tasks.

The signals associated with the sentence speech task were used to obtain cross-correlation functions between the musculus uvulae and the levator veli palatini. A Data Precision 6000 signal analysis system was used for the procedure. For this analysis, the signals were rectified and smoothed with a 30-ms time constant, then 512 points were sampled and compared at 5-ms intervals. This analysis determined the extent to which the envelopes of the levator and uvular EMG signals were similar.

Results

Musculus uvulae activity was observed for all speech tasks and for all subjects throughout every recording session. Therefore, the results clearly show that the muscle is active during speech. Of particular interest is the finding that activity of the musculus uvulae often paralleled that of the levator veli palatini. This was true not only for individual words, as illustrated in Figure 1, but also for sentences, as illustrated in Figure 2.

Usually, activity patterns for the musculus uvulae and levator veli palatini were similar, regardless of the task. In those cases that involved a clear difference, the difference occurred for nonspeech and not speech tasks. Figure 3 shows examples of such differences that occurred during swallowing, sniffing, and laughing. The observation that such differences were found indicates that the two electrode pairs were not measuring activity from the same motor units.

Cross-correlation functions were calculated to determine how closely activity patterns between the musculus uvulae and the levator veli palatini mirrored each other. Table 1 presents the peak values in the cross-correlation functions that were calculated for the sentence "No man pampered the puppy." The highest coef-

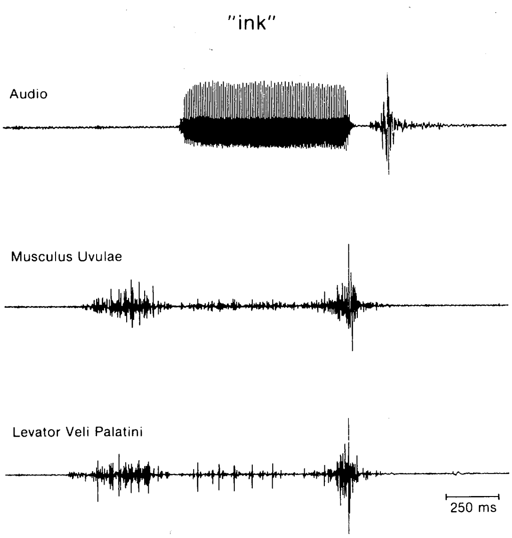

FIGURE 1 EMG activity patterns for the musculus uvulae and levator veli palatini recorded during the word "ink." A close similarity between patterns is shown (Subject 1, Session 2).

ficients in the cross-correlation functions were always found when the two signals were aligned in time; thus, the values given in Table 1 correspond to Pearson product moment correlation coefficients. In all cases, the correlation coefficients were relatively high.

DISCUSSION

The findings that the musculus uvulae is active during speech and that its activity varies in concert with that of the levator veli palatini suggest that the musculus uvulae serves a dynamic function that may be important in velopharyngeal closure activity. We propose that in addition to its probable function as a space-occupying tissue mass, the musculus uvulae serves as (1) a stiffness-modifying mechanism and (2) a velar extensor. For both of these latter functions, contractile tissue, as opposed to a passive tissue mass, is required.

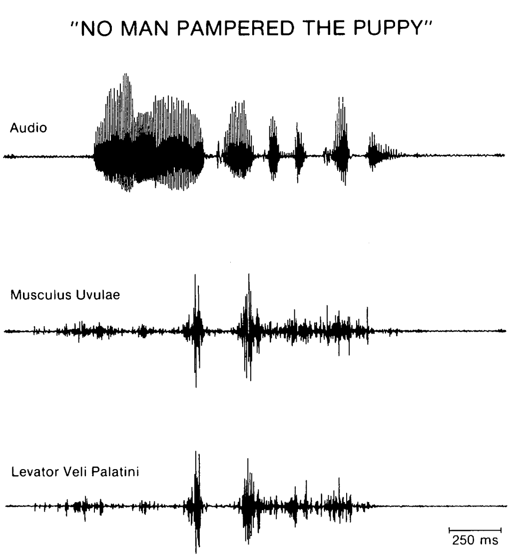

FIGURE 2 EMG activity patterns for the musculus uvulae and levator veli palatini recorded during the sentence "No man pampered the puppy." A close similarity between patterns is shown (Subject 1, Session 2).

