Deglutitive movement of the tongue under local anesthesia

TATSUYA FUJIKI, TERUKO TAKANO-YAMAMOTO, KEIJI TANIMOTO, JORGE NICOLAS PEREIRA SINOVIC, SHOUICHI MIYAWAKI, and TAKASHI YAMASHIRO. Deglutitive movement of the tongue under local anesthesia. Am J Physiol Gastrointest Liver Physiol 280: G1070–G1075, 2001.—The purpose of the present study was to investigate whether or not sensory input from the tongue affects deglutitive tongue movement. Subjects were seven healthy volunteers with anesthetic applied to the surface of the tongue (surface group) and seven healthy volunteers with the lingual nerve blocked by anesthetic (blocked group). We established six stages in deglutitive movement and analyzed deglutitive tongue movement and the time between the respective stages by cineradiography before and after anesthesia. After anesthesia in both surface and blocked groups, deglutitive tongue movement slowed and bolus movement was delayed. The deglutitive tongue tip retreated in the blocked group. These results suggest that delay of tongue movement by anesthesia causes weak bolus propulsion and that deglutitive tongue tip position is affected by sensory deprivation of the tongue or the region innervated by the inferior alveolar nerve.

DEGLUTITIVE TONGUE MOVEMENT is important for bolus propulsion (6, 7, 17). Although this movement is affected by the variables of the bolus swallowed, such as volume and viscosity (5, 26), no data exist on the neurophysiological control of deglutitive tongue movement. The tongue, having a high density of mechanical receptors, may be the main sensory region for recognizing the variables of the bolus swallowed (25), but this hypothesis has not been fully examined.

The relationship between sensation and function has been investigated using local anesthesia, such as block anesthesia (1, 18, 29) and surface anesthesia (2, 24). Although surface anesthesia incompletely removes sensation (15, 30), block anesthesia completely removes sensation of the region distal to the site of injection. For example, it is possible to extract teeth painlessly by using block anesthesia (3).

The purpose of the present study was to investigate whether sensory input from the tongue affects deglutitive tongue movement. Deglutitive tongue movement was analyzed by cineradiography under conditions of block and surface anesthesia of the tongue.

METHODS

Effect of surface anesthesia on tongue. The subjects were 48 healthy male and female volunteers ranging in age from 23 to 36 yr. They were examined for two-point discrimination and stereognostic ability before and after application of 8% Xylocaine spray or 2% Xylocaine jelly (Fujisawa Pharmaceutical, Osaka, Japan) to the tongue. A filter paper with either 700 mg of 8% Xylocaine spray or 1 ml of 2% Xylocaine jelly was applied to the tongue. The filter paper was a square of 4 × 4 cm, and one of the sides of the square had an arc with a radius of 7.5 cm. Each anesthetic was applied for 5 min. If both 8% Xylocaine spray and 2% Xylocaine jelly were used on the same subject, there was a 24-h interval between applications of the anesthetics. Two-point discrimination was tested using a sliding caliper. The two points of the calipers were placed with equal pressure on the mucosa of the dorsal tongue. The caliper points were closed by 1 mm from 5 mm until the threshold was reached at which two points could be identified. Stereognostic ability was tested using 10 geometric plastic shapes (13). One of the pieces was placed on the subject’s dorsal tongue. The subject was then asked to select the picture (from 10 pictures) that best corresponded to the shape on the dorsal tongue. To aid in identification, the subject was allowed to manipulate the shape in the oral cavity but without making contact with the teeth. These tests were performed before, immediately after, and 5, 10, and 15 min after anesthesia. The percentage of correct responses before and after anesthesia was compared using the Wilcoxon signed-ranks test.

Deglutitive movement of tongue under local anesthesia. Subjects were seven healthy volunteers (ages 23–25 yr) with surface anesthesia (surface group) and seven healthy volunteers (ages 24–29 yr) with block anesthesia (blocked group). They were without remarkable malocclusion and swallowing problems. Ethical approval was granted by the Ethics Committee of Okayama University Dental School in 1996, and all subjects gave informed consent. In the surface group, the surface of the tongue was anesthetized for 5 min with a filter paper with 700 mg of 8% Xylocaine spray. In the blocked group, the bilateral lingual nerve in the pterygomandibular space was blocked by 3.6 ml of 2% Xylocaine and 1:80,000 procaine jelly (line). The costs of publication of this article were defrayed in part by the payment of page charges. The article must therefore be hereby marked “advertisement” in accordance with 18 U.S.C. Section 1734 solely to indicate this fact.
epinephrine (Fujisawa Pharmaceutical). The adequacy of block anesthesia was confirmed by assessing the absence of touch sensation on the dorsal tongue.

