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A CINERADIOGRAPHIC AND ELECTROMYOGRAPHIC STUDY OF MUSCLES USED IN GLOSSOPHARYNGEAL BREATHING

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by

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1967

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A Thesis Presented to the

FACULTY OF THE GRADUATE SCHOOL

UNIVERSITY OF SOUTHERN CALIFORNIA

In Partial Fulfillment of the

Requirements for the Degree

MASTER OF ARTS

(Physical Therapy)

January 1967

UNIVERSITY OF SOUTHERN CALIFORNIA
THE GRADUATE SCHOOL
UNIVERSITY PARK
LOS ANGELES, CALIFORNIA 90007

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MASTER OF ARTS

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Date January, 1967

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CHAPTER I

INTRODUCTION

Glossopharyngeal breathing is a substitutionary method of breathing that can be used when the muscles of respiration are paralyzed. Those who have complete paralysis can depend entirely upon it for maintaining needed ventilation while away from respiratory aids. Others who have only partial paralysis with resultant impaired breathing ability can supplement with glossopharyngeal breathing. Some have adequate respiratory function but are unable to cough effectively because of abdominal muscle weakness. This group benefits from the use of the technique because it produces the pressure needed for raising mucus.

Freedom from the respirator makes it possible for patients to receive improved nursing care, adequate physical therapy treatment, occupational therapy training, and to take part in social activities. In some cases it has made feasible the return to a remunerative occupation.

Glossopharyngeal breathing is accomplished by a pumping action of the tongue and throat muscles. The present study was designed to examine this and related functions in an effort to obtain information to facilitate the teaching of glossopharyngeal breathing. Electromyography was used to investigate certain muscle actions. Coordination studies were effected by means of cineradiography.

The Problem

The purpose of this study was to identify the muscles used in glossopharyngeal breathing and to investigate their function in movements of the tongue and throat. To determine the relative electrical activity of the muscles, electromyographic studies were made. Cineradiography was employed to investigate gross muscle function during glossopharyngeal breathing. This knowledge may be useful in developing a more efficient method for teaching glossopharyngeal breathing.

Importance of the Study

Because the usefulness of glossopharyngeal breathing has been clinically demonstrated, medical personnel from many places desire to learn the technique in order to teach it. Some travel to a center where it is being taught that they may receive instruction. Time is necessarily limited in these instances. Therefore, it is important that the teaching methods be as efficient as possible. Others are unable to visit such centers and must learn from written instruction. Increased information may be of help in simplifying the written explanation.

It is difficult to teach patients who have an appreciable amount of weakness in the muscles of the throat. Sometimes months of training are required before they succeed, but these patients are usually the very ones who are most in need of glossopharyngeal breathing. Occasionally they must be discharged from the hospital because of financial or social problems before mastering the technique. Therefore, from the standpoint of the patient, it is very important that the teaching be simplified.

To shorten the learning period of glossopharyngeal breathing would be of definite advantage to both personnel and patients. If the investigation of the problem stated above results in a more effective method of teaching, this will be accomplished.

Limitations of the Study

The scarcity of literature written on the subject under consideration presented a definite limitation. Glossopharyngeal breathing has been recognized by the medical profession less than fifteen years. During the early part of that period only those specializing in respiratory problems understood its value. Not until more recently have those in the field of internal medicine, orthopedics, and physical medicine become aware of its potential. As a result, very little has been published about the varied aspects of the technique.

The cineradiography study was limited to eighteen subjects as only films with a clear image could be used. Only two subjects were available for the electromyography examinations. These subjects were hospital staff members and had no known history of muscle weakness in the glosso-pharyngeal area. This limited the muscle function samples to those obtained on two persons. However, in many instances, repeated samplings were made on the same subject.

The anatomical site for this study limited the number of available subjects since there are inherent danges in electromyography studies of the throat when needle electrodes are used. Precautions must be observed with needle insertions in the neck since large vessels lie in this area.

Operational Definitions

Glossopharyngeal breathing.--This is a substitute breathing method that can be used in cases of respiratory muscle paralysis. Glossa is the Latin word for tongue. Pharyngeal is that pertaining to the throat. Hence, in this technique, the muscles of the tongue and throat pump the air into the lungs. The letters GPB will be used for the abbreviation of glossopharyngeal breathing.

Reverse GPB.--The pumping of air from the lungs by using the tongue and throat muscles.

Cycle.--Phase 1 followed by phase 2 comprises a cycle in the GPB technique. Several cycles are required for one breath.

Stroke.--That phase of the GPB cycle in which a mouthful of air is forced into the lungs (Phase 2).

Electromyography.--A recording by tracings of the electric responses (action potentials) in a muscle.

Cineradiography.--The making of moving x-ray pictures.

Cervical cavity.--That area containing the pharynx, esophagus, larynx, trachea, and the thyroid gland.

Bolus.--A mass of food ready to be swallowed.

Sonance.--Sound.

Hypopharynx.--The pharyngeal end of the esophagus.

Silent speech.--Thinking of the phonation of a vowel without making an audible sound as defined by Buchthal.

Valsalva maneuver.--Expiratory pressure raised against the closed glottis.

Pulmonary compliance.--An index of the elasticity of the lungs and thorax.

CHAPTER II

REVIEW OF THE LITERATURE

Related Studies

The literature published on the subject of glossopharyngeal breathing is limited. There is a noticeable absence of articles relating to specific muscle function. Earliest mention of glossopharyngeal breathing in medical writings is found in the September, 1951, issue of California Medicine (Dail, 1951). This preliminary report gave a general description of the technique, comparing it with the lung breathing used by many amphibia. This accounts for the term "frog breathing" sometimes used. The report also presented a brief history of its inception at Rancho Los Amigos Rehabilitation Center. A patient was found to be breathing in an unusual manner when his iron lung was opened by the physician during a respiratory examination. Although complete paralysis of the diaphragm and intercostal muscles was present, the patient was able to maintain ventilation satisfactorily. Examination revealed certain movements of the tongue and throat. This accounts for the term glossopharyngeal.

Later detailed ventilation studies were carried out. Gas volumes and blood-gas measurements during GPB were recorded. Both spot determinations and tests over several hours were conducted. The respiratory adequacy of this technique was demonstrated by normal blood-gas values and by the maintenance of alveolar CO tension at its initial level during the period of glossopharyngeal breathing (Affeldt, et al., 1955).

