

A MANOMETRIC INVESTIGATION OF THE ALARYNGEAL SOUND SOURCE IN LARYNGECTONIZED SPEAKERS

by

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ABSTRACT

The location of the alaryngeal sound source sites were identified in four esophageal speakers by means of radiography and direct intraluminal manometry using miniature pressure transducers. These sound source sites were consistently found to be above the cricopharyngeal sphincter regions and not coincidental with them. The findings from this investigation do not support the generally held opinion that the cricopharyngeal sphincter subserves the function of an alaryngeal sound source.

It has been estimated that approximately two-thirds of all laryngectomized persons develop the ability to use alaryngeal speech, albeit with varying degrees of proficiency. However, despite the amount of information obtained over the past 60 to 70 years, relatively little is known about the basic physiology underlying this phonatory system. It is generally accepted that in esophageal voice production the laryngectomee insufflates his esophagus with air by either a sucking, pumping or injection technique. When eructated, this air generates a sound by causing some portion of the alimentary tract above the esophageal air reservoir to vibrate. The exact source of this sound generator remains uncertain.

Various locations within the upper alimentary tract have been identified with the alaryngeal sound source at one time or another, among which are the following: (1) between the dorsum of the tongue and the velum; (2) between the posterior wall of the oropharynx and the base of the tongue; and (3) between portions of the inferior constrictor muscle (Kallen, 1934). It has even been suggested (Pellegrini, 1957) that no real pseudoglottis or vibrating structure exists. Rather, that the air column itself produces a sound when it passes through a constricted section of the alimentary tract (a phenomenon analogous to that which occurs in organ pipes). The most commonly held opinion, however, is that the location of the alaryngeal sound source in the majority of esophageal speakers lies within the region of the cricopharyngeal sphincter (Moolenaar-Bijl, 1953; Levin, 1962; Snidecor, 1971; Simpson, Smith and Gordon, 1972; Greene, 1974).

Support for the inferred phonatory role of the cricopharyngeal sphincter has come from radiologic studies and observations of the structural characteristics of this sphincter. Although it is recognized that the cricopharyngeal sphincter opens reflexively during swallowing and vomiting, voluntary control of the sphincter is believed possible because of its striated muscle composition and its innervation (Putney, 1958; Seeman, 1958; van den Berg and Moolenaar-Bijl, 1959; Levin, 1962; Shipp, 1970; Greene, 1972, 1974). Levin (1962), for example, points out that in addition to its strategic location at the mouth of the esophagus, the cricopharyngeal sphincter can be "trained to act as a substitute for the vocal cords" because it contains striated muscle fibers which are innervated by the recurrent laryngeal nerve. Similarly, Greene (1972) accounts for the "extraordinary control and skill achieved by esophageal speakers in control of the pseudo-cords" on the basis that the upper portion of the esophagus is formed by striated muscle which receives its innervation from the recurrent laryngeal nerve.

Ellis (1971) and Sandmark (1973) point out, however, that there is no evidence that the recurrent laryngeal nerve supplies the cricopharyngeal sphincter since its function remains unaffected in persons with bilateral vocal fold paralysis. There is increasing evidence, on the other hand, that this sphincter may be under the control of the autonomic nervous system.

even though these structures are composed of striated muscle (Lund, 1968; Ellis, 1971; Ingelfinger, 1973; Sandmark, 1973).

It has been logical to assume that great care should be taken during surgery to spare the cricopharyngeal sphincter and its innervation, thereby preserving its sound producing capabilities (van den Berg and Moolenaar-Bijl, 1959; Hunt, 1964; Brodnitz, 1971; Greene, 1972). However, there is increasing physiologic evidence which suggests that a functionally intact sphincter may, in fact, be a deterrent to the acquisition of esophageal speech.

The cricopharyngeal sphincter is in tonic contraction during its normal physiologic resting state and, as such, it generates a zone of elevated pressure at the pharyngoesophageal junction (Winans, 1972; Pope, 1974). This high pressure zone, which is from two to four centimeters in length, acts as a physiologic sphincter against gastric and esophageal regurgitation of food (except when vomiting) during conditions of increased abdominal pressure. In addition, this physiologic barrier also prevents air from getting into the esophagus during inspiration (Dey and Kirchner, 1961; Ingelfinger, 1973; Winans et al., 1974).

This last described function of the cricopharyngeal sphincter is clearly incompatible with esophageal phonation, since getting air into the esophagus is precisely what the laryngectomee must do in order to set this sphincter into vibration. How, then, do laryngectomees overcome this elevated sphincter pressure to insufflate their esophagi? Dey and Kirchner (1961) and Winans et al. (1974) suggest that the surgically traumatized cricopharyngeal sphincter has less control over the passage of air into the esophagus. As a result, air can more easily be forced past the sphincter into the esophagus by increased oral and pharyngeal pressure. Physiologic support for this explanation has come from these investigators.

Using infusion manometry, Winans et al. (1974) demonstrated that mean resting cricopharyngeal sphincter pressures in laryngectomees (20.6 ± 2.8 mm.Hg) were significantly lower than in normal subjects (39.4 ± 4.2 mm.Hg). Furthermore, when they compared the mean resting sphincter pressures in good and poor esophageal speakers, they found that the good speakers had significantly lower pressures (13.1 ± 1.4 mm.Hg) than the poor speakers (29.6 ± 6.2 mm.Hg).