For the cineradiographic recording, a lead marker was fixed at the tongue tip, and barium paste (100% wt/vol, Barytensol, Fushimi Pharmaceutical, Kagawa, Japan) was applied to the nasal part of the pharynx of each subject. Each subject was seated on a chair and turned lateral to the face of the image intensifier. The subject’s head was stabilized by a cephalostat attached to the chair. Subjects were each asked to swallow 10 ml of liquid barium diluted 10% (wt/vol) with water, while looking at their own eyes in a mirror. Cineradiographic recordings were obtained at 68–84 keV with a 9-in. image intensifier (Shimadzu, Digitex 2400UX, Kyoto, Japan) and appropriate collimation so that a lateral image could be obtained of the entire mouth and pharynx. A cineradiographic image was recorded on 35-mm imaging film (FujiFilm, MI-CF, Tokyo, Japan) at 30 frames/s. These swallowing events were recorded three times, both before and after surface anesthesia. The swallowing events after surface anesthesia events were recorded three times, both before and after surface anesthesia. The swallowing events after surface anesthesia were recorded within 5 min of 8% Xylocaine spray application.

The cineradiographic image was analyzed in slow motion and by single-frame analysis using the playback capability of a Cineangio projector (Cap35B, Elk, Aichi, Japan). We established the following six stages of deglutition: *stage 1*, contact of the tongue tip with the maxillary incisors or the palatal mucosa; *stage 2*, loss of contact of the dorsal tongue with the soft palate; *stage 3*, passage of the bolus head across the posterior or inferior margin of the ramus of the mandible; *stage 4*, passage of the bolus head through the opening of the esophagus; *stage 5*, passage of the bolus tail across the posterior or inferior margin of the ramus of the mandible; and *stage 6*, passage of the bolus tail through the opening of esophagus. By modification of oral and pharyngeal transit time (21), we measured the times between each stage. Further, after cineradiographic images were traced on tracing paper and standard points and reference planes were established (Table 1), the measurements of deglutitive tongue movement were analyzed at several stages (Fig. 1; Ref. 10). As deglutitive tongue movement was highly variable among different individuals (11), the data recorded three times in each subject were averaged.

Tracings and measurements were performed by one investigator. To evaluate the intraexaminer error in tracing and measurements, one frame of cineradiographic images was traced and measured twice during deglutition in each subject on two separate occasions at least 1 mo apart. The method error was determined by Dahlberg’s formula of $ME = \sqrt{d^2/n}$ where $n$ is the number of subjects and $d$ is the difference

![Fig. 1. Measurements of deglutitive tongue movement. AP–E and AP–PP are distances on the palatal mucosa. MP-MT, MP-MS, PP-PT, PP-PS, C1-D, C1-Me, and PS-I are straight distances. P’-Ti is the shortest distance from the line crossing at a right angle to the palatal plane through PNS to Ti. See Table 1 for further explanation of abbreviations. a: contact of tongue and palate, AP–E/AP–PP × 100 (%); b: front part of dorsal tongue, MP-MT/MP-MS × 100 (%); c: middle part of dorsal tongue, PP-PT/PP-PS × 100 (%); d: rear part of dorsal tongue, C1-D/C1-Me × 100 (%); e: tongue tip, P’-Ti/PS-I × 100 (%).](http://ajpgi.physiology.org/DownloadedFrom/10.1152/ajpgi.00785.2016)
between two measurements of a pair. The method error did not exceed 0.01. The measurements of deglutitive tongue movement and time were compared before and after anesthesia by Wilcoxon’s signed-ranks test.

RESULTS

Effect of surface anesthesia on tongue. Two-point discrimination was not statistically significantly different before and after using either 8% Xylocaine spray or 2% Xylocaine jelly. Stereognostic ability significantly declined with application of 8% Xylocaine spray when the percentage of correct responses immediately after anesthesia was compared with that immediately after anesthesia ($P < 0.005$; Fig. 2). However, 5 min after anesthesia, stereognostic ability recovered to the level of that before anesthesia. Stereognostic ability with 2% Xylocaine jelly was not significantly different before and after anesthesia (Fig. 2).

