Role of the pharyngeal plexus in initiation of swallowing

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SINCLAIR, William J. Role of the pharyngeal plexus in initiation of swallowing. Am. J. Physiol. 221(5): 1260-1263. 1971.—In preparation for stimulation studies, 22 cats were electrolytically decerebrated. The intact cephalic branch of the pharyngeal branch of the vagus nerve (22a) was electrically stimulated to determine its role in the initiation of the swallowing reflex. Comparative data were recorded for the superior laryngeal nerve (SLN) and the glossopharyngeal nerve (GPN). Stimulation was noted visually and recorded electromyographically. Stimulation of branch 22a resulted in swallowing in six cases out of 18. Chronic ax and optimum frequency of stimulation for swallowing for branch 22a were 0.11 msec and 30-50 cycles/set, respectively. Afferents for swallowing were shown to be distributed among pharyngeal branches of the GPN. Stimulation studies indicated that the GPN is the primary afferent for swallowing initiated from the pharynx; branch 22a played a minor role. A composite schema is presented of those nerves that were found to contain afferents for swallowing. Small and larger sized fibers are suggested as interacting centrally to explain the observation that electrical stimulation of the SLN elicits swallowing more readily than stimulation of the GPN.

innervation of pharynx; reflex swallowing; pharyngeal reflex

REFLEX SWALLOWING may be initiated by mechanical or water stimulation of appropriate sites innervated by the trigeminal (TN), the glossopharyngeal (GPN), and the vagus nerves. Suitable electrical stimulation of the TN (7, 21), the GPN (3, 7, 14, 21), the superior laryngeal nerve (SLN) (3, 7, 9, 14, 15, 21), the recurrent branch (7, 15, 21), and the accessory recurrent branch (15) of the vagus nerve will also result in swallowing. The SLN is the primary afferent for swallowing initiated from the larynx, and the GPN serves a similar role for the pharynx. The pharyngeal branch of the vagus nerve (designated branch 22 by Stowell) has been reported to play a minor role as an afferent for the swallowing reflex initiated from the pharynx of the cat (16). The purpose of this study was to investigate the reflex activity resulting from electrical stimulation of the cephalic branch of the pharyngeal branch of the vagus nerve (22a). The other components of the pharyngeal plexus of nerves were also explored to determine the role played by each as an afferent for the swallowing reflex.

METHOD

In preparation for stimulation studies, 22 adult cats were electrolytically decerebrated at the level of the superior colliculus. The preparations were made in a fashion similar to those described in a previous study (16). In order to differentiate swallowing from other reflex activity, electromyographic recordings were made from mylohyoid, geniohyoid, and cricothyroid muscles. In addition, changes in intratracheal pressure were monitored by a volumetric pressure transducer (Grass PT5) attached to the trachea. Nerves under investigation were bathed in light paraffin oil and stimulated intact with bipolar electrodes fitted with a polyethylene sleeve. Nerves were excited using a square-wave stimulator (Grass S4) isolated from ground. In order to avoid shorting through tissue fluid around the nerves, the light paraffin oil was aspirated and replenished every 2 or 3 min. Except in those studies to determine the level of excitation reached in the swallow center when branch 22a and the SLN were selectively stimulated, 15 sec were allowed between successive stimulations in order to prevent central buildup of excitation. The resulting reflex activity was suitably amplified and photographed on 35 mm paper. The cephalic branch of the pharyngeal branch of the vagus nerve (Fig. 1, 22a) was investigated in 22 animals to describe its role in the initiation of reflex swallowing. Comparative data were also obtained from the SLN and GPN. In selected animals, data were obtained on the role played by the caudal ramus of the GPN which anastomoses with the pharyngeal plexus of nerves (Fig. 1, GPN 21), the small branches of the GPN which form a plexus over the pharyngeal mucosa (Fig. 1, 19b), the terminal branches of the GPN as it arborizes to supply the papillae on the dorsal surface of the base of the tongue (Fig. 1, 19a), the pharyngeal branch of the vagus nerve (Fig. 1, Vagus 22), and the caudal branch of the pharyngeal branch of the vagus nerve (Fig. 1, 22b).

Strength-duration curves and chronaxie determinations were made for the SLN, GPN, and branch 22a in four animals. Optimum and limiting frequencies were also determined for branch 22a. The optimum frequency was assessed by the brevity of the latent period to the initiation of the first swallow as well as the shortest interval encompassing the initiation of the three successive swallows. Branch 22a and the SLN were selectively stimulated in one animal to evaluate each nerve's contribution to the level of excitation in the swallow center. A threshold stimulus to the SLN, which resulted in a series of three swallows, was followed by a subthreshold stimulus applied to branch 22a at time intervals of 0, 5, 10, and 20 sec after the last re-
SWALLOWING

recorded swallow. The procedure was then reversed and a subthreshold stimulus was applied to the SLN after threshold stimulation of branch 22a.