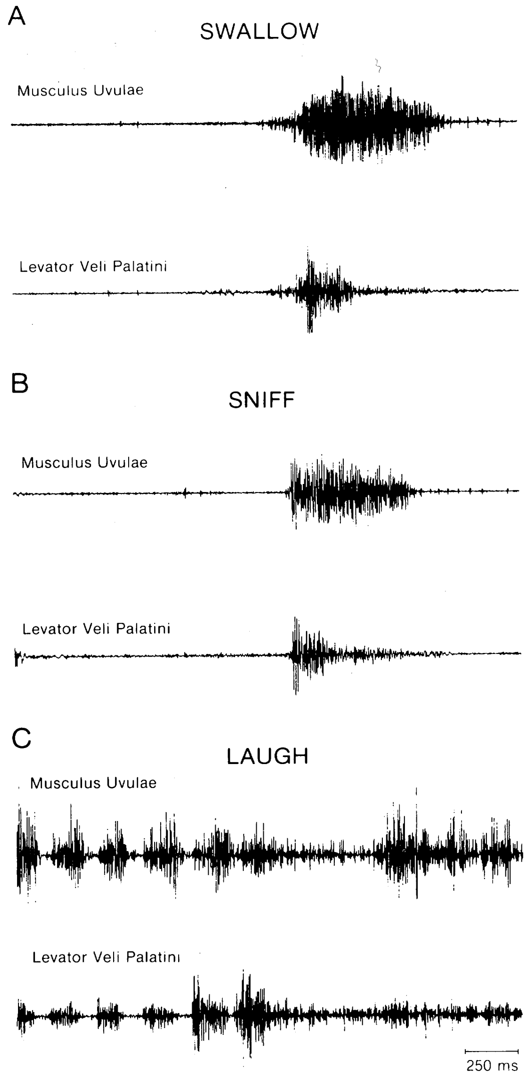

FIGURE 3 EMG activity patterns for the musculus uvulae and levator veli palatini recorded during swallowing, sniffing, and laughing. Dissimilar patterns are shown. *A*, Subject 1, Session 1. *B*, Subject 1, Session 1. *C*, Subject 2, Session 1.

The Musculus Uvulae As a Stiffness-Modifying Mechanism

Levator veli palatini muscle fibers are located deep to the musculus uvulae in the middle 40%

TABLE 1 Cross-Correlation Functions in Patterns of the Musculus Uvulae and the Levator Veli Palatini*

		Token				
Subject	*Session*	*1*	*2*	*3*	*4*	*5*
1	1	0.63	0.67	0.79	0.76	0.73
1	2	0.99	0.99	0.99	0.99	0.99
2	1	0.96	0.95	0.96	0.96	0.93
2	2	0.96	0.96	0.95	0.96	0.96
3		0.80	0.91	0.89	0.85	0.87

* Cross-correlation functions comparing EMG activity patterns between the musculus uvulae and the levator veli palatini muscle are given for the sentence "No man pampered the puppy." Five tokens of the sentence were obtained per session. Subjects 1 and 2 were tested in two separate sessions, and Subject 3 tested in only one session.

of the velum as measured from the anterior to posterior margin, excluding the uvula proper (Boorman and Sommerlad, 1985a). Therefore, the levator muscle is ideally situated to transfer its force to the musculus uvulae and to the nasal surface of the velum. If the top layer of the velum, including the musculus uvulae, were too compliant, the levator muscle might simply distort the velum by stretching the top layer upward instead of moving the entire velum. Thus, the velum must be just stiff enough to avoid distortion; at the same time, however, it must be compliant enough to allow stretching to reach the posterior pharyngeal wall.

Several investigators have studied elongation of the elevated velum (Mourino and Weinberg, 1975; Simpson and Colton, 1980; Simpson and Chin, 1981). The normal velum can be stretched on the order of 5 to 20% or greater, depending on the person's age and task performed. Quite likely, however, stiffness variability exists along the length of the velum. Velar stretch has been demonstrated in both the anterior as well as posterior half of the velum, although the posterior half, on the average, appears to provide the greater yield.

