USE OF THE FIBERSCOPE IN SPEECH RESEARCH

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In 1968, a new technique for observing the larynx by use of a fiberscope was reported.[1)*] The main point of this technique was to observe the laryngeal movements by inserting a special fiberoptics cable via the nasal passage without causing any disturbance to the articulatory movements of the speech organs. Since the first report, improvements have been achieved on the design of the fiberscope with cooperation of the technical staff of the manufacturer,[**] and our experience has proved the usefulness of this technique in obtaining important information on the laryngeal adjustments during speech utterances. Some of those data have been reported elsewhere.[3)4)5)6)]

In addition to the "standard" model which evolved from the original prototype, we have designed and tested two types of fiberscopes, one with a smaller outside diameter and another with a wider view angle. The former makes it easier to insert the fiberscope through the nose to the hypopharynx, and the latter gives the possibility of observing the movements of the pharyngeal wall as well as those of the base of the tongue. Promising results have been obtained in preliminary experiments. In this paper, we shall compare specifications of the three types of fiberscopes and describe some technique of observations by the use of them.

I. Specifications of the Fiberscopes

Basic Structure of the Fiberscope

Our specific requirements in the design of the fiberscope were: 1) that it have an outside diameter small enough to pass through the nasal cavity of a normal subject, 2) that it obtain an image with a good enough resolution for the analysis of glottal gestures, 3) that it be provided with a light

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* The superscript numbers refer to the list of references at the end of this paper.

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source of sufficient brightness and light-guide fiberoptics for the motion picture at a moderately high rate such as 50-60 frames per second.

First, the basic structure of the fiberscope which is common in all the three models will be described. Figs. 1 and 2 show the overall view and the structure of the standard model, an improved version of the fiberscope we reported in 1968. The fiberscope consists of two bundles of glass fibers, the light guide and the image guide. The light guide conducts the light for illumination of the field from the light source to the object-side end of the scope. The image guide is a bundle of aligned ("coherent") glass fibers and transmits the image from the object lens to the eye piece of the scope. The thickness of each glass fiber and the number of fibers used, as well as accuracy of correspondence of arrangements at the two ends, are the crucial design factors that determine the image quality. The diameters of the fibers used in our scopes are 9 microns for the image guide, and 22 microns for the light guide.

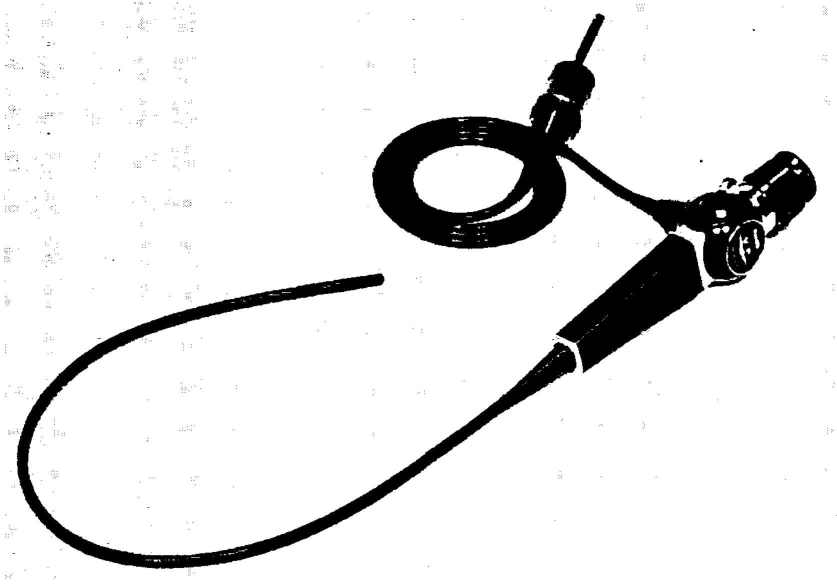

Fig. 1. A photograph of the fiberscope (standard model).