Further study of the mechanics of glossopharyngeal breathing was undertaken for the purpose of facilitating the teaching method. By means of visual examination and cineradiography it has been shown that in performing GPB the tongue, cheeks, and pharynx pump the air into the lungs. A series of pumping strokes is necessary for one inspiration. Simultaneous retraction of the tongue and descent of the larynx comprises the stroke. The average volume of air moved by a single stroke is 59 ml. during a period of 0.6 second. GPB vital capacities were over 5 times higher than the regular vital capacities in 42 patients studied. The average breathing time without respirator assistance was increased 184 times (Collier, et al., 1956). The effectiveness of GPB as an aid to coughing has been frequently noted clinically.

Harries and Lawes (1957) reported the usefulness of the cough-augmenting power of GPB from the clinical viewpoint.

Feigelson, et al. (1956) stated that studies indicate the increase in peak expiratory flow with a GPB cough seems to be directly related to both the volume of the glossopharyngeal breath and to pulmonary compliance.

An increase in the force of the cough as well as in mobility of the chest was reported by Loeser (1956).

Weerden (1958) stressed the fact that GPB enabled the patient to stretch his chest and cough effectively.

Collier, et al. (1956) made studies with 5 subjects in which expiratory flow rates were measured by means of the pneumotachograph. The average flow without GPB was 43 liters per minute. With GPB the average rose to 175 liters per minute.

Murphy, et al. (1956) reported the value of glossopharyngeal breathing in minimizing the loss of thoracic and pulmonary elasticity in respiratory paralysis. It was found to be more effective than the exsufflator or an exercise program because a larger amount of air can be inhaled which aids in maintaining compliance.

Dail, et al. (1956) stated that the advantages of glossopharyngeal breathing are numerous. Most important perhaps is the fact that it is a substitute method of breathing requiring no mechanical equipment and none of the usual respiratory muscles. The elimination of mechanical equipment is a definite safety factor (Dail, et al., 1955). It increases the length of time a patient can be free from the respirator. This allows for tub baths, opportunity to attend occupational therapy classes, participation in gymnasium activities with the physical therapist, and meeting appointments in the vocational guidance clinic. Coughing and chest stretching are medical advantages second only to breathing. The patient considers very important the advantages found in automobile travel, shopping, church attendance, visiting, and in some cases, the carrying on of business.

The psychological advantages of glossopharyngeal breathing have been mentioned in almost every report.

Kosonen and Sundstrom (1957) stated that psychologically GPB is of great value. After learning the technique patients are more active. Harries and Lawes (1957) reported improvement in the patient's personality. This has been observed repeatedly by the writer.

According to Dail and Wendland (1956) the disadvantages are several. The patient cannot sleep and usually cannot eat during GPB. Those with open tracheostomies cannot use it. The cosmetic aspect is a definite psychologic disadvantage. During an acute illness the patient will not have energy to perform GPB (Dail, et al., 1956). No complications resulting from GPB have been found in patients using this method for maintaining ventilation (Dail, et al., 1955).

Experience indicates that patients learn the GPB technique most readily when an organized instruction program is in effect. Several teaching approaches have been used with varying degrees of success. The most efficient method observed by the writer is one using sonance. The subject is taught to make certain sounds which result in the muscle actions desired.

The patient should be motivated before he is placed under instruction. This is best accomplished by educating him with regard to the advantages in his particular case. His general health should be satisfactory if there is to be an assurance of success. One of the chief hindrances to the learning process is fatigue. Therefore, the total program of those under GPB instruction must be thoroughly evaluated and controlled (Zumwalt, 1960).

Dail, et al. (1955) described glossopharyngeal breathing as a 4-step process.

Step 1. The cycle begins with the taking of a mouth and throat full of air. The tongue and the floor of the mouth are depressed simultaneously with an enlarging of the pharyngeal space. At this time the glottis is closed.

Step 2. The lips close. The soft palate muscles contract to close the nasal passages, thus trapping the air.

Step 3. The larynx opens. The floor of the mouth is raised and the tongue retracted synchronously with constriction of the pharyngeal space. This forces the air into the trachea.

Step 4. The larynx closes trapping the air in the lungs.

In 1962 Bonnet and Geubelle (1962) made an acoustical study of the phonetic teaching method. Nineteen subjects were tested. Sounds produced during glossopharyngeal breathing were recorded by displaying the acoustic waves on an oscilloscope and photographing the screen of the instrument.

Although the GPB sounds recorded varied from patient to patient, some common features were found. The interval between 2 successive sounds was silent except in those with a tracheostomy which produced a "scratching" of low intensity. In 17 subjects the sound showed 2 main components which were referred to as B^1 and B^2. The component B^1 had an abrupt start and a high intensity compared with B^2. The component B^2 had an intensity of only 15 to 40 per cent of B^1 in those who performed efficiently.

This preliminary study showed that a first component (B^1) of short duration and a second component (B^2) of comparatively low amplitude are produced when GPB is effective (Bonnet and Geubelle, 1962).

As a result of the above investigation an audio-visual method of teaching glossopharyngeal breathing was developed. The patient is able to compare by hearing and by sight, the characteristic features of the sound he produces, with that of the instructor. The sounds of both patient and teacher are visualized by means of a dual oscilloscope. The sonant effects of GPB by the instructor are played from a magnetic tape which was previously recorded. The patient's GPB sounds are picked up by a microphone connected to the second beam of the oscilloscope through an amplifier.

Four patients have been taught by the above method. Those using it feel that it is superior to the more commonly used phonetic method. Although equipment is used, this method does not eliminate the need for the constant presence of an expert GPB teacher (Bonnet and Geubelle, 1963).

A review of the literature on glossopharyngeal breathing brings into focus the many clinical advantages. There is general agreement with regard to its usefulness in everyday living. No one disputes the importance of the psychological effect upon the patient. Some have mentioned the problem of teaching GPB but only two have discussed it in any depth. Ventilation studies have been reported by several investigators but there is no contribution on the subject of muscle function.

Structure of the Laryngeal Column

A number of books on human anatomy have been reviewed and anatomists tend to be in agreement regarding the descriptions of the various structures and their relationships as found in the laryngeal column. The following presentation is a composite of the several sources investigated (Cates, 1948, Friedman, 1950, Goss, 1959, Grant, 1945, Plansky, 1964).