In view of the above kinds of information, it would probably be accurate to say that we do not have a clear understanding about the vibratory or alaryngeal sound source in laryngectomized speakers. A major reason for this lack of knowledge has been the relative inaccessibility of the pharyngoesophageal region to direct physiologic investigation. There have been a number of attempts to study the esophageal phonatory mechanism directly by means of radiography (Diedrich and Youngstrom, 1966; Simpson et al., 1972), electromyography (Shipp, 1970) and intraluminal balloon manometry (Salmon, 1965; Zinner and Fleshler, 1972; Weinhouse, 1973). The overall results of these studies remain equivocal, largely because of the limited physiologic perspective provided by these measurement techniques.

If we are to understand why some laryngectomees are more proficient than others as esophageal speakers, while still others are unable to develop this skill at all, it will be necessary to investigate the fundamental physiologic factors underlying alaryngeal phonation, i.e., the location and nature of the alaryngeal sound source. Measurement techniques must be used that can rapidly and accurately transduce tissue pressure changes which are associated with phonation. The purpose of this study was to identify the location of the alaryngeal sound source within the upper alimentary tract of four laryngectomized speakers and to describe some of the characteristics of these vibratory sites using radiography and recently developed techniques of intraluminal manometry.

METHOD

Subjects

Four laryngectomized individuals who met the following criteria were selected as subjects for this study:

(1) Subjects must not have had, in addition to their laryngectomies, pharyngectomies or extensive revisions of the cervical esophagus or tongue.

(2) Subjects must have been able to phonate, on demand, successive repetitions of the syllable /pa/ at a repetition rate of approximately one per second. In addition, they must have been able to sustain the vowel portion of this syllable for at least one second.

The four subjects who were included in this study consisted of two females, ages 52 and 60, and two males, ages 48 and 62. The elapsed time between surgery and the present investigation for the two females was approximately five and six years, while for the males it was four and six years. All four subjects used esophageal speech as their primary means of communication.

Instrumentation

1. Honeywell Esophageal Motility Probe (Model 31): This Probe consisted of three unidirectional pressure transducers spaced five centimeters apart along the Probe length, beginning five centimeters from the tip, and oriented at 120 degree intervals around the Probe. Each transducer, which was referenced to atmospheric pressure, used a diaphragm type gage that was capable of transducing both static and dynamic tissue pressures, up to 1200 mm. Hg, and at frequencies up to 5000 Hz. They were each marked with X-ray opaque material to facilitate and verify radiographic placement of the transducers. The entire Probe was housed in a silicone catheter 120 cm. long and five millimeters in internal diameter. The catheter was marked in one centimeter increments to provide an external reference to transducer position.

2. Esophageal and Hypopharyngeal Tissue Pressure Channels: The esophageal and hypopharyngeal tissue pressures were transduced by the Model 31 Probe and were amplified and filtered for artifact rejection by two signal-conditioning modules (Accudata 143 Bridge Amplifiers) — one for each of two¹ Probe transducers. The resultant signals were then used to drive a multichannel oscillograph (described below) for print-out of the tissue pressure wave forms.

3. Intraoral Air Pressure Instrumentation: Intraoral air pressures generated during phonation were obtained through a 12 cm. long polyethylene tube (PE 260 Intramedic Polyethylene Tubing; i.d. = 1.39 mm., o.d. = 1.90 mm.) attached to a pressure transducer (Statham PM 131 TC). The Statham Pressure Transducer, which was referenced to atmospheric pressure, used a diaphragm type strain gage and was capable of transducing static and dynamic air pressures from 0 to 2.5 p.s.i. The combined polyethylene tube and pressure transducer assembly had a frequency response which was flat (± 3 dB) to at least 160 Hz.

4. Intraoral Air Pressure Channel: Intraoral air pressures were amplified and filtered for artifact rejection by an Accudata 113 Bridge Amplifier. These conditioned signals were then amplified through the galvanometer amplifier of an Accudata 135A A.C. Coupled Bioelectric Amplifier for oscillographic write-out of intraoral air pressure wave forms.

5. Acoustic Signal Channel: Speech acoustic signals were transduced from the physical to the electrical domain by means of an Electro Voice 647 Microphone. These transduced signals were pre-amplified by a custom made audio amplifier (with VU meter) and further amplified to drive a galvanometer by an Accudata 143 Bridge Amplifier for oscillographic write-out of acoustic signals.

6. Oscillograph: All pressure signals were displayed simultaneously on a Honeywell 1508B Visicorder. This light beam oscillographic system provided a broad frequency response (up to 1000 Hz.) and trace integrity over a wide range of paper and writing speeds. Recordings were immediately available on eight-inch wide photosensitive paper.

¹In this study, only the upper and middle Probe transducers were used. By eliminating the third transducer, extensive pressure wave form overlap on the oscillographic write-out was avoided.

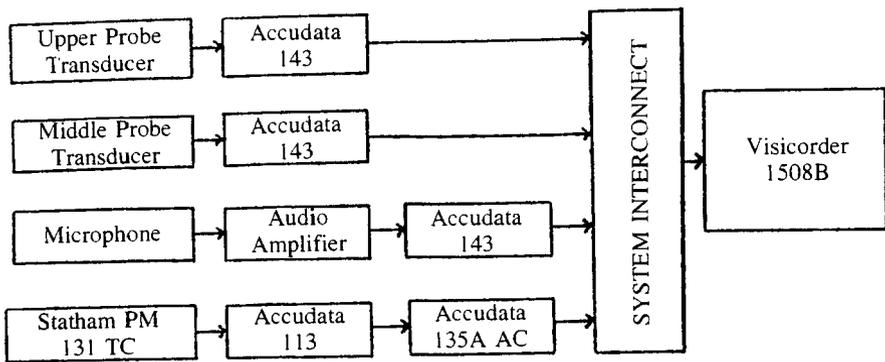


Figure 1. Block diagram of the pressure signal recording system.

