Electromyography of the Articulatory Muscles: 
Current Instrumentation and Technique

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The particular merit of electromyography (EMG) in speech research is that it can provide information about the speech gesture in its natural units and that it directly reflects the motor command from the central nervous system carried by neural impulses. Recent technical developments in EMG have made possible examination of the articulatory muscles without affecting natural speech performance. The present report describes a current technique used at Haskins Laboratories for the assessment of EMG data from the human articulatory muscles.

ELECTRODES

At present, hooked-wire electrodes are used exclusively. The wire currently in use is a platinum-iridium alloy (90%-10%) with polyester (Isonel) coating, the diameter of which is 0.002 in. (Consolidated Reactive Metals, P-91). This wire is ideal for these experimental purposes, since it is less easily crimped or bent than copper wire and less springy than stainless steel. In addition, the wire is possibly less irritative to human tissues than are other kinds of metal since no chemical reaction is to be expected.

The electrodes are made in essentially the same way as described by previous authors (Hirano and Ohala, 1969; Basmajian and Stecko, 1962). After a wire that is long enough to serve as a pair of electrodes (50-60 cm for percutaneous insertion and 80-90 cm for peroral insertion) has been prepared, the two free ends are threaded into the tip of a hypodermic needle (26 or 27 gauge and 3/4 to 2 in. in length) and pulled through the needle until a small loop remains. The loop is bent and cut with a razor blade to leave two short hooks of approximately 1-2 mm at the tip of the needle. Care is taken to make the two hooks of different lengths so as to avoid a possible short circuit by contact of the two cut ends in the muscle. The other ends of the wire are burned in a match flame to remove the polyester coating for connection to a preamplifier of the recording system.

For peroral insertion into the velopharyngeal muscles, the shaft of an electrode-bearing needle can be angulated to allow easier access to the target muscles.

For EMG of some laryngeal muscles, a specially designed probe is used for peroral insertion by indirect laryngoscopy. The probe consists of an L-shaped metal rod and the shaft of a 26-gauge needle cut and epoxy-bonded to the end of the shorter arm of the rod. The hooked-wire electrodes are made by threading the wire through the carrier needle in the conventional manner and also through a thin polyethylene tube bonded along the rod (Figure 1).

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An L-shaped Probe Used for Peroral Insertion of the Hooked-Wire Electrodes into the Posterior Cricoarytenoid and the Interarytenoid

Note: The shaft of a 26-gauge hypodermic needle is epoxy-bonded to the shorter arm.
The advantages and disadvantages of hooked-wire electrodes have been discussed so fully by previous authors (Hirano and Ohala, 1969; Harris, 1970) that no further comment will be made in the present report.

GENERAL PROCEDURES

Sterilization of the needle and the wire electrodes is accomplished either by high-pressure heat or by antiseptic solutions.

Before each experiment, if it is deemed necessary to inhibit salivation, 7-10 drops of Tincture of Belladonna is administered by mouth. For peroral insertion of the electrodes, topical anesthesia is administered to the pharynx using Cetacaine\(^1\) spray and to the larynx, by this same method, in the case of laryngeal EMG. This is followed by a gargle or instillation of 2-3 ml of 2\% Xylocaine.\(^2\) The percutaneous insertions are preceded by topical administration of 2\% Xylocaine without epinephrin through a Panjet-70 air jet (Panray)\(^3\) at the site of the needle insertion.

The skin is disinfected at the site of insertion with an alcohol swab. A ground electrode (a gold earring) is attached to the ear lobe of the subject. During electrode insertion, an oscilloscope and an amplifier-speaker system are used for monitoring the pertinent muscle activity. After insertion into an appropriate site, the electrode-bearing needle is withdrawn leaving the electrodes hooked in the target muscle.

Whatever position is taken during electrode placement and its verification, the data recording is made with the subject in an upright sitting position. Oscillographic monitoring of selected EMG channels is provided throughout the procedure.

INSERTION TECHNIQUES AND VERIFICATION OF ELECTRODE PLACEMENT

Correct placement of the electrodes in the target muscle is prerequisite to the entire experimental procedure in an EMG study. The exact placement of the electrodes is easier if (1) the target muscle is close to or immediately beneath the covering skin or the mucosa and the insertion is possible under direct inspection or (2) there is little possibility of contamination with other muscles. In any case, verification of electrode placement is absolutely necessary.

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1. Cetacaine (trade name) is packaged in a 50-ml aerosol bottle and contains the following: ethyl aminobenzoate, 14\%; butylamino-benzoate, 2\%; benzalkonium chloride, 0.5\%; cetyltrimethylammonium bromide, 0.005\%. A one-second spray releases 0.1 ml of solution, and usually three to four seconds of spray are needed to anesthetize the oral and pharyngeal mucosa. (Gaskill and Gillies, 1966).