The laryngeal column is the unified tongue-hyoid-larynx structure. Because the interrelationship of the several divisions is very complex it is essential to consider this area as a unit in order to better understand how it functions in the living subject. The various parts are united in suspension by ligaments and muscles, thus forming an intrinsically mobile column. The stable points for attachments are the cranium, the mandible, and the sternum.

Bones and Ligamentous Attachments

The hyoid bone.--The only bony structure of the laryngeal column is the hyoid bone. Situated in the anterior part of the neck it lies between the mandible and the thyroid cartilage. The central portion of the hyoid is known as the body from which 2 greater and 2 lesser cornua project posteriorly and superiorly. The hyoid bone is suspended from the skull by 2 styloid processes of the temporal bones to the apex of each lesser cornu.

The hyothyroid ligaments.--Between the hyoid bone and the thyroid cartilage is a broad, fibro-elastic layer known as the hyothyroid membrane. Its lower attachment is on the upper border of the thyroid cartilage. The fibers run upward, passing behind the hyoid bone and attach to its upper surface. Between the membrane and the posterior surface of the hyoid is a bursa which facilitates upward movements of the larynx.

Cartilages and Supporting Structures

The larynx.--The 9 cartilages which form the larynx include the single thyroid, cricoid, and epiglottis, and the paired arytenoids, corniculates, and cuneiforms. The larynx is situated in the anterior part of the neck between the hyoid bone above and the trachea below. It lies on the level of the fourth, fifth, and sixth cervical vertebrae. The cartilages of the laryngeal column are held together and attached to other structures by ligaments and special folds of mucous membrane.

The cricoid cartilage.--The base or foundation of the larynx is the cricoid cartilage which is a modified section of the trachea. Behind and below, this specialized structure is cartilaginous; above and in front, it is membranous. The part that is formed by the cartilage is called the cricoid which is shaped like a signet ring with the wide part placed posteriorly. Although smaller than the thyroid cartilage, it is thicker and stronger. The posterior section is termed the lamina. At the midline of its outer surface is a longitudinal ridge to which the esophagus is attached.

The arytenoid cartilages.--On the upper border of the posterior cricoid, placed side by side, are 2 small pyramidal-shaped cartilages called the arytenoids.

Each arytenoid cartilage is connected to the cricoid by a capsule and a ligament. The capsule is attached to the margins of the articular surface. These articulations are diarthrodial and allow for rotation and gliding movements.

The thyroid cartilage.--The anterior ends of the vocal cords are attached in the angle of the thyroid cartilage which is formed by the junction of 2 cartilagenous plates.

The laminae are quadrilateral in shape with the posterior angles extending into processes or horns. One process on each side extends upward toward the hyoid bone and these are referred to as the superior horns. Those elongated in the downward direction are the inferior horns. The inner surfaces of the tips of the latter articulate with a raised joint surface on the outside of the cricoid cartilage. These are also diarthrodial articulations, having rotatory and gliding movements. These joints allow tension changes in the vocal cords by increasing or decreasing the distance between their cricoid and thyroid attachments.

On the outer surface of each lamina an oblique line runs downward and forward from the superior cornu to the lower border. The sternothyroid, thyrohyoid, and inferior constrictor muscles attach on this line.

The epiglottic cartilage.--Perhaps the most interesting cartilage of this area is the epiglottis. Its apex is attached in the angle of the thyroid cartilage above the ventricular folds. The broad free end is held in place by the hyoepiglottic ligament. The epiglottis lies behind the tongue. Between the tongue and the epiglottis on either side of the median fold are 2 depressions, the valleculae.

The corniculate cartilages.--In the ary-epiglottic fold and situated on the summits of the arytenoid cartilages are the cone-shaped corniculate cartilages. These are small and appear as nodules in the membrane.

The cuneiform cartilages.--Anterior to the corniculate cartilages are the tiny cuneiform cartilages which are elongated yellow elastic structures also imbedded in the membrane. These 2 sets of cartilages give firmness to the edge of the folds when they are drawn together in closure of the larynx.

Musculature Relations

The laryngeal column is controlled by means of muscles. Some of these are intrinsics, being located entirely within the column itself. This group is made up largely of those within the larynx but include also the thyrohyoids, the middle constrictors, and the hyoglossi. The larger number are extrinsic and give attachments to the occipital bone, the sphenoid, the styloid process, the mandible, the scapula, and the sternum.

Muscles of the laryngeal column fall into 4 categories--those of the tongue, the pharynx, the hyoid bone, and the larynx. They will be considered in that order.

The tongue.--The tongue is composed of a group of striated muscles that give it the ability to change shape when needed. The intrinsic muscles acting with the extrinsic muscles enable the tongue to move rapidly during the activities it has to perform.

The areas of the tongue are described as the tip, the dorsum, inferior surface, and left and right margins. The dorsum extends backward and downward as far as the valleculae, where it meets the epiglottis. The posterior portion of the tongue is rough. This is necessary for the handling of food in the mouth.

The intrinsic muscles of the tongue originate and insert within the tongue, whereas the extrinsic muscles originate outside of the tongue and include:

1. The genioglossus muscle originates on the superior mental spine of the mandible and inserts along the under surface of the tongue all the way from the tip to the root. The lowest fibers have an attachment to the hyoid bone. It has the shape of a fan and can be described as a flat triangular muscle.

2. The hyoglossus muscle is lateral to the genioglossus and inserts into the side of the tongue. It arises from the hyoid bone with extensive attachments thereon. It lies in an almost vertical plane between the hyoid and the tongue.

3. The styloglossus muscle arises near the tip of the styloid process and extends downward and forward into the side of the tongue. Its insertion is in 2 parts. The longitudinal portion blends with the fibers of the longitudinalis inferior near the dorsal surface of the tongue. The oblique portion overlaps the hyoglossus and decussates with its fibers.

4. The palatoglossus extends from the soft palate to the side of the tongue to form the anterior pillar of the fauces.

The above muscles are all supplied by the hypoglossal nerve except the palatoglossus, which receives its innervation from the cranial part of the spinal accessory nerve.

<u>The pharynx</u>.--The pharynx is a vertically placed ovoid tube. It is open in front throughout its length. The upper part opens to the nasal passages. The middle opens to the mouth cavity. Lower, opposite the hyoid bone and upper part of the thyroid cartilage, the pharynx opens to the larynx. This area is called the laryngeal pharynx and ends behind the cricoid cartilage where the open pharynx becomes the closed esophagus.