In the object-side end of the scope, there is a hard tip portion which houses the objective lens coupled to the end of the image guide fibers cemented and fixed (Fig. 2B). The optical system is designed to have a straight forward view. The glass fibers of the light guide at this end are arranged so that they form a ring surrounding the objective lens. The tip of the scope has a tapered outer edge for facilitating the insertion through the nasal passage.

A direction control unit (Fig. 2A) has an angle lever connected to a piece of thin wire through which a flexible section of the cable near its hard tip can be bent to desired directions. From the control unit, the light guide is derived forming another flexible cable which leads to the optical connector to the light source. The image guide fibers terminate in the eye piece forming a cemented fixed end, and this end surface is placed in the image plane of the ocular lens. The eyepiece can be connected to a camera or a 16 mm cine-camera by means of an adaptor. A few cine-adaptors are provided for different sizes of the image on the film.

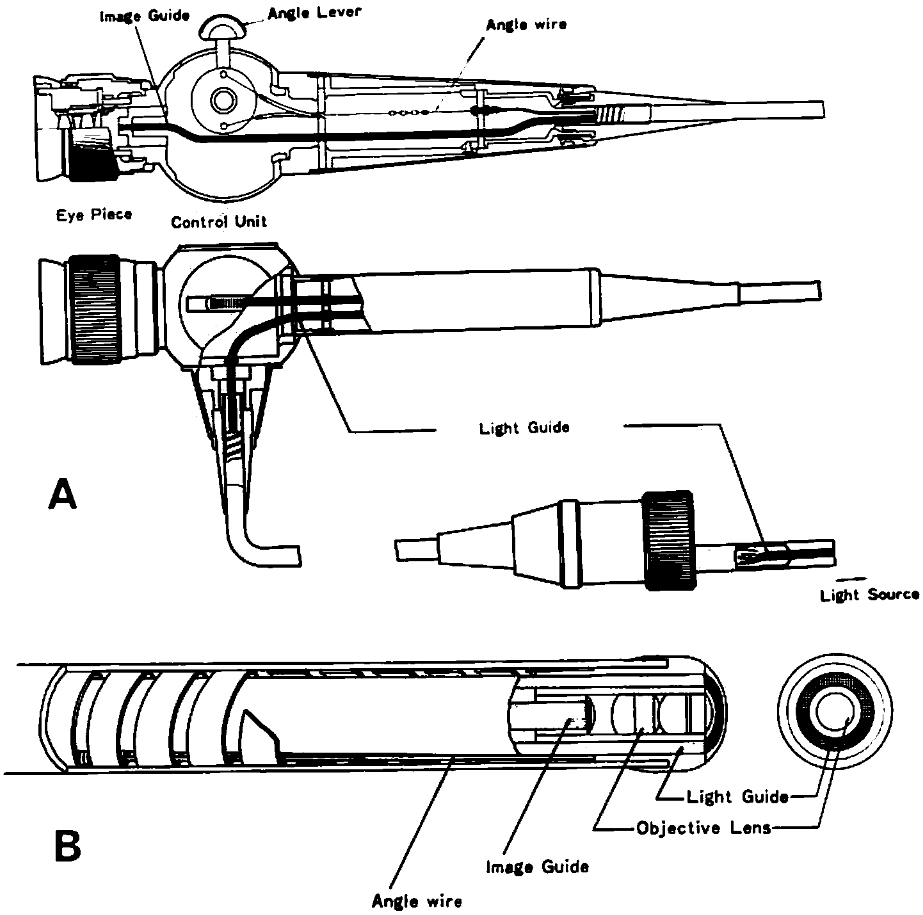

Fig. 2. A schematic drawing of the structure of the fiberscope. A: the control unit and the eye piece, B: the flexible cable and its hard tip in magnification.

The Standard Model

The outside diameter of the cable is 5.5 mm at the hard tip, and 5.3 mm at the flexible portion. The objective lens has an image field angle of 44 degrees which determines the diagonal dimension of the square image field. The object to lens distance is designed to be 15 to 50 mm. Fig. 3B shows a pattern viewed through the scope at a distance of 35 mm. By use of an adaptor for a 4x magnification, the image-carrying end surface of the image guide is projected on the film as a square of approximately 6 x 6 mm^2. For this image size, when a 300W xenon lamp is used as the light source, a sufficient exposure can be obtained at a frame rate of 64 per sec for the motion picture of the glottis at an object distance of about 35 mm with use of a photographic emulsion of ASA 500. Specifications of the fiberscope are listed in Table 1, comparing the three models.