2. Recent studies (Shipp, 1968; Zemlin, 1969) revealed no discernible effect of topical anesthesia on normal laryngeal behavior.

3. Panjet-70 delivers approximately 0.1 ml of the anesthetic solution to circumscribed intradermal depth up to 6 mm penetration.
In principle, correct placement of the electrodes is verified by monitoring the muscle activity induced by appropriate gestures that have been considered pertinent for the contraction of the target muscle. For some articulatory muscles, however, there is a lack of normative EMG data on which our verification can rely, as Shipp et al. (1968) have pointed out. Verification thus depends to a certain extent on the experimenter's empirical judgment based on his knowledge of anatomy and clinical and experimental practice. Further effort will be needed to reach unanimous agreement on the normative behavior of the articulatory muscles, although some individual variation both in anatomy and in function must always be taken into consideration.

**Intrinsic laryngeal muscles**

**Posterior cricoarytenoid (PCA).** The PCA is reached perorally by indirect laryngoscopy using the L-shaped needle holder described above. Using this approach, one can insert the needle parallel to the alignment of the muscle fibers; insertion is performed under inspection with a laryngeal mirror. During insertion, the subject is in a sitting position and is asked to phonate a sustained vowel so as to open his hypopharyngeal lumen for easier access to the site of insertion, which is illustrated in Figure 2. The insertion is thus made into the belly of the muscle on the cricoid cartilage through the hypopharyngeal mucosa. By this approach, there is little possibility of contamination with neighboring muscles unless the insertion is made too cranially.

Identification is made by having the subject repeat short periods of vowel phonation interspersed with deep inspiration. The PCA is active for inspiration and suppressed for the period of phonation, and this pattern is very characteristic.

**Interarytenoid (INT).** The insertion into the INT can be made either perorally or percutaneously. For peroral approach, the same technique is used as for the PCA and insertion is made at the midline between the two arytenoid prominences (Figures 3 and 4). By the percutaneous route, the transporting needle is inserted through the cricothyroid space, penetrating the skin and the cricothyroid membrane at the midline. Under inspection with a laryngeal mirror, the needle is pushed backwards and slightly upwards so as to pierce the anterior wall of the interarytenoid region to reach the INT (Figures 3 and 4). Both approaches are made with the subject in a sitting position. There is almost no possibility of contamination with other muscles in this case.

Verification of the placement is made by asking the subject to repeat short periods of phonation. The general pattern of INT activity is almost reciprocal to PCA; there is marked activity for the period of phonation.

**Cricothyroid (CT).** The percutaneous route is always taken with the subject in a supine position. Insertion is made at a point above the cricoid ring and approximately 1 cm lateral to the midline. The needle is directed posterolaterally and slightly upwards aiming at the lower edge of the thyroid lamina. This is the same technique as reported by Hirano and Ohala (1969).

Verification of the correct placement is made by asking the subject to attempt an ascending scale. The CT shows marked activity for a quick rise in fundamental frequency.
A Diagrammatic View of the Larynx During Sustained Phonation by Indirect Laryngoscopy

Fig. 2

Note: A cross (x) indicates one point of needle insertion into the posterior cricoarytenoid
A Sagittal Section of the Larynx with Illustration of the Direction of Needle Insertion to the Interarytenoid

A. Percutaneous Route

B. Peroral Route

Fig. 3
Indirect Laryngoscopic View of the Larynx During Quiet Respiration

Note: An arrow (→) indicates the direction of a needle inserted percutaneously into the subglottal space towards the interarytenoid area. A cross (x) indicates one point of needle insertion into the interarytenoid by the peroral route.

Fig. 4
There is, however, a possibility of misplacement of the electrodes either in the lateral cricoarytenoid (LCA) if the placement is too deep or in the sternohyoid (SH) if the insertion is too superficial. In order to differentiate the CT from the LCA, the subject is asked to attempt breath-holding or swallowing. These maneuvers should not give EMG activity unless the placement is into the LCA. For discrimination from the SH, the subject is then asked either to open his jaw by resisting the experimenter's hand holding it or to raise his head from the headrest. These attempts will elicit marked activity if the insertion is not deep enough and the electrodes are hooked into the SH.

Thyroarytenoid (VOC). Percutaneous insertion is made with the subject in a supine position attempting sustained phonation. The skin is pierced at a point close to the midline at the level of the cricothyroid space. The needle is then directed cranially and slightly laterally penetrating the cricothyroid membrane to reach the muscle from its inferior surface (Figure 5). This route is slightly different from that reported by Hirano and Ohala (1969), since the needle does not pass through the subglottal space but through the submucous tissues near the anterior commissure.