Deglutitive movement of tongue under local anesthesia. After going across the posterior or inferior margin of the ramus of the mandible (stage 3), the bolus head passed late through the opening of the esophagus (stage 4) after anesthesia in both the surface and blocked groups ($P < 0.05$; Tables 2 and 3). Furthermore, in the blocked group, the period from passage of the bolus head through the opening of esophagus (stage 4) to passage of the bolus tail across the posterior or inferior margin of the ramus of the mandible (stage 5) extended after anesthesia ($P < 0.05$; Table 3).

In measurements of deglutitive tongue movement, the contact between tongue and palate was shorter after versus before anesthesia at the time the dorsal tongue lost contact with the soft palate (stage 2) and the bolus head passed across the posterior or inferior margin of the ramus of the mandible (stage 3) in both the surface and blocked groups ($P < 0.02$, $P < 0.05$) (Figs. 3A and 4A). Furthermore, in the blocked group, the contact between the tongue and palate was shorter, and the front and rear parts of the dorsal tongue were larger after than before anesthesia at the time the bolus head passed through the opening of the esophagus (stage 4) ($P < 0.05$) (Fig. 4A, B, C, and D). The tongue tip retreated after versus before anesthesia at the time the bolus head passed through both the posterior or inferior margin of the ramus of the mandible (stage 3) and the esophageal opening (stage 4) in the blocked group ($P < 0.05$; Fig. 4E).

DISCUSSION

Methods of removing superficial sensation from the tongue include infiltration anesthesia, surface tongue anesthesia, and block anesthesia for the lingual nerve. Infiltration anesthesia for the tongue was not used in the present study, because such anesthesia affected intrinsic muscle activity in a preliminary experiment. The effects of surface anesthesia on the tongue were evaluated by oral stereognostic ability. This ability is defined as the ability to detect tactile stimuli from three-dimensional shapes placed on the dorsal tongue and to identify them (19), and it depends primarily on the sensory input from the lingual surface (12). In the present study, the surface tongue anesthesia induced by 8% Xylocaine spray affected oral stereognostic ability immediately after anesthesia but did not affect it by 5 min after anesthesia. This result indicated that 8% Xylocaine spray had an influence on the tongue that was not sustained more than 5 min. Therefore, the swallowing events after surface anesthesia were recorded within 5 min of 8% Xylocaine spray application. We also used block anesthesia in our study of deglutitive movement of the tongue under local anesthesia because surface anesthesia induced by 8% Xylocaine did not significantly differ.
spray may incompletely remove superficial sensation from the tongue (30). Block anesthesia of the bilateral lingual nerve in the pterygomandibular space removes almost all superficial sensation from not only the tongue but also the region innervated by the inferior alveolar nerve (29). Furthermore, it may block the mylohyoid nerve, which innervates the mylohyoid muscle and the anterior belly of the digastric muscle (14), although all subjects in the present study could perform mandibular movements such as opening, lateral, forward, and backward motions after block anesthesia the same as before anesthesia.

In the present study, after crossing the posterior or inferior margin of the ramus of the mandible, the bolus head passed late through the esophageal opening after anesthesia in both the surface and blocked groups. Furthermore, in the blocked group, the period from passage of bolus head through the esophageal opening to passage of the bolus tail across the posterior or inferior margin of the ramus of the mandible was extended after anesthesia. Significance represents after vs. before anesthesia.

### Table 3. Time between 6 stages of deglutition in blocked group

<table>
<thead>
<tr>
<th>Stages</th>
<th>Before Anesthesia</th>
<th>After Anesthesia</th>
<th>Difference</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 2</td>
<td>173(33.3–277.8)</td>
<td>146(11.1–566.7)</td>
<td>27(–433.3–177.8)</td>
<td>NS</td>
</tr>
<tr>
<td>2 to 3</td>
<td>93.7(55.6–155.6)</td>
<td>93.7(44.4–200)</td>
<td>0(–44.4–55.6)</td>
<td>NS</td>
</tr>
<tr>
<td>3 to 4</td>
<td>88.9(44.4–122.2)</td>
<td>174.6(77.8–455.6)</td>
<td>–85.7(–333.3–0)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>4 to 5</td>
<td>212.7(144.4–266.7)</td>
<td>257.1(211.1–311.1)</td>
<td>–44.4(–100–33.3)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>5 to 6</td>
<td>301.6(244.4–411.1)</td>
<td>314.3(222.2–455.6)</td>
<td>–12.7(–144.4–133.3)</td>
<td>NS</td>
</tr>
</tbody>
</table>