The musculus uvulae appears to be in a favorable position to provide stiffness along the midlength of the velum, while at the same time allowing stretch in the most anterior and most posterior regions of the velum. This appears to be so because musculus uvulae fibers do not traverse the entire length of the velum. Contrary to a common misconception perpetuated by some anatomy text authors, the musculus uvulae does *not* originate at the posterior nasal spine; rather, it originates discretely posterior to the hard palate and becomes diffuse in the uvula proper (Azzam and Kuehn, 1977).

In its most cohesive form, the musculus uvulae is located at about 25 to 60% along the length of the velum (Kuehn and Kahane, 1986). It is in this region where the muscle could provide its major longitudinal stiffness. Approximately the most anterior 25% and the most posterior 40% of the velum would appear to allow greater stretch than the midlength. Collagenous arches extending from the musculus uvulae to the oral aspect of the velum (Langdon and Klueber, 1978) may be important in bonding the layers of the velum so that the levator veli palatini would not lift the top layer, including the musculus uvulae, separately from the bottom layer.

A consistent observation was that musculus uvulae EMG activity increased and decreased in parallel with the levator veli palatini muscle activity during speech. This observation suggests that the musculus uvulae may change its stiffness, depending on velar position or on the force placed on the velum by the levator. It is not clear why stiffness necessarily would vary from a velar-lowered to a velar-elevated position. It appears that for the purpose of avoiding deformation of the velum, a constant and high level of stiffness would be adequate. It is possible that variable stiffness may be advantageous in avoiding muscle fatigue that could result if the musculus uvulae contracted at a continuous and high level of activity. Thus, with a lowered velum, velar stiffness is not necessary and the musculus uvulae can be inactive, thereby conserving energy.

Variable stiffness also might be related to neurologic expediency. In many neuromotor systems, it has been hypothesized that coordinative structures involve specific interdependencies among muscles (Kuehn et al, 1982). It may be that such a mechanism operates to send parallel signals to the levator veli palatini and to the musculus uvulae. When one muscle increases its activity, and thus its stiffness, the other muscle also does.

Resolution of the uncertainty of why stiffness of the velar midlength would vary instead of remaining constant awaits further investigation. However, we feel that the possible function of the musculus uvulae in extension of the velum, to be discussed next, provides the most compelling explanation of why the activity of this muscle would be modified in parallel with that of the levator veli palatini.

The Musculus Uvulae As a Velar Extensor

In his description of normal velopharyngeal closure movements as observed through an endoscope, Pigott et al (1969) stated that "sometimes the levator ridge hardly seemed to contact the pharyngeal wall, but the contracting musculus uvulae flipped the passive free margin of the palate back into contact, where it stuck momentarily to the pharyngeal wall, before dropping away (as the levator relaxed)." Although these investigators did not study the musculus uvulae electromyographically, the data of the present study lend support to a "flipping" or extensor role for the musculus uvulae.

The proposed extensor role of the musculus uvulae could be characterized in different ways. Two possibilities are that it acts as (1) a flexible beam or (2) a pulling force about a boundary. For both models, it is important to note that the musculus uvulae lies close to the nasal surface of the velum and it is the only muscle whose fibers course in the direction of the long axis of the velum. Thus, it is the only muscle that, upon contraction, can exert a longitudinal compressional force on the upper portion of the velum.

Figure 4 shows the flexible beam model. Each of the beams consists of two layers. Figure 4A shows a beam with no forces acting on it. Figures 4B through 4D show beams in which compressional forces are exerted on the top layer only. It can be seen in Figure 4B that the ends of the beam curl upward. If one end of a straight beam is fixed, as in Figure 4C, and the top layer is compressed, the unfixed end will curl upward as shown. If one end of a curved beam is fixed and the top layer is compressed, as shown in Figure 4D, the unfixed end will curl upward and the beam will tend to straighten.

The proposed extensor role of the musculus uvulae is similar to the model shown in Figure 4D. The musculus uvulae lies in the upper half of the curved velum. When it contracts, it exerts a compressional force along the nasal side of the velum. Because the oral side of the velum is relatively compliant, contraction of the musculus uvulae would tend to straighten the curved velum.