For verification, the subject attempts to produce low-frequency phonation. The VOC also shows activity during swallowing. Although there is little possibility of contamination with other muscles, the electrodes can pick up the mechanical vibration of the vocal fold if the placement is made too close to the free margin of the fold. In such a case, replacement of the electrode by another insertion is mandatory.

Lateral cricoarytenoid (LCA). The point of insertion is almost the same as for the CT. The needle is then directed laterally and slightly cranially penetrating the cricothyroid membrane at a point anterior to the inferior tuberculum of the thyroid cartilage and deeply enough to reach the LCA. This route is similar to that reported by Hirano and Ohala (1969). (See Figure 5.) Contamination with the VOC can be avoided if the direction of insertion is kept lateral and less cranial so as to stay along the contour of the cricoid ring.

Identification is made by having the subject attempt breath-holding or glottal stop production. These maneuvers, as well as swallowing, give marked activity and serve to discriminate the LCA from the CT as described above.

Strap Muscles of the Neck

Sternohyoid (SH). The contour of the SH can be palpated or even seen through the skin when the subject is asked to raise his head from the headrest in supine position with his head kept extended, unless the subject has a very short, fat neck. The contour is usually clear at the level of the thyroid lamina where the insertion is made. This region is also preferable to avoid possible contamination with other muscles. As the subject raises his head in a supine position, the needle is inserted lateral to the midline parallel to the alignment of the muscle fibers. This technique is similar to that reported by previous authors (Hirano et al., 1967).
A View of the Larynx with the Right Thyroid Ala Removed

Note: Arrows indicate the direction of needle insertion into the thyroarytenoid (A) and into the lateral cricoarytenoid (B). (This figure is a modification of Hirano and Ohala, Fig. 6, 1969.)
The exact placement is verified if marked activity is observed when the subject raises his head from the supine position, opens his jaw, or produces very low-frequency phonation.

**Sternothyroid (ST).** The ST is covered by the SH for almost its entire course in the neck except for the most caudal portion, where it tends to run more medially than the SH, since the ST attaches to the sternum more medially than the SH, as illustrated in standard textbooks of anatomy.

Therefore, our attempt at reaching this muscle is made by inserting the needle at a level 2-3 cm above the suprasternal notch and at the anterior border of the sternomastoid muscle and by directing the needle cranio-laterally. When the subject contracts this muscle by holding his head up from the head-rest in a supine position, we usually feel penetration of its fascia followed by marked EMG activity observed on a monitor oscilloscope. The gross pattern of activity of the ST is not much different from that of the SH so that absolute discrimination from the SH may still be questionable, although it is claimed that the ST appears to be more relevant for pitch lowering than the SH (Simada et al., in press; Hirano, pers. com.).

**Thyrohyoid (TH).** The TH runs directly on the thyroid lamina and attaches to the linea obliqua, where it is covered by other strap muscles. Insertion of the needle is made at the level of the superior edge of the thyroid lamina, and the needle is pushed caudally and laterally aiming at the linea obliqua until the tip of the needle hits the surface of the cartilage. The cut ends of the electrodes should then be placed in the muscle tissue of the TH, since there is some distance between the hooked ends of the electrodes and the very tip of the beveled end of the needle touching the cartilage.

The EMG activity is observed on a monitor oscilloscope when the subject is asked to attempt quick jaw opening or retraction of the tongue. Again, functional differentiation of the strap muscles is not possible on the basis of present knowledge, so that we must rely on anatomical expectation.

**Velopharyngeal Muscles**

The peroral approach is always attempted with the subject in a sitting position for insertion into the velopharyngeal muscles. The electrode-bearing needle (usually with an angulated shaft) is held by a pair of alligator forceps.

**Levator palatini (LEV).** Insertion is made into the levator "dimple" on the soft palate with the subject attempting sustained open vowel phonation. The tip of the needle is directed latero-cranio-posteriorly approximately 10 mm from the surface of the mucosa.

Verification is made by asking the subject to repeat the production of [s]. Marked activity can be observed for this strong oral gesture if the electrodes are placed properly.

**Palatoglossus (PG).** The PG is the muscular component of the anterior faucal pillar. This muscle is reached by inserting the angulated needle into the anterior pillar either cranio-caudally or in the opposite direction. Since the insertion is made under direct inspection, verification is satisfied if marked activity is shown when the subject swallows.
Palatopharyngeus (PP). In our EMG study, the PP is regarded as the muscular component of the posterior faucal pillar, although there has been some controversy in the past literature on its anatomical description (Bosma and Fletcher, 1962; Fritzell, 1969).