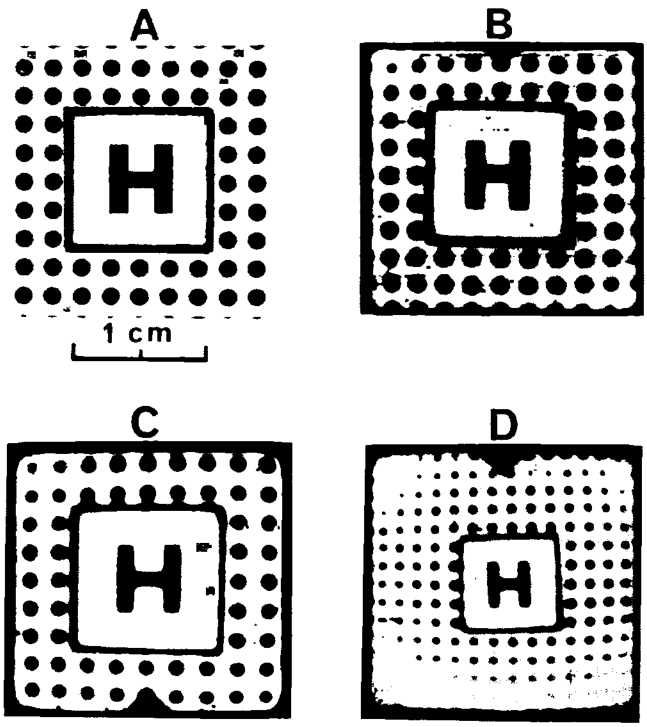

Fig. 3. Images of a test pattern viewed through three types of fiberscopes. A: original pattern, B: by the standard model, C: by the thinner model, D: by the wide-angle model. There are some fiber alignment defects in the standard model used here.

The Thinner Model

This fiberscope has an outside diameter of 4.4 mm at the hard tip of the cable and 4.6 mm at the flexible portion. Our present version has a bending section near the tip giving a bending angle of +30 to -60 degrees. As listed in Table 1, the objective lens gives a range of the object to lens distance of 13-70 mm with approximately the same field angle as the standard model. The smaller outside diameter was accomplished at the expense of the number of the glass fibers in both the image and the light guides, and the image size on the film is approximately $4 \times 4\ mm^2$ with the 4x adaptor. An example of the image viewed through this model is shown in Fig. 3C. By use of the same light source as in the standard model, a rate of 50 frames per sec has been obtained for the glottis at about 35 mm from the lens with use of an emulsion rated at ASA 250.

Table 1: Specifications of the Fiberscope

	Standard Model	Thinner Model	Side-Angle Model
Objective Lens			
Angle of View Field	44°	42°	65°
Range of Observation Distance	15-50 mm	14-70 mm	7-∞ mm
Hard Tip			
Length	12 mm	8.4 mm	7.5 mm
Outside Diameter	5.5 mm	4.4 mm	5.2 mm
Bending Section			
Angle	+0°, -30°	+30°, -60°	+30°, -60°
Length	(35 mm)	(10.8 mm)	12 mm
Outside Diameter	5.1 mm	4.5 mm	5.4 mm
Flexible Cable			
Working Length	557 mm	556 mm	557 mm
Glass Fiber			
Image Guide	9 μ	9 μ	9 μ
Light Guide	22 μ	22 μ	22 μ
Outside Diameter	5.3 mm	4.6 mm	5.6 mm
Eye Piece Magnification			
Visual Observation	22.7 x	22.7 x	22.7 x
Photographic Image	2.5 x, 4 x	2.5 x, 4 x	2.5 x, 4 x

The Wide-Angle Model

This model was designed to observe the movements of the pharyngeal wall and the base of the tongue as well as the larynx. For this purpose, the objective lens gives a view angle of 65 degrees, and the range of the object to lens distance is from 7 mm to infinity. The outside diameter of the scope is comparable with the standard model, while the image size on the film is approximately 4 x 4 mm^2 when a 4 x adaptor is used. Specifications are listed in Table 1, and the image pattern viewed through this fiberscope is exemplified in Fig. 3D. Using the 300W xenon lamp as the light source, a frame rate of 64 per sec has been successfully used for cinegraphy of the pharyngeal view including the larynx with use of an emulsion of ASA 250.