Subject Preparation

In order to minimize intraesophageal probe shifts, the subjects were placed in position on a high backed wheelchair such that their backs and heads were tilted back at an angle of approximately 20 degrees relative to the vertical plane. This position allowed them to maintain a relatively immobile posture throughout the procedures with a minimum of discomfort.

Once the subjects had been settled into position, the probe was passed through each subject's nares into the esophagus. When the probe was estimated to be within the desired intraesophageal location, its placement was verified on the basis of recognized pressure patterns. Following verification, a boom-suspended microphone was positioned approximately four inches directly in front of each subject's lips. In addition, an audio amplifier VU meter was placed in such a way as to allow for its easy visibility by the subjects. When these procedures had been completed, the subjects were given a phonation practice session.

During the practice session, each subject attempted to produce phonations of the syllable /pa/ that were as consistent in quality and intensity as possible. In order to produce consistently loud phonations the subjects were instructed to visually monitor the VU meter in front of them during their phonations. The investigator then ascertained the region where the phonations were most consistently reached. This region was then marked with a black grease pencil and the subjects were requested to peak the VU needle within their region.

Procedure I

In order to obtain information about the location of the four alaryngeal sound sources, it was necessary to secure information about the cricopharyngeal sphincter locations so that they could be used as points of reference for the sound sources. The purpose of Procedure I was to locate the four subjects' sphincters by means of their resting pressures. This procedure is described as follows.

The oscillographic recording paper drive mechanism was activated to run at a speed of 2.5 mm./second and the subjects were instructed to remain as still as possible and to hold their breath. Then, on signal, the probe was withdrawn upward at a continuous rate (approximately 1 cm./second) until the upper probe transducer was within the hypopharynx. This continuous withdrawal or pull-through procedure was repeated twice for each subject. The pressure values obtained from each of the two pull-throughs were then summed and averaged to provide one overall resting pressure value for this sphincter region.

Procedure II

During this procedure, techniques of intraluminal manometry were used to record dynamic tissue pressures from within the upper alimentary tract during the repetitive phonation of the

syllable /pa/. Specifically, the subjects were asked to phonate this syllable in succession at a repetition rate of approximately one per second. In addition, intraoral air and sound pressures were recorded concurrently in order to: (1) verify the location of the alaryngeal sound source by comparing the vibratory pattern obtained from this region with the sound pressures, and (2) assist in the identification of the onset, duration and termination of the vibrations obtained from the alaryngeal sound source.

Procedure II was begun with the repositioning of the probe transducers within the body of each subject's esophagus. Next, the oscillographic recording paper drive mechanism was activated to run at a speed of 2.5 mm./second. The probe transducers were then withdrawn upward in one centimeter increment steps. At each incremental level, the probe was maintained in position until its placement had been verified and the subjects had phonated the syllable /pa/ several times in succession. If either of the two probe channels showed phonation-related vibrations that were coincidental with those seen in the sound pressure channel, the probe was advanced downward toward the stomach in one-half centimeter increments. The subjects phonated at each increment, until such probe channel vibrations were no longer visible. When this level had been found, its distance from the subjects' nares was noted and the actual dynamic pressure recordings were initiated. However, if neither of the two probe channels showed pressure vibrations at the first upward incremental withdrawal from the body of the esophagus, the probe was withdrawn another one centimeter increment and the same procedure followed as just described. This entire withdrawal/verification/phonation process was repeated until the upper probe transducer could be localized just below the level where phonation-related vibrations just began to appear on the probe channels. This level will be subsequently referred to as the Starting Level.

Just prior to the actual dynamic pressure recording, the subjects were instructed to assume an Oral Set (mouth open) and the intraoral air pressure tube was inserted into their mouths. Then, on signal, the oscillographic recording paper drive mechanism was activated to run at a speed of 100 mm./second, followed immediately by the subjects' closing their mouths for the initiation of the first syllable in the repetitive sequence. The subjects were requested to keep repeating the syllable until instructed to stop. While they were phonating, one of the investigative assistants monitored the VU meter and kept a record of the number of repetitions made by the subjects. When each subject produced at least three phonations that were at their appropriate VU level (± 1 dB), the assistant called "stop" whereupon the subjects stopped phonating, the oscillographic paper speed was reduced and the intraoral air pressure tube withdrawn from the subjects' mouths and cleared of moisture in preparation for the next round of syllable recordings.

Procedure III

In addition to obtaining manometric information about the alaryngeal sound source, it was also desirable to locate this region in relation to some anatomic referent such as the vertebrae. The obvious reason for doing this is that the results of this investigation could more easily be compared with the results obtained from the more traditional radiologic studies of this region. Procedure III was designed to provide this information.

Upon completion of Procedure II, the probe was again passed downward into the body of the esophagus to the Starting Level. The probe was then withdrawn upwards until the middle probe transducer was at the level where the phonatory-related vibrations were of greatest amplitude. When this transducer had been appropriately placed, the probe housing catheter was stabilized in position by securing it to the subjects' nose with tape. A frontal and lateral still X-ray were then taken of sound source region.

Data Measurement

At the conclusion of each of the three procedures, each subject's oscillographic record was compared with the syllable phonation tally made by the investigative assistant who monitored the

subjects' VU meter during Procedure II. From this tally the three phonation samples were identified at each one-half centimeter recording level which were within the designated intensity limits set for each subject. A one-tenth of a second segment of the oscillographic pressure record was then selected from approximately the center of each phonatory sample for measurement.