The lateral wall of the pharynx consists mainly of the 3 constrictor muscles. They arise anteriorly from firm attachments and sweep around the pharynx to join the muscle of the opposite side in a midline raphe. This is a fibrous band arising from the pharyngeal tubercle at the base of the skull. The constrictors lie in front of the cervical vertebrae with longus cervicis and capitis between.

The pharynx is important as an air passage, as a tube for the passage of food, and in phonation. The muscles comprising it are the following:

1. The superior constrictor is a quadrilateral muscle, thinner than the other 2 constrictors. It arises from the medial pterygoid plate, its hamulus, the alveolar process of the mandible, the pterygomandibular raphe, and a few fibers from the side of the tongue. It curves backward to be inserted into the median raphe and by means of an aponeurosis attached to the basilar portion of the occipital bone.

2. The middle constrictor is fan-shaped and arises from the greater cornu of the hyoid bone, the lesser cornu of the hyoid, and the stylohyoid ligament. The lower fibers descend beneath the constrictor inferior, the upper fibers overlap the constrictor superior, and the middle fibers run transversely. It is inserted into the median raphe.

3. The inferior constrictor is the thickest and largest of the constrictors. It originates from the sides of the cricoid and thyroid cartilages and inserts into the median raphe. The upper fibers ascend to overlap the middle constrictor.

4. The stylopharyngeus is a long, slender muscle. It arises from the base of the styloid process and passes down between the superior and middle constrictors to be inserted into the posterior border of the thyroid cartilage with the pharyngopalatinus.

5. The salpingopharyngeus arises from the auditory tube near the orifice and passes downward to blend with the pharyngopalatinus.

6. The palatopharyngeus arises from the soft palate, extends downward and lateralward to meet the stylopharyngeus, and with it inserts on the thyroid cartilage. This muscle forms the posterior fauces.

The muscles of the pharynx are supplied by the vagus and glossopharyngeal nerves.

The suprahyoid muscles.--The muscles that control hyoid movements from above are usually considered as a group and termed the suprahyoid muscles. Those controlling the hyoid from below are known as the infrahyoid group. The suprahyoids will be discussed first.

1. The digastric muscle consists of 2 bellies connected by an intermediate tendon which is attached to the hyoid bone by a fascial loop. The anterior belly arises from the digastric fossa of the mandible and ends in the intermediate tendon. The posterior belly arises from the mastoid notch of the temporal bone. The anterior belly lies against the inferior surface of the mylohyoid muscle a little to the side of the midline. It is innervated by the mylohyoid nerve while the posterior belly is supplied by a branch from the facial.

2. The stylohyoid muscle arises near the base of the stylohoid process and inserts on the greater cornu of the hyoid bone. The tendon is usually split near the hyoid to form a passageway for the belly of the posterior digastric. The stylohyoid is supplied by a branch of the facial nerve.

3. The mylohyoid muscle arises from the mylohyoid line of the mandible. The posterior fibers attach to the body of the hyoid bone. The remaining fibers meet each other in the midline raphe, thus forming a diaphragm. This muscle is innervated by the mylohyoid branch of the

inferior alveolar nerve, which is a branch of the mandibular division of the trigeminal nerve.

4. The geniohyoid muscle arises from the inferior mental spines of the mandible and attach to the body of the hyoid bone. It lies on the superior surface of the mylohyoid muscle along the midline. Fibers of the first and second cervical nerves which accompany the hypoglossal nerve give it innervation.

With the above muscle attachments in mind the hyoid bone may be pictured as being held in a sling. It is hung between the mandible and the stylomastoid area of the temporal bone. This arrangement affords a movable floor for the oral cavity.

The infrahyoid muscles.--The infrahyoid muscles are often spoken of as the strap muscles of the neck. They are depressors of the laryngeal area, thus becoming important in deglutition and glossopharyngeal breathing. Branches of the first 3 cervical nerves provide their innervation.

1. The sternohyoid is a thin, narrow muscle that arises from the medial end of the clavicle and the upper part of the manubrium sterni. It passes upward and medialward to be inserted in the lower border of the body of the hyoid bone.

2. The sternothyroid muscle lies beneath the preceding muscle and is wider and shorter by reason of its

attachment on the oblique line of the thyroid cartilage. It arises directly below the sternohyoid on the posterior surface of the manubrium sterni and from the edge of the first rib. At the lower part of the neck the 2 sternothyroids are in close contact but diverge as they pass upward.

3. The thyrohyoid arises from the oblique line on the lamina of the thyroid cartilage and is inserted into the lower border of the greater cornu of the hyoid bone. It is small, thin, and quadrilateral, appearing to be a continuation of the sternothyroid muscle.

4. Arising from the upper border of the scapula, the omohyoid muscle consists of 2 fleshy bellies and is united by a central tendon as in the digastricus. The superior belly is inserted into the lower border of the body of the hyoid bone. It is bound down to the clavicle by a fibrous expansion which forms a sheath around the central tendon.

<u>Intrinsic muscles of the larynx</u>.--The intrinsic muscles of the larynx are enclosed in folds of special membranes. Together these form the sphincters that are important in regulating the air-flow through this passageway.

The interior of the larynx is divided into 2 parts by the vocal folds known as the true vocal cords. Above the folds the space is known as the vestibule. Within this area are the vestibular folds which are more commonly called the false vocal cords. Between each vestibular and vocal fold is a space known as the ventricle. The anterior part of the ventricle leads up by a small opening into a pouch of mucous membrane. This pouch contains about 60 mucous glands. Action of the thyroepiglotticus muscle compresses these glands and causes the secretion of mucus for lubricating the vocal cords.

The chink or slit formed by the 2 vocal folds is the rima glottidis or glottis. Its shape varies considerably. During the production of a high note, it is only a linear slit. In extreme abduction, as in forced inspiration, it is triangular in shape with the base placed posteriorly.

The space below the vocal folds is at first elliptical but becomes cylindrical for attachment to the trachea below.

The intrinsic muscles of the larynx are:

1. The cricothyroid is the only intrinsic muscle located on the outside of the cartilages. It is triangular in shape, originating on the anterior and lateral portion of the cricoid cartilage. Its lower fibers run backward to insert on the inferior cornu. The anterior fibers run upward to be inserted on the lower border of the thyroid cartilage. Its nerve supply is the external laryngeal.