In addition to the original purpose of observing the pharynx, we found this model very useful for examining movements of the velum through the nasal passage. Preliminary data on the movements of the pharyngeal wall and the velum during speech will be reported elsewhere.

II. Positioning of the Fiberscope

Observation of the Larynx

Prior to the insertion of the scope, a surface anesthesia is applied on the mucous membrane of the nasal cavity, the inferior nasal meatus, and the epipharyngeal wall of the subject. The anesthesia is usually not necessary in the mesopharynx or below, and is not recommended in the larynx for normal physiological conditions of the voicing control.

Once the tip of the scope is inserted into the nasal passage, it is easy to push the fiberscope into the epipharynx and down to the hypopharynx leaving the slightly bent tip free for bending. The tip of the scope is placed usually near the level of the tip of the epiglottis as shown in Fig. 4a. A good view of the glottis can be obtained in this position by combining rotation of the cable, and adjustment of the angle lever. Readjustments of the head position is sometimes also helpful in obtaining a good view.

Observation of the Pharyngeal Wall

The anesthesia of the nasal cavity and the epipharynx is applied in the same way as in the observation of the larynx. The tip of the scope in this case is positioned in the mesopharynx as shown in Fig. 4b. Here, we see the lateral and the posterior pharyngeal wall, the base of the tongue, and the larynx and the piriform sinuses through this fiberscope as shown in Fig. 5.

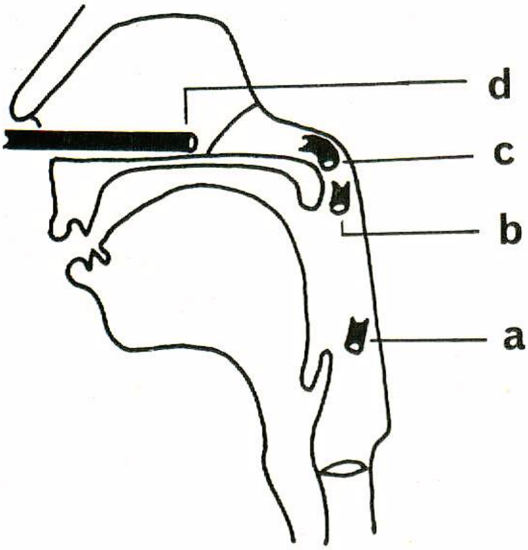

Fig. 4. Positioning of the fiberscope for viewing (a) the larynx, (b) the pharynx, (c) the velopharngeal passage, and (d) the velum.