Of specific measurement interest within the one-tenth of a second segment were the amplitudes of the sound source pressures (analogous to glottal pressure during normal phonation) and sub-sound source pressure (analogous to sub-glottic pressure during normal phonation) seen in the two probe pressure channels. The mean sound source pressure amplitudes were obtained by drawing an envelope around the vibratory pressure data and taking eleven peak-to-peak measurements within the one-tenth of a second segment. These eleven measures were then averaged to yield a mean amplitude measure for the sound source pressures. This was done three times for each of the two probe channels within each one-half centimeter recording level resulting in six individual mean amplitudes. Subsequently, the six mean amplitude measures from each one-half centimeter recording level were averaged to yield one overall mean sound source pressure measure.

The overall mean sub-sound source pressure amplitudes for each one-half centimeter recording level were derived in essentially the same manner as described for the sound source pressure amplitudes. However, instead of taking eleven peak-to-peak measures within the one-tenth of a second segment, these eleven measures were made from baseline pressure to the sub-sound source pressure peak.

Mean resting pressure amplitudes were derived by taking baseline pressure to resting peak pressure measures from two pull-through samples, for each subject, and averaging these measures to obtain one overall mean resting pressure value for each subject's sphincter.

RESULTS

The first question of interest in this investigation was concerned with the location of the alaryngeal sound sources relative to the cricopharyngeal sphincters and vertebrae. Figure 2 is a graphic representation of the mean resting tissue pressures recorded from the pharyngo-esophageal regions of the four subjects during Procedure I. This figure shows that for each subject a zone of elevated pressure, representing the cricopharyngeal resting pressure, is present in this region. The overall mean resting pressures for each of the four subjects' sphincters, however, remain low, being 5.73 ± 2.90 mm.Hg for subject 1M, 12.94 ± 6.12 mm.Hg for subject 2M, 4.04 ± 3.02 mm.Hg for subject 1F and 1.05 ± 0.40 mm.Hg for subject 2F (group mean = 5.94 ± 5.05 mm.Hg).

The distance of 1M's cricopharyngeal sphincter from his nares is from 20.0 to 23.3 cm., for a total sphincter length of 3.3 cm. This location corresponds to the vertebral levels C5 to C7. The distance of 2M's sphincter is from 21.0 to 24.2 cm. or, from approximately C5 down to C6. The length of his sphincter is approximately 3.2 cm. 1F's overall sphincter length is 2.4 cm. and ranges in distance from 20.3 to 22.7 cm. or, from C5 to C6. For 2F the cricopharyngeal sphincter is located from C7 to T1 or from 22.5 to 24.5 cm. from her nares. This would give her a sphincter length of 2.0 cm.

Figures 3a, b, c, d are graphic representations of the mean sound source and sub-sound source tissue pressures recorded from each subject's upper alimentary tract during phonation of the syllable /pa/ in Procedure II.

Although phonation-associated vibratory pressure activity is present at varying levels along the upper alimentary tracts of these subjects, there is in each case a relatively limited region of heightened vibratory pressure activity. This represents the alaryngeal sound source, which coincides with a marked drop in sub-sound source pressure.

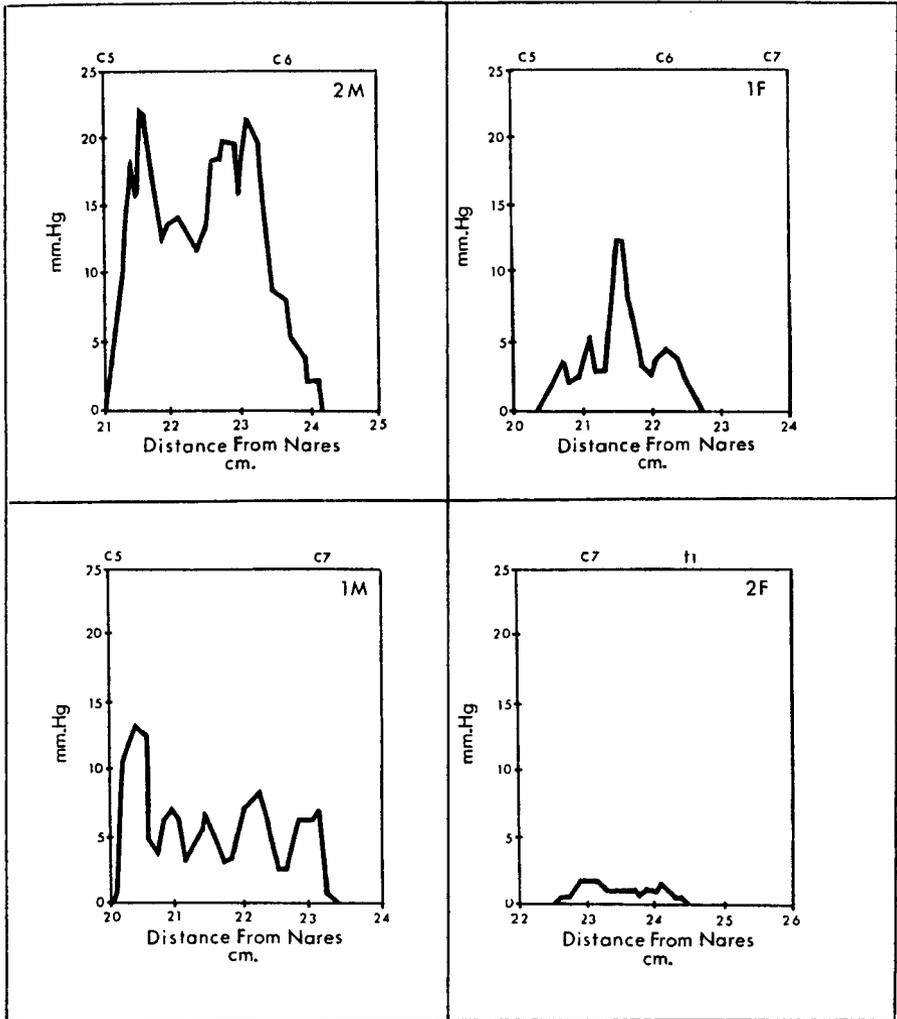


Figure 2. Mean resting pressures recorded from the cricopharyngeal sphincter regions of four laryngectomized subjects.