2. The posterior cricoarytenoid muscle is the abductor of the vocal coards. It arises from the posterior

surface of the cricoid. The fibers converge to be inserted into the back of the muscular process of the arytenoid cartilage.

3. The lateral cricoarytenoid muscle is smaller than the preceding one. Arising from the upper border of the arch of the cricoid cartilage it passes upward and backward to be inserted into the muscular process of the arytenoid cartilage.

4. The arytenoid is a single muscle that originates from the posterior surface of one arytenoid cartilage and is inserted into the corresponding part of the opposite one. It contains oblique and transverse fibers.

5. The thyroarytenoid muscle is broad, thin, and has several attachments. It arises in the lower half of the angle of the thyroid cartilage and inserts on the arytenoid cartilage. A portion of its fibers run parallel with the vocal cords and these form the vocalis muscle. Other fibers are prolonged into the aryepiglottic fold and run to the epiglottis giving the term thyroepiglotticus muscle.

The recurrent laryngeal nerve supplies all the above muscles except the cricothyroid muscle which is supplied by the external laryngeal nerve. These are branches of the vagus(X).

A review of the structure of the various components of the laryngeal column as described above is important in the electromyographic study of glossopharyngeal breathing. Needle electrodes were placed in the muscles controlling the tongue, hyoid, and laryngeal movements. Needle insertions were also made through the thyroid cartilage in order to study the intrinsic muscles of the larynx.

Function of the Laryngeal Column

The laryngeal column plays an important role in certain vital processes. The 2 chief functions are usually considered to be that of providing an airway for the respiratory system and preventing the entrance of foreign bodies into the lungs. The phenomenon of deglutition is also of primary import. Although phonation has been assigned a secondary role by some investigators, its significance cannot be minimized in man. Function of the laryngeal column is also important in the execution of glossopharyngeal breathing. As indicated in the name, the tongue and throat structures are employed in its performance. A coordinate pumping action of the muscles of the tongue and pharynx forces air through the larynx into the lungs. The mechanisms of coughing, vomiting, defecation, urination, and parturition also have counterparts in laryngeal function.

Deglutition

Since one of the basic requirements for life is the ingestion of food, the mechanism of deglutition has been the subject of much study. In years past some investigators published conclusions without evidence to support their statements. This led to confusion and many contradictions are now found in the literature.

One of the early impressions was set forth by Magendie in which he suggested that the bolus was moved by consecutive actions of the pharynx and the esophagus (Saunders, 1951). Some of those who followed him agreed, while others took exception to his ideas. One interesting concept was propounded by Barclay in which he maintained that the bolus was pulled into the pharynx by a negative pressure (Saunders, 1951). This has since been refuted by Saunders (1951) and his associates. Clinical observations have given support to the idea that the bolus is pushed through the lower pharynx by positive pressure. Negus reported that studies on a patient with a pharyngostome showed that during swallowing a jet of water squirted from the opening with a pressure of between one hundred and two hundred millimeters of water. Consecutive activation of the mouth, pharynx, and esophagus has been verified by roentgen examinations (Saunders, 1951).

The first phase of the deglutitory process is a preparation for carrying the bolus from the mouth to the pharynx. The tongue is the primary agent in this movement. Following mastication the tongue places the bolus within a groove on its superior-posterior surface. Then the whole body of the tongue is rolled backward upon the hyoid bone. At this time the levator veli palatina raises the soft palate to prevent entrance of the bolus into the nasal cavity. This action is not to be confused with the later soft palate function in which it supplements the superior constrictor in further elevation of the pharynx.

The basic movements of the pharynx are twofold. The first movement is an elevation of the whole pharyngeal tube. The second, a descending peristaltic wave within the pharyngeal wall. This has been likened to the swallowing mechanism of the snake. The stylopharyngeus acts in elevation, while the constrictors are responsible for the peristaltic action. It is interesting to note that in species with cessation of respiration during deglutition, as in man, the swallowing mechanism is rapid. Those species with adequate air passage during swallowing have a slow pattern. Cessation of respiration is a reflex act resulting from stimuli arising in the pharynx from the presence of food (Pressman and Keleman, 1955).

The reflex phenomenon of swallowing is believed to occur when the food spills over the epiglottis. Progress of the bolus is now accompanied by an upward motion of the pharyngeal walls. At this point the hyoid bone reaches its maximum elevation with simultaneous elevation of the palate.

During the above performance the lower pharynx has remained unchanged except for that caused by laryngeal elevation. The hypopharyngeal sphincter has been closed. As the bolus reaches the hypopharynx the larynx moves upward toward the hyoid bone and the floor of the pharynx rises to effect opening of the sphincter. This is accomplished immediately preceding the arrival of the bolus. The fact that elevation of the column takes place while the food mass is descending gives support to the concept of reflex pharyngeal action during deglutition. The sphincter area remains in the elevated position until almost complete penetration of the bolus. Its return is grossly synchronous with lowering of the hyoid and larynx. The amount of food retained in the hypopharynx after a single swallow depends upon the composition of the bolus (Bosma, 1957). Shelton, et al. (1960) have described the act of swallowing in relationship to hyoid movements because it is easily seen in radiographic studies, is centrally located, and acts in unison with the tongue and the larynx. These findings have been correlated with the 3 phases of swallowing as described by Gray (Goss, 1959).

Phase 1 was characterized by cephalad movement of hyoid bone with elevation of the larynx and a dorsad motion of the tongue. In some cases the tongue moved upward or downward as well as posteriorly. Displacement of the larynx was always simultaneous with hyoid movement. The tongue usually touched the posterior wall of the pharynx on dorsad action. Laryngeal closure in this phase was found in 50 per cent of the cases.

Phase 2 showed ventrad or ventrad and cephalad displacement of the hyoid. At the same time the larynx elevated and closed. The portion of the tongue between the hyoid and the valleculae moved ventrad or cephaloventrad. After passage of the bolus the tongue moved dorsad before elevation of the larynx in 5 subjects. Either of these actions could clear the valleculae. In all subjects the tongue and dorsal wall of the pharynx were in contact after passage of the bolus. In phase 2 the closure of the laryngeal vestibule which began in phase 1 was completed. Peristaltic waves in the constrictors varied from subject to subject. In the majority of cases studied the cervical vertebrae moved dorsad. At the end of phase 2 the bolus was out of view in the film of some subjects. In the others the tail of the bolus could be seen in the upper esophagus.