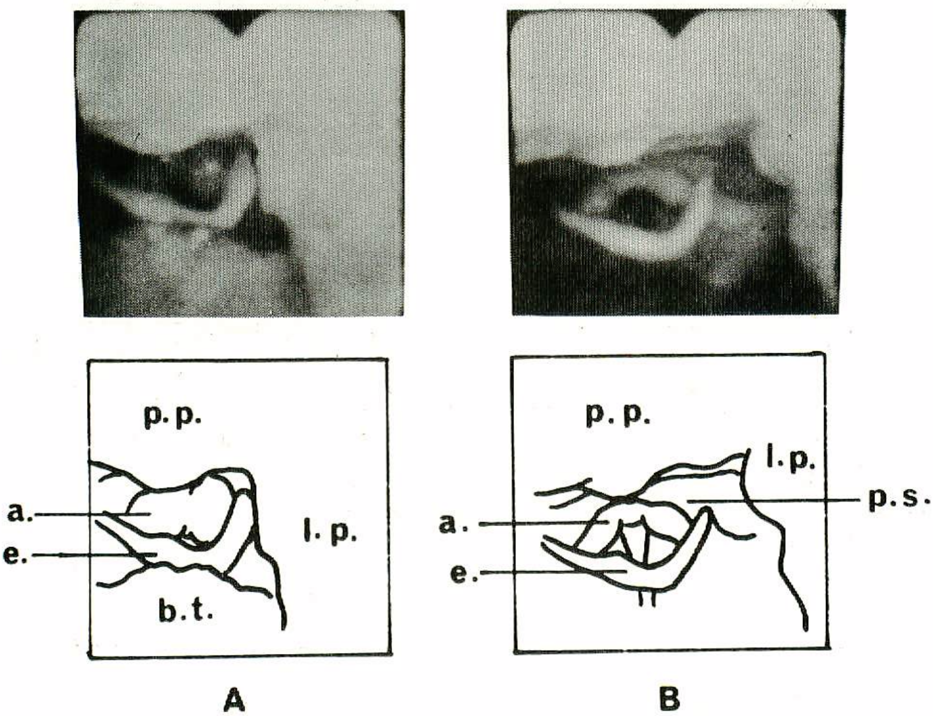

Fig. 5: Pharyngolaryngeal views for articulations of (A)[a] and (B)[s]. p. p. : the posterior pharyngeal wall, l. p. : the lateral pharyngeal wall, a: the arytenoid, e: the epiglottis, b. t. : the base of the tongue.

For an articulation of the vowel [a] (Fig. 5A), the base of the tongue is drawn back pushing the epiglottis to cover the glottis, and the lateral pharyngeal wall shifts toward the midline. Thus a narrowing of the pharyngeal cavity is observed. For an articulation of [s], the base of the tongue moves forward running out of the field. The lateral pharyngeal wall stays on the side, and wide space in the pharynx is observed (Fig. 5B).

Observation of the Velum

The tip of the scope stays in the nasal cavity near the choana (Fig. 4d). In this position, as seen in Fig. 6, the posterior wall of the epipharynx, and the nasal surface of the velum are clearly observed. In Fig. 6A which is for an articulation of [e], the velum is elevated and a convex edge line is seen in the middle of the view field. For [s] (Fig. 6B), the velum is elevated to the extreme, viz. to the upper margin of the field.

A study of the dynamic characteristics of the velar movements in connection with pronunciation of nasal sounds is underway.