Inspection of each subject's pressure graph shows that for 1M (Fig. 3a), the alaryngeal sound source region is located at a distance of from 13.0 to 19.5 cm. for a total length of approximately 6.5 cm. The mean peak pressure (31.69 ± 8.90 mm.Hg) of this sound source site is located at 16.5 cm. from this subject's nares. This location corresponds to vertebral level C3. The region of heightened vibratory pressure activity for subject 2M (Fig. 3b) is from 14.0 to 20.5 cm. for a total length of approximately 6.5 cm. For this subject, the mean peak sound source pressure (15.48 ± 3.84 mm.Hg) is located at 18.0 cm. or C3. 1F's region of increased vibratory pressure activity (Fig. 3c) ranges from approximately 16.5 to 20.5 cm. for a total length of 4.0 cm. Her mean peak sound source pressure (18.44 ± 2.48 mm.Hg) can be seen at approximately 18.5 cm. or C4. Finally, inspection of 2F's pressure graph (Fig. 3d) shows her alaryngeal sound source region to be located at a distance of from 13.5 to 25.0 cm. The total length of this region is approximately 11.5 cm., with the mean peak sound source pressure (10.51 ± 5.88 mm.Hg) occurring at 18.5 cm. or C4.

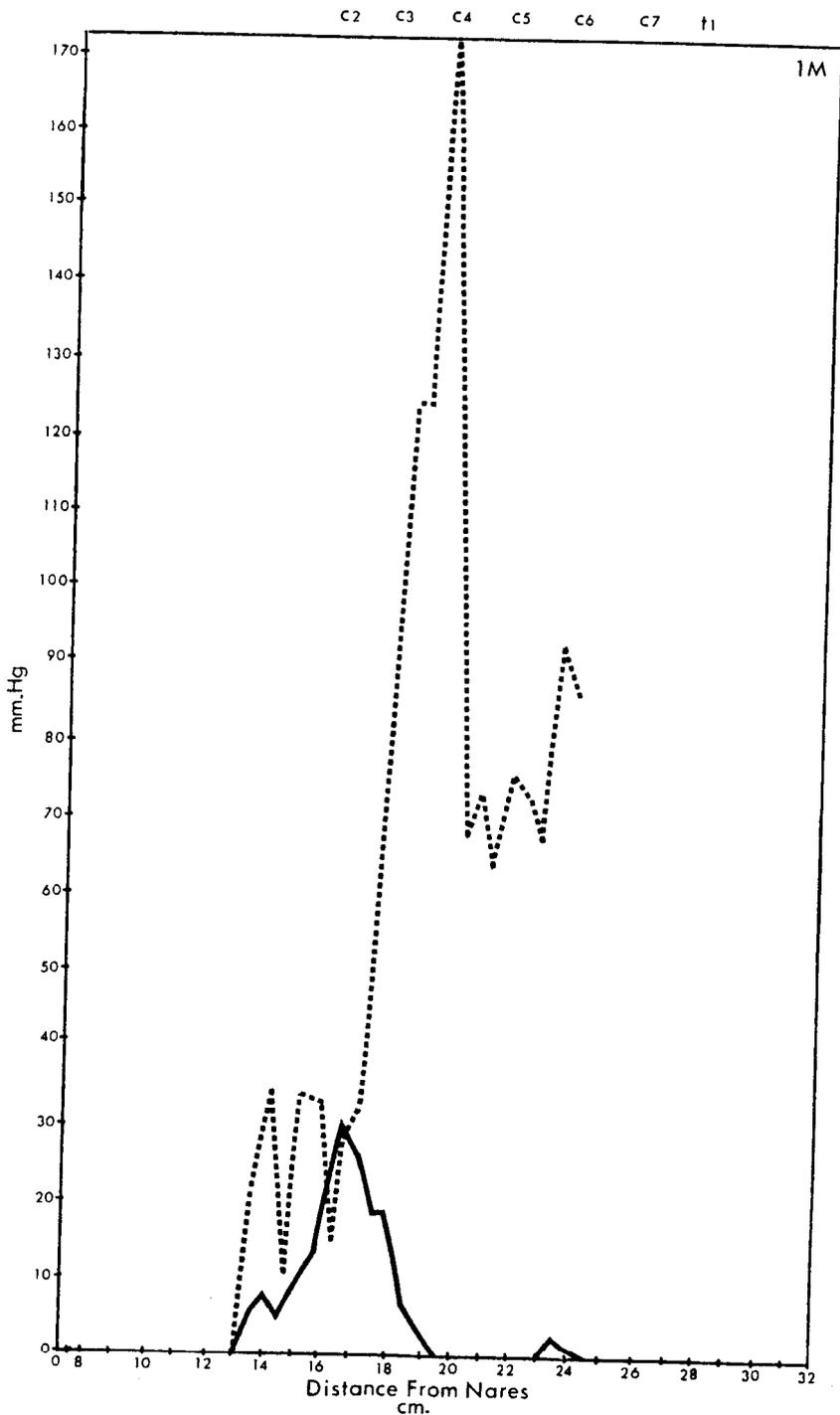


Figure 3a. Mean sound source (—) and sub-sound source (--) pressures recorded from 1M's upper alimentary tract during phonation.