In phase 3 the hyoid descended in an oblique dorsad-caudad direction or dorsad and then more directly caudad. The tongue moved ventrad in all subjects, reopening the pharynx. The descent of the larynx was accompanied by opening of the laryngeal vestibule. This was common to all cases studied.

The investigation of deglutition is within the scope of this study because of certain functional similarities it has to glossopharyngeal breathing. The muscles of the soft palate close the nasal passages in both mechanisms. The pharyngeal wall constricts to apply pressure during both swallowing and GPB. The tongue is the primary agent in carrying the bolus to the throat for the swallow and in forcing the air into the throat for GPB. In over 500 cases reviewed, the writer observed that not one learned to perform glossopharyngeal breathing while unable to swallow.

Phonation

Scientific investigations in the field of phonation have noticeably increased during the last few years. In the past, anatomical studies were usually conducted by members of the medical profession while the function of these structures as related to sound production was chiefly studied and understood by the voice teacher. This separation has prevented progress because the knowledge of each group was needed by the other. Another difficulty arose from the fact that muscle function during electrical stimulation in laboratory experiments differed from that function found during voluntary voice production.

Pressman and Keleman (1955) report the intrinsic muscles of the larynx are so arranged that they form 3 tiers which produce the sphincteric action of the larynx. The first tier is the aryepiglottic sphincter and is the superior inlet of the larynx. Its folds which contain fibers from the thyroarytenoid muscles extend from the arytenoid cartilages to the lateral margins of the epiglottis. Closure is effected by the approximation of the folds in a puckering manner. Rigidity is provided by the embedded cartilages. A posterior gap is filled in by the arytenoid cartilages and the anterior space by the tubercle of the epiglottis which is pulled down by muscle contraction. Studies indicate that this is a simple muscular closure. It functions primarily during deglutition but also in vomiting, gagging, and in the presence of foreign bodies.

The middle sphincteric tier is formed by the ventricular folds commonly known as the false vocal cords. These form the roof of the ventricle and can be described as shelf-like. The under surface slants upward and lateralward from the free margins to the laryngeal wall. This formation gives a valve-like action to the cords. Air pressure from above can open the cords with ease. However, pressure from within the thorax can be resisted up to 30 millimeters of mercury (Pressman and Keleman, 1955). Closure of the false cords is concerned with trapping air below the level of the larynx for increasing intrathoracic pressure. This is necessary in coughing, vomiting, defecation, urination, and parturition. The same pattern is followed in all closures but differs in timing. For the cough it is rapid but in chest fixation it is effected more slowly. Closing of the vestibular folds is accompanied by closing of the true cords. The sequence is as follows: (1) anterior portion of the true vocal cords close first with a posterior progression (2) as the approximation is completed the false cords begin a similar progression (3) each portion closes tightly before the remainder of the fold makes contact with the opposite margin.

The vocal folds or true vocal cords comprise the third and lower tier. They present a formation that is just reverse to that of the ventricular folds. Consequently, they are able to resist pressure from above up to 140 millimeters of mercury but are easily opened by pressure from below. Hence, strength is not an important factor. The glottis was called a safety valve by Marshall as far back as 1868. Under normal conditions incoordinated movements between the 2 sides of the folds have never been reported.

Action of the pharyngeal portion of the tongue, hyoid bone, and larynx during phonation have been investigated, but are still not understood. Shelton, _et al._ (1960) have reported their investigations of the phonation pattern of subjects using the sound "m." This letter was chosen because it is accompanied by the least amount of mandibular motion. Cinefluorographic film studies were made of 10 normal persons. Deglutitory and phonetic movements were obtained for each one. The findings on the pattern of deglutition are reported elsewhere in this paper. No consistent pattern of phonation for the consonant "m" could be found.

In some persons the hyoid descended and then elevated while in others it elevated, descended, and elevated again. One subject showed relatively no displacement of hyoid, tongue, or larynx. Two cases showed hyoid elevation with no descent. Throughout, the movements in phonation were less extensive than those in deglutition. Although there were many variations in the pattern of phonation, none were similar to the swallow pattern. However, certain movements within the patterns were similar for both functions. For example, elevation of the hyoid and the larynx, some movements of the posterior tongue, opening and closing of the laryngeal ventricle, and change in the shape of the laryngeal vestibule.

The tongue and the hyoid do not always move in the same direction in either swallow or speech. Simultaneous movement in opposite directions was seen in several subjects.

Shelton (1960) suggests that perhaps the greater consistency in the deglutition pattern can be partially accounted for by reason of the reflex nature of swallow, while phonation is a learned pattern.

The function of the epiglottis has been the subject of considerable discussion through the years. Clinical findings have shown that there is little disability resulting from amputation of the epiglottis. Negus (1962) contended that the epiglottis is an olfactory organ, being concerned chiefly with the sense of smell and that in man it makes no important contribution to the swallow mechanism.

Bosma (1957) stated that there is much difference of opinion regarding the position of the epiglottis during deflection of the bolus. As a result of fluoroscopic studies some report that it remains in an upward position. Others report that it bends far downward. Negus maintains its position depends on the circumstances of the swallow and these differ. The bolus is usually deviated from the midline by the epiglottis. If fluid is swallowed it spills over the posterior wall of the epiglottis to descend along the posterior wall of the pharynx.

Often, reference is made in the literature to the lid-like action of the epiglottis. Bosma (1957) reported that this is a false concept. The epiglottis was spotted on the mid-dorsal surface with ink and following a swallow, ink was imprinted on the false vocal cords. Spots on the margin marked the posterior pharyngeal wall. Those more cephalad imprinted the arytenoid cartilages. Thus general closure of the vestibule of the larynx is indicated.

Welin (Bosma, 1957) reported that he noted a slow and jerky return of the down-tipped epiglottis in 5 patients who complained of feeling an obstruction in the throat.

Buchthal has reviewed the various concepts of phonation as a basis for present investigations. He reported that through the years the myoelastic theory of phonation has been widely accepted. This concept was formulated by Johannes Muller in 1837. He assumed that the voice was generated by air pressure from the trachea moving over the oscillating vocal cords. According to this theory, pitch depends upon the tension of the vocal cords.