RESULTS

In 18 animals, electrical stimulation of branch 22a resulted in increased motor activity limited to the superior pharyngeal musculature and a slight change in the depth of respiration. Reflex swallowing was noted in addition to the observed motor and respiratory effects in only six animals. Marked respiratory reflexes such as coughing were not observed. In two animals, electrical stimulation resulted in respiratory movements similar to sniffing.

Swallowing initiated by electrical stimulation of branch 22a at 0.2-0.5 v with square pulses of 1 msec duration was characterized by an initial swallow of short latency (1.5 sec). Sequential swallowing activity could be elicited but was not consistent as a finding for the SLN or the GPN. "Afterswallowing" activity was not recorded for branch 22a when electrical stimulation was terminated. These data are summarized in Table 1. Electrical stimulation of branch 22a at higher voltages (2.6 v) than those required for swallowing did not result in marked initial inspirations or coughing. Limb movements and vomiting were occasionally noted.

The optimum frequency of stimulation of branch 22a for swallowing at 0.2-0.5 v with square pulses of 1 msec duration was found to be 30-50 cycles/sec. Table 1 summarizes the results of stimulation for swallowing within and beyond the optimum frequency range. Sporadic swallowing could be recorded when branch 22a was stimulated as low as 10 cycles/sec and as high as 300 cycles/sec. The swallowing reflex fell off sharply below 15 cycles/sec and above 100 cycles/sec. The limiting frequencies were therefore determined to be 15 and 100 cycles/sec.

Electrical stimulation of branch 22b resulted in sporadic swallowing activity; the observed increase in motor activity in this instance was limited to the muscles of the lower pharynx and larynx. In four animals examined, two showed swallows when branch vagus 22 was stimulated electrically, but all demonstrated increased motor activity in the pharynx and larynx.

Electrical stimulation of the SLN at 0.2-0.5 v with square pulses of 1 msec duration initiated reflex swallowing in all 15 animals examined. The average latency to the first recorded swallow was 4.0 sec and was much longer than that recorded for branch 22a (1.5 sec). The time interval required to encompass the initiation of three successive swallows (9.0 sec) was approximately the same as that for branch 22a. Consistently, sequential swallowing activity was more readily elicited from the SLN. These data are summarized in Table 1. Electrical stimulation of the SLN at higher voltages (2.6 v) than those required for swallowing was characterized by marked initial respiratory reflexes and coughing. Limb movements and vomiting were occasionally noted.

Electrical stimulation of the GPN at 0.5 v with square pulses of 1 msec duration elicited swallowing activity in 19 animals; however, reflex swallowing was evoked with much greater difficulty than with the SLN or branch 22a. In only two animals could no swallowing activity be elicited. When swallowing activity was recorded, the latency to the first swallow and the time to initiate three successive swallows was much longer than for the SLN or branch 22a (see Table 1). Sequential and afterswallowing activity was a consistent finding for the GPN. Electrical stimulation of the GPN at higher voltages (2.6 v) than those required for swallowing was characterized by marked initial respiratory reflexes often accompanied by limb movements. Occasionally, vomiting or coughing was also recorded.

Electrical stimulation of branch 19a and 19b in the three and five animals examined respectively resulted in swallowing activity in all instances. Stimulation of branch GPN 21 resulted in swallowing activity in only three of the five animals investigated. The respiratory effects associated with stimulation of these three branches of the GPN were similar to those recorded for the main trunk of the GPN, except that these effects were less intense and no limb movements or coughing were noted. Figure 1 summarizes the results of the stimulation studies; the shaded areas represent probable pathways for the afferent fibers initiating reflex swallowing.

The strength-duration curves for swallowing for the SLN, GPN, and branch 22a are summarized in Fig. 2. Note that the threshold for swallowing initiated by electrical stimulation of the GPN tends to be higher than that of branch 22a or the SLN. For a pulse duration of 1 msec, the threshold for swallowing initiated by stimulation of the GPN (0.4 v) is approximately twice that required for branch 22a or the

TABLE 1. Results of electrical stimulation of SLN, GPN, and 22a for swallowing

<table>
<thead>
<tr>
<th>Nerve Branch</th>
<th>SLN</th>
<th>GPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimum frequency</td>
<td>SLN</td>
<td>GPN</td>
</tr>
<tr>
<td>Outside range, 10-50 cycles/sec</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Optimum range, 30-50 cycles/sec</td>
<td>59</td>
<td>30</td>
</tr>
<tr>
<td>No. of nerves tested</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>No. of recorded stimulations</td>
<td>41</td>
<td>1</td>
</tr>
<tr>
<td>Average latency to first recorded swallow</td>
<td>1.5 sec</td>
<td>2.0 sec</td>
</tr>
<tr>
<td>Range</td>
<td>0.2-6.1</td>
<td>0.2-4.5</td>
</tr>
<tr>
<td>No. of latencies under 1 sec</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Average time interval to initiate 3 swallows</td>
<td>9.0 sec</td>
<td>10.0 sec</td>
</tr>
<tr>
<td>Range</td>
<td>0.2-10.5</td>
<td>2.2-26.9</td>
</tr>
<tr>
<td>No. of stimulations resulting in 3 swallows</td>
<td>20</td>
<td>56</td>
</tr>
<tr>
<td>No. of stimulations resulting in more than 3 swallows</td>
<td>15</td>
<td>36</td>
</tr>
</tbody>
</table>