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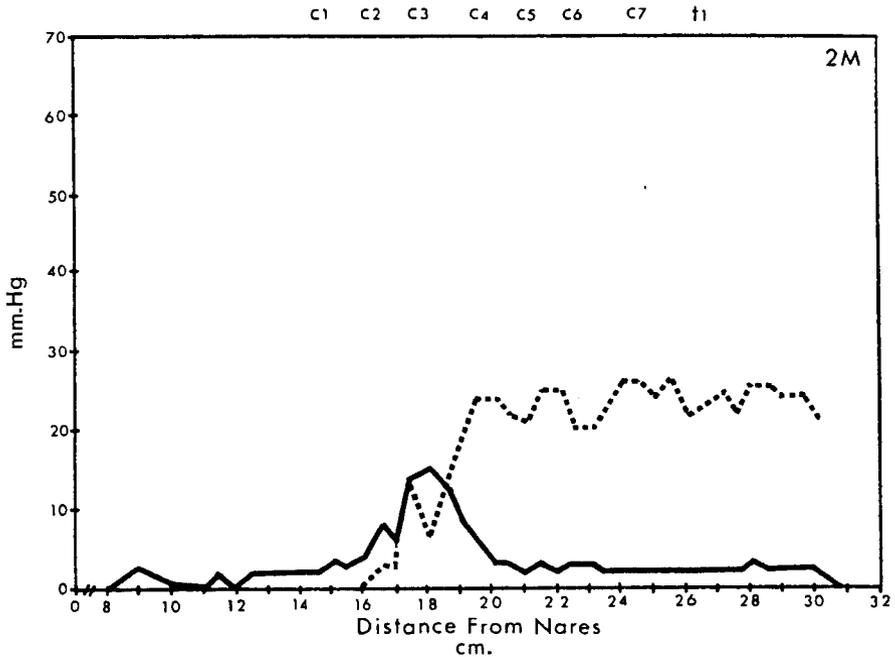


Figure 3b. Mean sound source (—) and sub-sound source (- -) pressures recorded from 2M's upper alimentary tract during phonation.

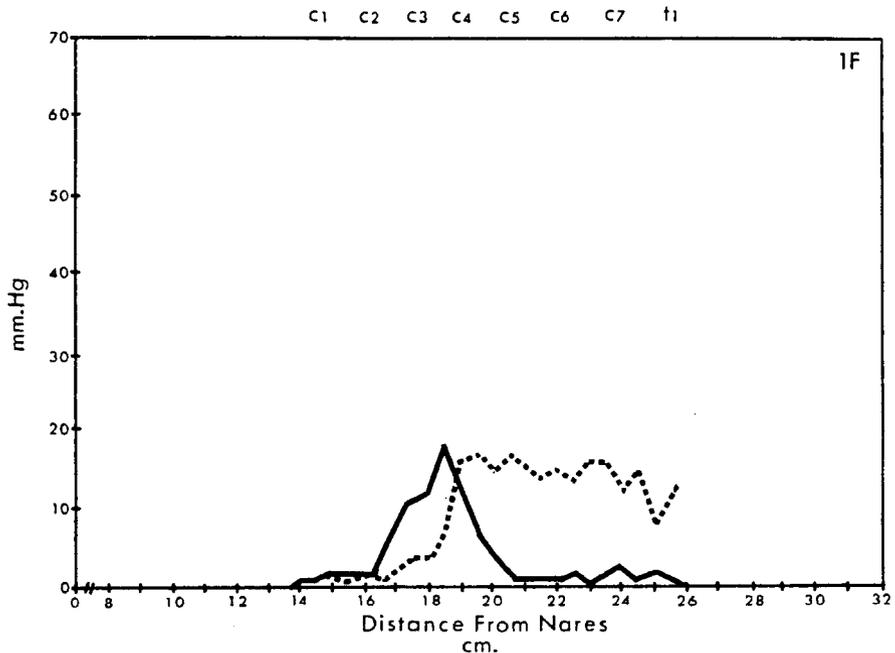


Figure 3c. Mean sound source (—) and sub-sound source (- -) pressures recorded from 1F's upper alimentary tract during phonation.

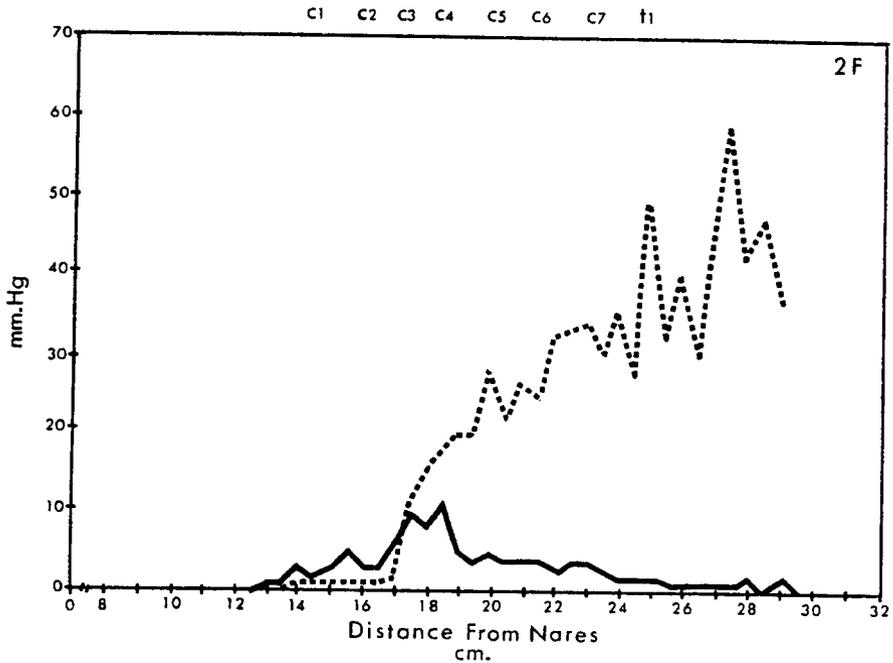


Figure 3d. Mean sound source (—) and sub-sound source (· ·) pressures recorded from 2F's upper alimentary tract during phonation.