In 1950 a French physicist and singer named Husson proposed a revolutionary hypothesis, maintaining that the air current played only a secondary role in speech. The primary factor he considered to be movements resulting from nerve impulses. In order to test this theory by Husson, Doctor Faaborg-Anderson, in 1954, began an electromyographical study of the intrinsic laryngeal muscles. In 1958, Dr. Buchthal (1959) from the University of Copenhagen reported the results of the above investigation at a meeting of the British Association for the Advancement of Science.

The vocalis muscles, the thyroarytenoid, the transverse arytenoid, and the cricothyroid were the adductor muscles tested by Anderson. The posterior cricoarytenoid, the only abductor muscle of the vocal cords, was also included in the study. The above muscles were accessible by means of indirect laryngoscopy with the exception of the cricothyroid which was reached by inserting the needle through the skin.

Contraction of the vocal muscle and of the thyro-arytenoid draws the thyroid and the arytenoid cartilages together. This results in cord adduction, shortening, and tension. The transverse arytenoid assists in the adduction. The cricothyroid muscle acts synergically with the vocal muscle as it stretches and adducts the cords.

A slight degree of activity was present in the intrinsic laryngeal muscles during the absence of phonation, even when the subject was in a relaxed position. This activity remained during cessation of breathing. Some felt that this may represent proprioceptive postural activity. The existence of sensitive nerve endings in these muscles is disputed since there are no muscle spindles in the intrinsic laryngeal muscles (Buchthal, 1959).

Previous findings by Weddell that there is increased activity during inspiration were confirmed by Buchthal (1959). The increase occurred first in the thyro-arytenoid, half a second later in the cricothyroid, and still later in the vocal muscle. The reason for this activity is not clear but it has been suggested that it may prevent the cords from flapping with the movement of air.

During phonation there was an increase of activity in all adductor muscles investigated. It began and reached its maximum before any audible sound could be recorded.

When the sound ceased, the electrical activity stopped. The changes in activity during sound production were simultaneous in all adductor muscles tested.

The abductor, the posterior cricothyroid muscle, showed a marked degree of spontaneous activity. It was greatly reduced shortly before onset of audible sound and remained so during phonation.

The discharge frequency of a single motor unit during phonation was studied in 6 subjects. Before audible tones, the frequency rose from 10 to 40 discharges per second. During sound it was constant at 25 to 30 per second, and at the end of phonation, decreased to the initial value. With increase in volume the frequency did not change. However, with increase in pitch there was an increase in activity in all adductor muscles.

That increase in cord tension is more important than rise in air pressure for an increase of pitch was demonstrated by varying the intensity of air currents through a tracheal cannula. The pitch of phonation remained unchanged. The increase of electrical activity of the vocal muscle as the pitch increases is in agreement with the myoelastic theory that tension of the vocal cord determines the pitch.

An increase of laryngeal muscle activity was also found in "silent speech" which is the thinking of the phonation of a vowel without making an audible sound. It was also demonstrated that the more complex the thinking, the greater the electrical activity. Some psychologists believe that thinking is always associated with movements of the intrinsic laryngeal muscles.

The electromyographical findings of the above study are consistent with the theory of Muller: (1) that the pitch of the sound produced is determined by the active and passive tension exerted by the intrinsic laryngeal muscles, (2) that the active agent in sound production is the air pressure (Buchthal, 1959).

Many valuable observations have been made from clinical experience. Some of these investigators (Briess, 1957) do not have scientific evidence to support their assertions. Nevertheless, good results have been obtained in patient care in some areas. Clinical experience with thousands of voices has led Briess and other investigators to believe that the balanced interplay between the thyro-arytenoid and cricothyroid muscles is essential for normal phonation. The same balance is necessary between the posterior and lateral cricoarytenoids.

Briess reported that larynologists have observed benign lesions of the vocal cords disappear as a result of relief of tension in the throat. This has been repeatedly accomplished by means of exercises and without the use of medication or surgery. One of the more important exercises is that of chewing while talking. This relieves laryngeal tension which is demonstrated by a definite lowering of the pitch of the voice after treatment (Briess, 1957).

There is need for organization, comparative studies of work already done, and summarizing of findings in the field of phonation. Moreover, much remains yet to be investigated.

CHAPTER III

METHOD OF PROCEDURE

The design of this study was to identify the muscles used in glossopharyngeal breathing and to determine their functional relationships. As a basis for this investigation the muscles of the cervical cavity were dissected. Coordination studies of these muscle groups were made in living subjects by means of cineradiography. Actions of individual muscles were tested by electromyography.

Dissection of the Cervical Cavity

Some of the muscles used in glossopharyngeal breathing were examined by means of dissection. The purpose was twofold. First, it was felt such examination would facilitate electromyographic studies being conducted. Second, visualization of detailed origins and insertions of muscles should give a better understanding of specific functions.

The area studied by dissection is commonly known as the anterior triangle of the neck. This region has been described as a cavity and compared with the abdominal area

(Grant, 1948). Behind, it is bounded by the cervical vertebrae. The lateral boundaries are the scalene muscles which are said to be comparable to the obliques. The space is confined anteriorly by the strap muscles which correspond to the rectus abdominis. Below, the cavity is continuous with that of the thorax.

The cervical cavity contains the following "cervical viscera:" the pharynx, esophagus, larynx, trachea, and the thyroid gland. These are all in the midline and on either side lie the carotid artery, jugular vein, and the vagus nerve.

The strap muscles were first investigated. These were studied from the standpoint of position and size to aid in electromyography. The sternohyoids were found to be thin and less than an inch wide. At their origins on the manubrium they were separated by three-fourths of an inch. About midway to their insertions they were seen to come together and continue side by side to the hyoid bone. The sternothyroids were slightly wider than the sternohyoids. They were in apposition at the manubrium but separated somewhat as they ascended to the oblique lines of the thyroid cartilages. No tendinous inscriptions were found as described in Gray. The thyrohyoids were difficult to distinguish from the sternothyroids at their attachments on the oblique line. They were quadrilateral in shape and thin. The omohyoids gave the impression of being atypical because of their small size. Gray has assigned them the important function of tensing the cervical fascia to prevent compression of the large vessels during prolonged inspiration (Goss, 1959).