Figure 5A shows tracings of two cineradiographic film frames. The solid lines depict a velar-lowered situation. The dashed lines show a fully elevated velum with contact along a considerable length of the velum against the posterior pharyngeal wall. The elevated velum of Figure 5B is a hypothetical configuration of the velum that might occur if the musculus uvulae were not contracting and therefore not providing a longitudinal compressional force in the top layer of the velum. With a mechanism such as that described for Figure 4D, it may be that the "straightening" force provided by the musculus uvulae moves the posterior half of the velum into better contact as that shown in the actual elevated configuration of Figure 5A.

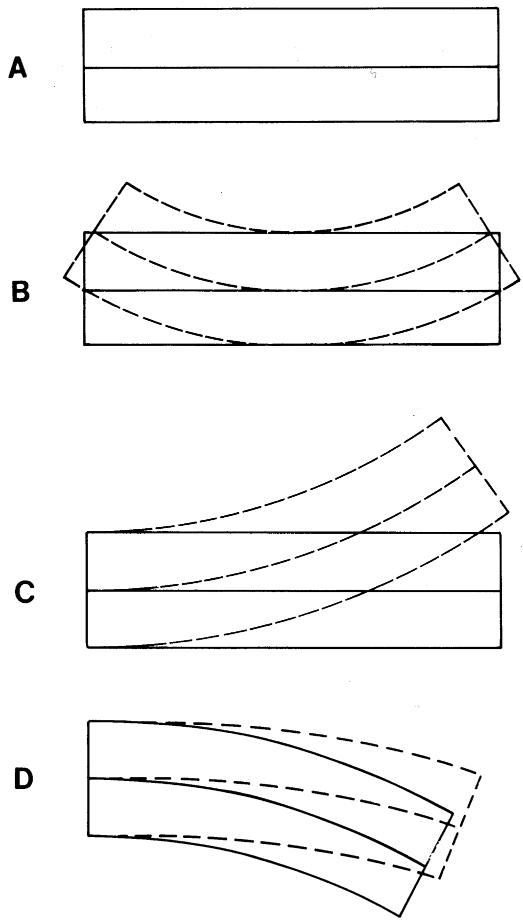

FIGURE 4 Two-layered flexible beam model. *A*, equilibrium, no forces acting upon the beam. *B*, beam free at both ends, compressional force acting upon the top layer only causes curling upward of the beam at both ends. *C*, beam fixed at left end, free at right end; compressional force in top layer only causes curling upward of the beam at the free end. *D*, curved beam fixed at left end, free at right end; compressional force in top layer only causes upward movement of free end, thus tending to straighten the beam.

Boorman and Sommerlad (1985a) studied the effects of pulling on the levator veli palatini muscles in cadavers without manipulating the musculus uvulae. They observed an elevated velar configuration that was described as "more acute" than the elevated velum of live subjects. That observation is analogous to the elevated velum shown in Figure 5B, in which the musculus uvulae is not contracting, and is in contrast to the elevated velum shown in Figure 5A, in which the musculus uvulae is contracting. Therefore, it is argued that a tighter and more extensive velopharyngeal seal would occur with the musculus uvulae contracting than with the musculus uvulae not contracting.

A second method of viewing the possible extensor role of the musculus uvulae is more sim-

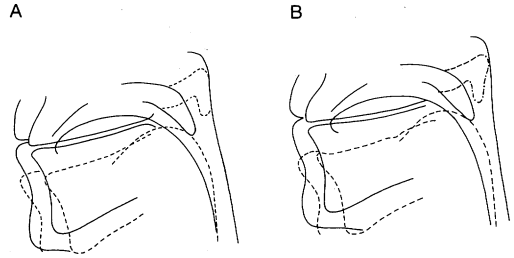

FIGURE 5 Tracings of cineradiographic film frames of a normal subject. Solid lines show the velum lowered configuration. *A*, dashed lines show velum elevated, making extensive contact with the posterior pharyngeal wall. *B*, dashed lines are identical to the dashed lines of *A*, except that the posterior half of the velum has been replaced with a hypothetical portion shown by the dotted-dashed line segment. The hypothetical segment is meant to depict the elevated velum *without* contraction of the musculus uvulae, resulting in little or no contact between the velum and posterior pharyngeal wall.