Values (in ms) are means of range given in parentheses. After crossing posterior or inferior margin of the ramus of the mandible (stage 3), bolus head passed late through the esophageal opening (stage 4) after anesthesia. Furthermore, time from passage of bolus head through the esophageal opening (stage 4) to passage of the bolus tail across the posterior or inferior margin of the ramus of the mandible (stage 5) extended after anesthesia. Significance represents after vs. before anesthesia.

**P < 0.02, after vs. before anesthesia.**
we suppose that the anesthetic for the tongue was inadequate in their study.

In the present study, the contact between the tongue and palate was shorter after versus before anesthesia when the dorsal tongue lost contact with the soft palate and the bolus head passed across the posterior or inferior margin of the ramus of the mandible in both the surface and blocked groups. These results suggest that deglutitive tongue movement became slower due to a decrease in sensitivity of the tongue surface at these times. As deglutitive tongue movement causes bolus propulsion (6, 7, 17), the delay of deglutitive tongue movement caused by anesthesia may have caused weak propulsion of the bolus, resulting in delayed bolus transport.

The contact between tongue and palate during deglutition changes according to the form of the oral cavity (9, 27) and bolus consistency (26, 28, 31). The superficial and proprioceptive sensation of the tongue may recognize and modulate this contact (25). In the present study, the surface and block anesthesia removed superficial sensation in the tongue, but left the proprioceptive afferents of the tongue, which travel in the hypoglossal nerve and not in the lingual nerve (1, 8). Therefore, a decrease in contact between the tongue and palate might indicate that proprioceptive sensation, not superficial sensation, in the tongue mainly carried the sensory information about the form of the oral cavity and the variables of the bolus.

At the time the bolus head passed through the esophageal opening, the contact between the tongue and palate was shorter, and the front and rear parts of the dorsal tongue were larger after versus before anesthesia in the blocked group, but not in the surface group. Therefore, the deglutitive tongue movement became slower with block anesthesia at this time, which might affect the inferior alveolar nerve and the mylohyoid nerve, differing from surface anesthesia. The inferior alveolar nerve block removes the sense of perception but does not affect the motor (29, 34). On the other hand, the mylohyoid nerve block affects the motor of the mylohyoid muscle and the anterior belly of the digastric muscle (32), which elevate the hyoid and the larynx during deglutition (33). The elevation of the hyoid and the larynx begins at the onset of the pharyngeal swallow that is activated when the bolus head passes across the posterior or inferior margin of the ramus of the mandible (20). The movement of the tongue, hyoid, and larynx coordinates swallowing (11). Therefore, the delay of deglutitive tongue movement when the bolus head passes through the esophageal opening may be affected by the mylohyoid nerve block.

Peripheral sensory information from several regions of the oral mucosa has been shown (14, 16, 22, 23) to participate in a reflex response involving tongue muscu-
lature and movement, suggesting these reflex responses are related to deglutitive tongue movement (16, 22). In the present study, the rising threshold of the superficial sensation in the tongue with local anesthesia may affect these reflex responses to alter tongue movement.

In the blocked group, the tongue tip retreated after versus before anesthesia when the bolus head passed through both the posterior or inferior margin of the ramus of the mandible and the opening of the esophagus. Cook et al. (4) reported that a complex of tongue tip and base movement occurred in a tight temporal relationship at the inception of swallowing. In the present study, the change in the tongue tip position with block anesthesia may have been involved in the delay in the movement of the dorsal tongue during deglutition.

The neurophysiological control of deglutition depends on a medullary swallow center, which modifies the intensity and duration of activity by peripheral feedback (25). However, peripheral feedback has not been well understood (e.g., the intraoral sensation used to recognize the variables of the bolus to be swallowed). In the present study, sensory input from the tongue affected deglutitive tongue movement and bolus transit time, suggesting that sensory input from the tongue plays the role of peripheral feedback to modulate some aspects of the central nervous system control of deglutition, thus affecting the neurophysiological control of deglutitive tongue movement.

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REFERENCES