The insertion is made into the posterior faucal pillar under direct inspection. Verification of correct placement is, therefore, satisfied if EMG activity is monitored during swallowing.

Superior constrictor (SC). The tip of an angulated needle is directed cranially to reach the posterior pharyngeal wall lateral to the midline at the estimated level of velopharyngeal closure. The insertion is made under inspection and, therefore, placement is verified if EMG activity is observed for swallowing.

Middle constrictor (MC). Insertion is made using an angulated needle directed caudally into the posterior pharyngeal wall near the level of the tip of the epiglottis. The tongue of the subject is protruded and held for better visualization of the site of insertion.

Practically, precise discrimination of the upper portion of the middle constrictor from the lower fibers of the superior constrictor is difficult, since the constrictor muscles of the pharynx are interlayered at the level of transition from one to the other (Hollinshead, 1966). Therefore, it should be mentioned that what we attempt to examine as the middle constrictor is rather a topographical representation of the pharyngeal constrictor at this particular level. Verification of electrode placement is made in essentially the same way as for the SC.

Suprathyroid and Tongue Muscles

These muscles are reached percutaneously with the subject in a sitting or semi-Fowler position.

Anterior belly of digastric (AD). The contour of the AD is palpable if the subject attempts to open his jaw by resisting the experimenter's hand holding it or if he strongly pushes the tip of his tongue on to the upper alveolar ridge with his mouth slightly open. Insertion is made, with the subject attempting either one of the maneuvers mentioned above, at a point near the anterior attachment of the muscle to the mandibular ridge. The needle is directed obliquely to the surface of the skin aiming at the muscle belly. Verification is made by having the subject open his jaw, a movement which should be accompanied by marked EMG activity. There is little possibility of contamination with other muscles.

Mylohyoid muscle (MH). Insertion into the MH is made near the ridge of the mandible, lateral to the lateral margin of the AD and anterior to the hyoid bone. The experimenter puts his finger onto the floor of the mouth to palpate the tip of the needle perorally. This technique is similar to that reported by Smith and Hirano (1968). (See Figure 6.) Verification is made if the EMG activity is monitored when the subject retracts the tongue backwards or produces [k] repeatedly.
A Frontal Section of the Inferior Portion of the Face Illustrating the Direction of a Needle Inserted into the Mylohyoid (A) and into the Anterior Belly of Digastric (B)

A Sagittal View of the Inferior Portion of the Face Illustrating the Direction of Needle Inserted into the Genioglossus (C) and into the Geniohyoid (D)

Note: A fingertip of the experimenter is placed on the floor of the mouth, close to the alveolar ridge, to palpate the tip of the needle. (This figure is a modification of Smith and Hirano, Fig. 1, 1968.)

Note: A finger is palpat ing to evaluate correct needle placement in the genioglossus. (This figure is a modification of Smith and Hirano, Fig. 2, 1968.)
This muscle is so thin that electrode placement is not always satisfactory in spite of the fact that there is little possibility of contamination with other muscles.

Genioglossus (GG). A percutaneous approach is always taken, although the peroral approach is possible as reported by previous authors (Sauerland and Mitchell, 1970). The needle is inserted perpendicularly to the surface of the skin at the midpoint between the hyoid bone and the mandibular ridge in the paramedian line. The needle is then directed deep enough to be palpated by the experimenter's finger inserted onto the floor of the mouth of the subject. The technique employed in our experiment is the anterior GG placement described by Smith and Hirano (1968). (See Figure 7.)

Exact placement is verified by having the subject protrude his tongue or swallow; vigorous activity should be monitored for these maneuvers. Little possibility of contamination with other muscles is expected if the needle is directed and palpated as described above.

Geniohyoid (GH). The needle is inserted in the paramedian line more caudally than the insertion point for the GG, approximately 10 mm above the level of the hyoid bone. At this level, the MH is almost a tendinous structure covering the inferior surface of the GH. The needle should not be inserted too deeply but should be stopped after the penetration of that tendinous tissue which can usually be felt by the tip of the needle. The estimated depth of insertion is approximately 2-2.5 cm (Figure 7).

Verification of the placement by observing the EMG signal does not seem to be straightforward since there is a conflict of opinions on the function of this muscle (Cunningham and Basmajian, 1969). According to our observation, however, there is some difference in the pattern of the EMG activity of this muscle for swallowing and tongue protrusion of that of the GG, with which the GH is most likely to be confused. Namely, as Cunningham and Basmajian (1969) reported, GH activity follows with some delay in time that of GG activity for the initiation of swallowing, and for simple tongue protrusion, the GH appears to be less active than the GG. Further investigation will be necessary for satisfactory EMG assessment of this particular muscle.

REFERENCES