The muscles of the floor of the mouth were also examined. The anterior belly of the digastricus was more clearly defined than the other muscles in this area. An interesting variation was also noted. Some fibers from the intermediate tendon were attached to the mylohyoid muscle. These were present on the left side only. The fibers of the mylohyoid muscles were continuous as the median raphe was missing. They appeared as a sling extending from one side of the mandible to the other side. This variation is mentioned by Gray (Goss, 1959). The layers of fibers composing this muscle were somewhat thinner than the digastricus. Just above the mylohyoids and lying together along the midline were the geniohyoids. Together their width was approximately one inch. They were about the same thickness as the anterior digastricus. Above the geniohyoids was the well-defined tendon of the genioglossi by which they are attached to the superior spine of the symphysis menti. These are fleshy muscles with considerable strength as can be demonstrated by giving resistance to protraction and retraction of the tongue.

The above information was of definite value in the electromyographic studies since it provided guide lines for determining the correct insertion areas of specific muscles.

Cineradiography

Cineradiography, the making of moving pictures by x-rays, has greatly facilitated the study of body actions that are not accessible to visual examination.

A basic x-ray apparatus is used to throw an image onto a screen. This is accomplished by a beam of x-rays projected through an anatomic body. Many of the photons which comprise the beam are absorbed. A few pass through and emerge on the other side. If the emerging photons fall on a fluorescent screen, some are absorbed and their energy is converted into light. Anatomic tissue does not absorb equally, therefore the rays vary in intensity and the screen exhibits an image pattern (Morgan, 1961).

An electronic image tube or image amplifier is used as a screen intensifier. A photoelectric layer creates an electron image. This is accelerated through the tube by electrical potentials. Because of the acceleration, the viewing screen is many times brighter than the x-ray screen. The brightness is also increased because the viewing screen is smaller. The image is then seen through an eyepiece that brings it back into normal perspective. The image amplifier makes possible cinefluoroscope, as without it, excessive radiation doses would be necessary (Morgan, 1961).

In this study both the pharyngeal and laryngeal areas were photographed during glossopharyngeal breathing. Two methods of photographing the image were employed. In the first method the image was photographed directly by a motion picture camera which was synchronized with the pulses of the x-ray equipment. The second method consisted of using specialized equipment called Fluorex Cineradiograph, manufactured by Westinghouse X-ray Corporation. Filming was done at 30 frames per second. All films for this study were produced by photographers who specialize in the various techniques of cineradiography.

After the film from the motion picture camera had been developed it was cut so that the strip pertaining to each subject was separate. The 2 ends of each strip were spliced, forming a loop. This loop was placed in a projector and repeatedly shown on the screen as long as needed for study. Showing was timed at 15 frames per second.

The above procedure made possible a functional study of the tongue, soft palate, pharyngeal walls, and the larynx during glossopharyngeal breathing.

Electromyography

Standard clinical electromyographic equipment was used for examination of muscle function. This included electrodes, an amplification system, a medium for calibration, and the recording apparatus.

The electrodes used were coaxial electromyograph needles. These varied in length from 1 1/2 to 2 1/2 inches. Needles, rather than surface electrodes, were employed because of marked localization of findings. With surface electrodes the examiner is unable to differentiate between muscles lying beside, deep to, or superficial to the muscle under study. The coaxial needle selected enables sampling of a much smaller area of muscle tissue than even the monopolar needle electrode.

The coaxial needle electrode consists of fine insulated wire within a hollow needle. The inner conductor is the active electrode, and is connected to one of the 2 input leads. The needle shaft is connected to the ground input lead, thus becoming the ground electrode. Sterilization of the needles was effected by autoclaving. The skin area was sponged with a Zephirin solution prior to needle insertion. No anesthesia was used.

Muscle potentials were picked up by the electrode and led to a preamplifier and an amplifier. Thus the potentials were amplified to dimensions large enough for study. Standardization of potentials was accomplished by introduction of a current of predetermined amplitude and frequency thus providing both voltage and time calibration.

The EMG is provided with an output lead which fed the motor unit potentials into a dual channel tape recorder (Heathkit). Voice sounds and motor unit potentials were simultaneously recorded. Later these were played back and studied by stereophonic earphones and the dual beam oscilloscope. For the purpose of discussion the range of action potential amplitudes was grossly divided into 4 classifications (very high, high, moderately high, and low).

The sites for needle insertions used in this study are described below. Tests were made with the subject lying in the supine position.

Cricothyroid

The needle was inserted one-half inch to the right of the midline between the cricoid and the thyroid cartilages. It was slanted to the lateral, cephalad, and posterior positions.

Thyroarytenoid

The insertion was made through the cartilage immediately below the level of the thyroid notch and three-fourths of an inch to the right of the midline. The needle was slanted medially.

Sternohyoid

The needle was inserted between the hyoid bone and the thyroid cartilage three-fourths of an inch to the right of the midline. Recordings were made at the depth of one-fourth inch.

Sternothyroid

The insertion was made three-fourths of an inch below the oblique line of the thyroid cartilage and one inch left of the midline. The depth of the needle was approximately three-fifths of an inch.

Omohyoid

The insertion for the superior belly of the omohyoid muscle was made between the hyoid bone and the thyroid cartilage 1 inch to the right of the midline. During depression of the larynx the inferior belly was palpated above the clavicle just anterior to the border of the trapezius.

Genioglossus

The site for needle insertion was between the hyoid bone and the mandible one-fourth inch from the midline. Recordings were made with the needle at a depth of one and one-half inches.

Mylohyoid

The needle was inserted three-fourths of an inch posterior from the point of the chin and one-half inch to the right of the midline. The needle was inserted to a depth of one-half inch.

Geniohyoid

The insertion was made between the hyoid bone and the mandible three-fourths of an inch from the point of the chin. The needle was one-fourth of an inch to the right of the midline at a depth of three-fourths of an inch and slanted slightly medially.

Thyrohyoid

The needle was inserted immediately above the oblique line of the thyroid cartilage and three-fourths of an inch to the left of the midline.

Stylohyoid

The needle was directed anteriorly while being inserted one and one-fourth inches posterior to the angle of the jaw and one-half inch below the mastoid process.

Styloglossus

The insertion site of the needle was one-half inch below and one inch medial to the angle of the mandible. The needle was slanted upward and medially.

Inferior pharyngeal constrictor

The needle was inserted 1 inch below the tip of the ear lobe, posterior to the ramus of the mandible and slightly above the angle of the mandible. The depth of the needle was 2 1/2 inches.