ilar to that of other extensor muscles of the body. For example, the extensor pollicis longus, which originates in the forearm, sends a tendon across the wrist to attach to the distal phalanx of the thumb. Upon contraction of this muscle, the thumb is extended. In contrast to the structure of other extensor muscles, however, the musculus uvulae does not possess a tendon that extends across a joint. Instead, the muscle extends across the dorsal aspect of the levator sling. The levator sling may act as a boundary around which the musculus uvulae can exert a force. An extensor mechanism of this type is illustrated in Figure 6.

Figure 6 is a tracing of the midsagittal outline of a cadaver velum that was partially elevated. A hypothetical levator veli palatini muscle and musculus uvulae have been sketched inside the velar outline. The top arrow represents the force generated by the musculus uvulae contracting toward the more fixed end of the velum, that is, toward the aponeurosis and hard palate. The arrow beneath the uvula represents the direction of movement of the posterior portion of the velum. The force would cause the velum to move toward the posterior pharyngeal wall.

The variable EMG activity found in this study suggests that the extensor force provided by the musculus uvulae allows variation in the extension of the velum. High activity levels of the musculus uvulae in concert with those of the levator veli palatini would help to provide a more complete velopharyngeal seal.

Clinical Implication

Can the function of a missing or hypoplastic musculus uvulae be restored surgically? It appears that if the musculus uvulae were to serve as a passive space-occupying structure, compliant implant material or repositioning noncontractile tissue might suffice. However, the effects of musculus uvulae activity on velar stiffness and extension, as proposed in this report, would not occur. One surgical strategy might involve transferring muscle tissue, as opposed to noncontractile compliant substances, to the nasal aspect of the velum. If the transferred muscle fibers were arranged longitudinally, their action might stiffen the midlength of the velum as well as extend the velum, as depicted in Figure 6.

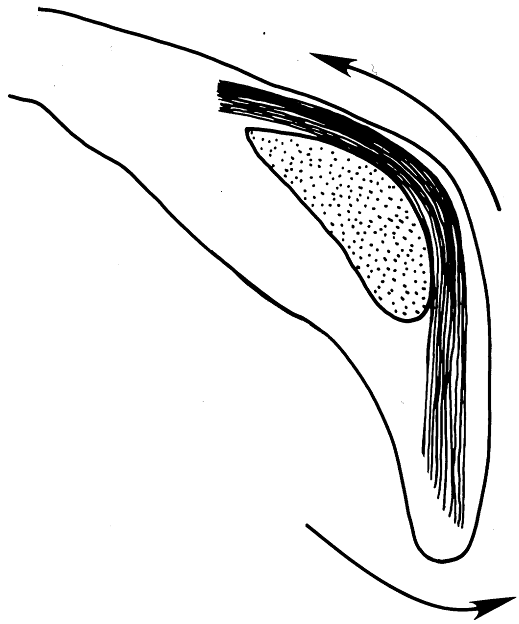

FIGURE 6 Tracing of the mucosal outline of a sagittal section from a normal adult cadaver. Stippled area represents the position of the levator veli palatini cut in cross section. Adjacent lines represent longitudinal fibers of the musculus uvulae. Top arrow represents the force exerted by the musculus uvulae in relation to the levator sling, which serves as a boundary. Arrow beneath the uvula represents the direction of velar movement toward the posterior pharyngeal wall.

A final note pertains to scar tissue. From a mechanical perspective, scar tissue is a relatively stiff substance. If the scar tissue extends too far anteriorly or posteriorly, this can limit the ability of the velum to stretch. The result is that the levator veli palatini would have to exert more force to achieve closure if indeed the range of movement would allow closure. Therefore, it seems that both the degree and location of stiffness along the velar length may be important factors in achieving proper velopharyngeal closure.

In conclusion, varying musculus uvulae activity may be an important aspect in velopharyngeal functioning. Additional research is necessary to further substantiate the possible role of the musculus uvulae in modifying stiffness and velar extension. Surgical techniques then might be designed to take these factors into account more effectively.

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