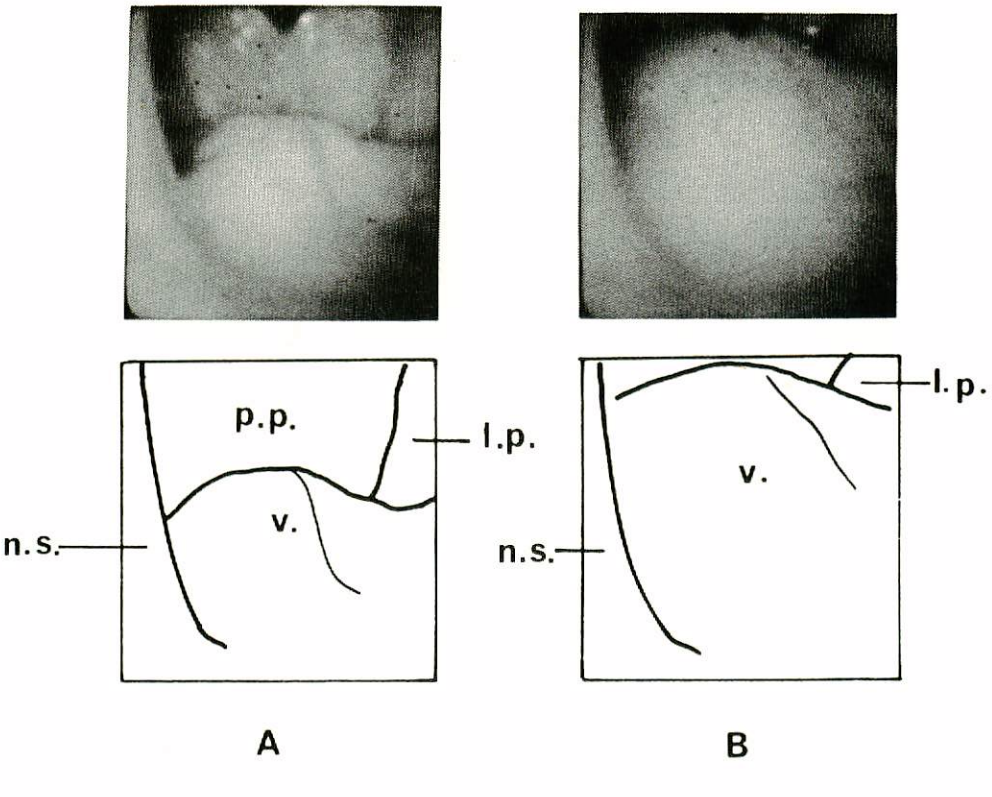

Fig. 6. Elevation of the velum viewed from the nasal cavity in articulations of (A) [e] and (B) [s]. v: the velum, n. s. : the nasal septum, p. p. : the posterior pharyngeal wall, l. p. : the lateral pharyngeal wall.

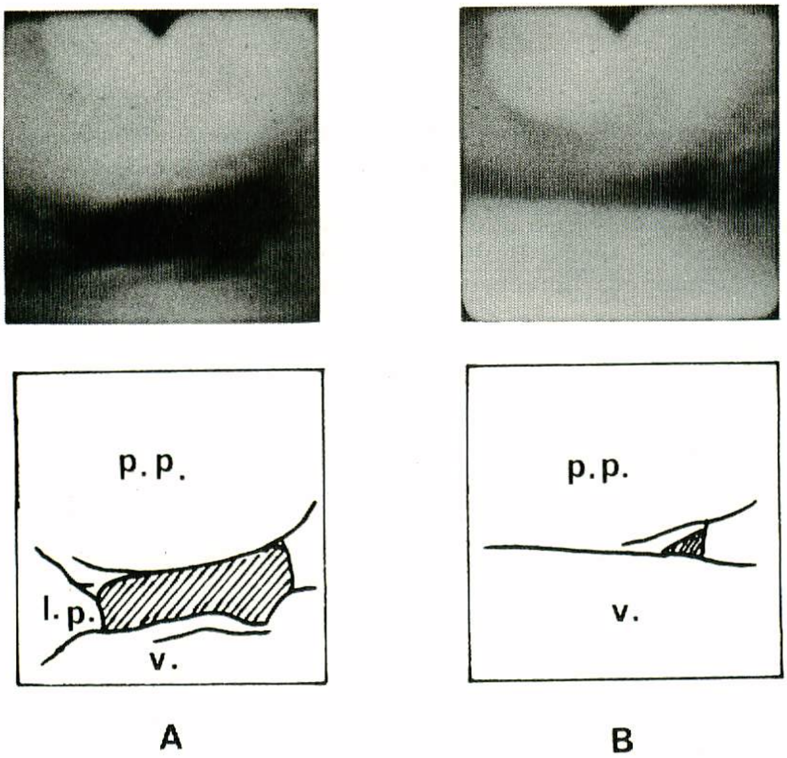

Fig. 7. The velopharyngeal passage viewed from the epipharynx during articulations of (A) [a] and (B) [e]. p. p. : the posterior pharyngeal wall, l. p. : the lateral pharyngeal wall, v. : the velum.

Observation of the Velopharyngeal Passage

The fiberscope is pushed to the posterior pharyngeal wall with the tip bent downward (Fig. 4c). Here we can observe the opening and closing of the velopharyngeal passage during speech articulations. Figure 7A shows the condition in an articulation of the vowel [a] which happens to be slightly nasalized. The velopharyngeal passage in this case is definitely open. For the vowel [e], as shown in Figure 7B, there is a stronger velopharyngeal closure although a slight opening still remains in this case too.

References

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