The sound source and sub-sound source pressure patterns in Figures 3a,b,c,d suggest that subsequent to the insufflation of the esophagus with air, the upcoming esophageal air flow encounters a resistance within the region of C3-4. This resistance, in turn, causes a build up of sub-sound source pressure. Eventually, this pressure increases to a level where it overcomes the resistance, resulting in a sudden drop in sub-sound source pressure and vibration of the resistive structure. This aerodynamic picture is clearly analogous to that seen in normal phonation.

An examination of Figures 2 and 3a-d reveals that for each subject the alaryngeal sound source and cricopharyngeal sphincter regions are not coincidental. Rather, they are separated such that in all four cases the sound source is above the cricopharyngeal sphincter regions. Specifically, for each subject the alaryngeal sound source is located at the approximate level of C3-4. On the other hand, the four cricopharyngeal sphincter regions are located between levels C5 and T1, which is the general location of the pharyngo-esophageal junction.

DISCUSSION

The results of this manometric investigation are in agreement with the general physiologic and aerodynamic assumptions made about the alaryngeal phonatory system but do not support the opinion that the cricopharyngeal sphincter subserves the function of the alaryngeal sound source.

The phonation associated pressure patterns seen in Figures 3a-d suggest that the increased sub-sound source pressures result from a resistance offered to the upcoming esophageal air flow by the alaryngeal sound source and that the rapid decrease of this pressure, at the approximate point of heightened sound source pressure activity, reflects a sudden drop in this

resistance. If the cricopharyngeal sphincter did, in fact, subserve the function of an alaryngeal sound source in these four subjects, then this rapid decrease in sub-sound source pressure should have occurred at the level of the cricopharyngeal sphincter, i. e., C5 to T1. However, it clearly did not, but rather, this pressure pattern was consistently seen to occur above the sphincter regions at approximately C3-4.

Because the esophagus has the ability to shift vertically, as well as contract sequentially, a question was raised (Pope, 1976) about the possibility that the cricopharyngeal sphincter may have shifted upwards from its resting position to the C3-4 vertebral level and had, in fact, functioned as the alaryngeal sound source in these subjects. In order to definitively answer this question, it would be necessary to tag this sphincter region with radio opaque material and to radiographically observe the extent of its vertical excursions during alaryngeal phonation. However, it is suggested that in view of the location of the alaryngeal sound sources within the hypopharynxes, it is unlikely that the sphincter region could make such a large upward shift.

Since radio opaque material was not used during the radiographic portion of this investigation (Procedure III), it was not possible to identify the soft tissue structures that subserved the function of the alaryngeal sound sources in the four subjects studied. On the basis of the present findings and other radiographic studies that were able to identify soft tissue structures during phonation (Brighton and Boone, 1937; Vrticka and Svoboda, 1961; Diedrich and Youngstrom, 1966; Simpson et al., 1972), it would seem reasonable to assume that the four alaryngeal sound sources observed in this study were subserved by areas of tissue constriction within the hypopharynx which are similar to those depicted in Diedrich and Youngstrom's (1966) radiologic studies. Substantiation for this assumption, however, will have to come from additional radiographic-manometric investigations of the alaryngeal sound source regions during phonation.

In view of the above assumption regarding tissue constriction, it would be expected that these constrictive areas should have reflected heightened resting pressures during Procedure I and that these resting pressures would have been of greater magnitude than those obtained from the four cricopharyngeal sphincter regions. However, no such resting pressures were recorded. This would seem to indicate that these constrictions manifest themselves only during phonation — a situation analogous to that of vocal fold approximation during normal phonation. Although the exact nature of this tissue constriction is not known, it is suggested that its occurrence is related, at least in part, to increased muscular tension during phonation and to the Bernoulli phenomenon.

In considering the alaryngeal sound source localization findings in this investigation, one might ask what, if any, functional significance does the cricopharyngeal sphincter have in alaryngeal phonation? Dey and Kirchner (1961) found that esophageal speech in some of their laryngectomized subjects occurred in the absence of a functioning cricopharyngeal sphincter. From this they concluded that the sphincter was not necessary for esophageal speech production. More recently, Winans et al. (1974) demonstrated that good esophageal speakers had significantly lower mean resting sphincter pressures than poor esophageal speakers. This would indicate that the better speakers had looser, less functional sphincters than the poorer speakers. Low mean resting sphincter pressures were also recorded in this investigation. These three studies, and in particular the one by Winans et al. (1974), suggest that a normally functioning cricopharyngeal sphincter may be significant to alaryngeal phonation in that it might deter such phonation by preventing the insufflation of the esophagus with air. In order to better understand the functional significance of the cricopharyngeal sphincter to esophageal phonation, it will be necessary to manometrically investigate both good and poor alaryngeal speakers' sphincter regions and to note the magnitudes of their respective resting pressures.

It can justifiably be argued that since only a small number of non randomly selected subjects were used in this investigation, these results may not be representative of the majority of alaryngeal phonatory systems and that, in fact, the alaryngeal sound source is usually located

within the cricopharyngeal sphincter. Until many more subjects are studied with the manometric techniques used in the present investigation, this possibility will have to remain tenable. At the same time, however, one has to be impressed with the consistency of the obtained results suggesting that perhaps these findings are relatively representative.