The strength-duration curves for swallowing for the SLN, GPN, and branch 22a are summarized in Fig. 2. Note that the threshold for swallowing initiated by electrical stimulation of the GPN tends to be higher than that of branch 22a or the SLN. For a pulse duration of 1 msec, the threshold for swallowing initiated by stimulation of the GPN (0.4 v) is approximately twice that required for branch 22a or the
DISCUSSION

Results of this study indicate that the GPN is the primary afferent for swallowing initiated from the pharynx of the cat. This supports the findings of previous investigators (3, 7, 14, 21). In contrast to the GPN, branch 22a clearly plays a minor role in the initiation of reflex swallowing from the pharynx and probably distributes afferents for swallowing via branch vagus 22. The GPN distributes afferents for swallowing mainly through branches 19a and 19b. It is more frequently via branch GPN 21. Branch 19b probably innervates areas corresponding approximately to regions which were found to be most reflexogenetic for swallowing when mechanically stimulated (16). With so much sensory overlap, branch 22a would be expected to add sensory support to these same areas. Since the base of the tongue may (4) or may not (16) produce swallows when mechanically stimulated, results reported here for branch 19a may have been due to spread of excitation to the main trunk of the GPN. Since branch GPN 21 anastomoses freely with the pharyngeal plexus, it is possible that branch 22a may distribute afferents for swallowing via branch GPN 21 to the main trunk of the GPN. In those instances where the GPN was shown to have no swallowing activity, branch 22a would be expected to assume more significance in initiating swallowing from the pharynx. This may explain why bilateral glossopharyngeal rhizotomy has no effect on the swallowing reflex (1).

The optimum and limiting frequencies for swallowing found in this study of branch 22a are comparable with Doty's (3) findings for the SLN of the cat and indicate their probable convergence upon common swallowing half-centers (4).

The differences both in the latent periods to the initiation of the first swallowing reflex and the time interval to include the initiation of three successive swallows elicited by electrical stimulation of the SLN, GPN, and branch 22a are best explained by the central effects of the different sensory afferents excited in each nerve. Pain input has been suggested as masking expected gustatory sensation when the human SLN was electrically stimulated (11). Also, electrical stimulation of the central cut end of the SLN after section of the GPN has been reported as increasing swallowing activity (20). Since observed latencies to the first swallow were shortest for branch 22a, there may be either less central inhibition to swallowing activity when this nerve is stimulated or more excitation centrally in the swallowing center.

Evidence to reject the latter explanation is shown by the lack of observed afterswallowing when electrical stimulation of branch 22a was terminated. Also, the swallowing reflex was not facilitated when a subthreshold stimulus to the SLN was applied following swallowing activity initiated by threshold stimulation of branch 22a.

Because SLN did facilitate the swallowing reflex, and since both the SLN and GPN often gave afterswallowing activity, both nerves are given larger central representation in the swallowing centers than is branch 22a.

Whether small or larger sized fibers are chiefly involved in the swallowing reflex has not been established; both medium (6) and larger sized fibers (12, 17) have been implicated as afferents for the swallowing reflex. The results of chronaxie determinations indicate that the afferent fibers initiating reflex swallowing from the pharynx are probably in the small or medium size range. However, these data must be interpreted with care since histological studies describe the SLN (5, 10, 11) and the GPN (2, 22) as ho-
mogeneous mixed nerves. The shortness of the latency to the first swallow initiated by electrical stimulation of branch 22a and the absence of other reflex activity so typical of the SLN and GPN may indicate that swallowing is initiated by afferent fibers typified in this nerve. Presently available data indicate that branch 22a is composed of sensory fibers chiefly of the small myelinated type (5). However, little data are available on the caliber spectrum of the nerve fibers making up branch vagus 22 and its cephalic (22a) or caudal (22b) ramifications. Since slightly higher voltages were required to elicit coughing instead of swallowing from the SLN and GPN, the nerve fibers serving as afferents for the cough reflex are probably only slightly smaller than the afferent fibers initiating the swallowing reflex. However, the interaction of small and larger sized fibers centrally as presented by Melzack and Wall (8) to explain spinal gating for pain must also be considered. Selective blocking of certain populations of nerve fibers and observing the resultant changes in reflex activity may prove successful in describing more clearly the fiber size serving as the afferent for the swallowing reflex. Histological analysis of the branches 22a, 22b, and vagus 22 is underway and may prove helpful since a knowledge of the caliber spectrum of fibers composing these nerves may also shed some light on the diameter of the fibers involved in swallowing.

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