This issue of representativeness also brings up the question of just what influence the probe itself may have had on these results. In view of the consistency of the localization results, it is probably unlikely that the probe had any effect on the location of the four alaryngeal sound sources. On the other hand, the probe may have had a damping effect on the vibrating structures and a psychological affect on the subjects. Although acoustic measurements were not made of each subject's phonation before and after probe insertion, a voice quality difference was perceived by the investigator. The insertion of the probe into the subjects' esophagi also appeared to have a psychological affect on them in that they became more tense and rigid. This resulted in an increased effort by the subjects to initiate phonation. All of the subjects did, in fact, report that they had to work or strain harder in order to produce a sound. However, this problem resolved itself within the first five to ten minutes following probe insertion — probably because the subjects adapted to the situation and began to relax. Because of this problem, each subject was given time to relax and accommodate to the probe before the start of the data collection procedures.

In conclusion, because this study was essentially exploratory in nature, and consequently limited in design, the overall results obtained with respect to the four alaryngeal phonatory systems must remain suggestive rather than conclusive. However, this investigation has demonstrated that the intraluminal manometric techniques employed herein are a potentially valuable source of information about some of the physiologic determinants of alaryngeal phonation.

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REFERENCES

- Brighton, G.R. and Boone, W.H., Roentgenographic demonstration of method of speech in cases of complete laryngectomy. **American Journal of Roentgenology**, 38, 571-583, (1937).
- Brodnitz, F.S., **Vocal Rehabilitation**. Minnesota: American Academy of Ophthalmology and Otolaryngology, (1971).
- Dey, F.L. and Kirchner, J.A., The upper esophageal sphincter after laryngectomy. **Laryngoscope**, 71, 99-115, (1961).
- Diedrich, W.M. and Youngstrom, K.A., **Alaryngeal Speech**. Springfield, Ill.: C.C. Thomas, (1966).
- Ellis, F.H., Jr., Upper esophageal sphincter in health and disease. **Surgical Clinics of North America**, 51, 553-565, (1971).
- Greene, Margaret C.L., **Disorders of Voice**. New York: Bobbs-Merrill, (1972).
- Greene, Margaret C.L., **The Voice and Its Disorders**. Philadelphia: Lippincott, (1974).
- Hunt, R.B., Rehabilitation of the laryngectomee. **Laryngoscope**, 74, 382-395, (1964).
- Inglefinger, F.J., How to swallow, and belch and cope with heartburn. **Nutrition Today**. January/February, (1973).

- Kallen, L.A., Vicarious vocal mechanisms. **Archives of Otolaryngology**, 20, 460-503, (1934).
- Levin, N.M., Esophageal Speech. In N.M. Levin (Ed.), **Voice and Speech Disorders: Medical Aspects**. Springfield, Ill.: C.C. Thomas, (1962).
- Lund, W.S., The cricopharyngeal sphincter. **Journal of Laryngology**, 82, 353-367, (1968).
- Moolenaar-Bijl, Annie J., The importance of certain consonants in esophageal voice after laryngectomy. **Annals of Otolaryngology, Rhinology and Laryngology**, 62, 979-989, (1953).
- Pellegrini, V., On the so-called pseudo-glottis in laryngectomized persons. **Journal of Laryngology and Otolaryngology**, 71, 405-410, (1957).
- Pope, C.E., II., Esophageal physiology. **Medical Clinics of North America**, 58, 1181-1199, (1974).
- Pope, C.E., II., Personal communication (1976).
- Putney, F.J., Rehabilitation of the post-laryngectomized patient: Specific discussion of failures advanced and difficult technical problems. **Annals of Otolaryngology, Rhinology and Laryngology**, 67, 544-549, (1958).
- Salmon, Shirley J., Pressure variations in the esophagus, pharyngeal-esophageal constriction, and pharynx associated with esophageal speech production. **Unpublished doctoral dissertation**. University of Iowa, (1965).
- Sandmark, S., The pharyngoesophageal sphincter. In H.R. Sorensen, O. Jepsen and S.A. Pedersen (Eds.), **The Function of the Esophagus**. Denmark: Odense University Press, (1973).
- Seeman, M., Pathology of the esophageal voice. **Folia Phoniatica**, 10, 44-50, (1958).
- Shipp, T., EMG of pharyngoesophageal musculature during alaryngeal voice production. **Journal of Speech and Hearing Research**, 13, 184-192 (1970).
- Simpson, I.C., Smith, J.C.S. and Gordon, Margaret T., Laryngectomy: The influence of muscle reconstruction on the mechanism of oesophageal voice production. **Journal of Laryngology and Otolaryngology**, 86, 961-990, (1972).
- Snidecor, J.C. Speech without a larynx. In L.E. Travis (Ed.), **Handbook of Speech Pathology and Audiology**. New York: Appleton-Century-Crofts, (1971).
- van den Berg, J. and Moolenaar-Bijl, Annie J., Crico-pharyngeal sphincter, pitch, intensity and fluency in esophageal speech. **Pract. Otolaryngology, Rhinology, Laryngology**, 21, 298-315, (1959).
- Vrticka, K. and Svoboda, M., A clinical and x-ray study of 100 laryngectomized speakers. **Folia Phoniatica**, 13, 174-186, (1961).
- Weinhouse, Iris., An intraluminal pressure study of laryngectomized subjects. **Unpublished doctoral dissertation**, City University of New York, (1973).
- Winans, C.S., The pharyngoesophageal closure mechanism: A manometric study. **Gastroenterology**, 63, 768-777, (1972).
- Winans, C.S., Reichbach, E.J. and Waldrop, W.F., Esophageal determinants of alaryngeal speech. **Archives of Otolaryngology**, 99, 10-14, (1974).
- Zinner, E.M. and Fleshler, B., Intraesophageal pressures during phonation in laryngectomized patients. **Journal of Laryngology and Otolaryngology**, 86, 129-140, (1972).