Externally Induced Vibration on Massive Vocal Fold

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Abstract

For successful performance of phonosurgery, it is most important to maintain the flexibility of the vocal fold. Unfortunately, however, there has been no direct effective method so far for assessing the flexibility of the vocal fold membrane. If the vocal fold surface showed any abnormal region where good vibration could not be observed, reduced flexibility was expected in this area. Hitherto, for observation of the vocal fold vibration, a laryngostroboscope has been in use clinically. However, the laryngostroboscope can not be applied effectively when the patient is unable to phonate for reasons such as under general anesthesia with tracheal tube or when his/her voice is too hoarse to drive a laryngostroboscope well. Instead of observing phonatory vibrations, Fukuda designed a new vibratory method that makes it possible to externally induce wavelike motion on the surface of the vocal fold even under aforementioned unfavorable conditions. In this study, by using the new method, it was possible to observe externally induced vibration on the normal membrane surrounding the abnormal region with mass as well as in the abnormal region itself such as in polyp, cyst, or polypoid degen-
eration. We were also able to examine whether the abnormal regions with mass would have any effect on the vocal fold. As a result, by this method of externally inducing vibration, we were able to detect the mucous membrane lined cavities of the polyp on the surface. The mass had hardly any effect on the normal region.

Key words: flexibility, externally induced vibration, vocal fold with mass, stroboscope

Introduction

Prior to carrying out a laser surgery for early carcinoma of the larynx under general anesthesia, a precise information where the cancer itself invades is requested. Since pathogenesis of carcinoma is likely to result in a stiff vocal fold, the evaluation of the flexibility of the vocal fold membrane is very helpful for making sure of the tumor site.

Up to now, the flexibility of the membrane has been assessed with laryngostroboscopy. As a matter of course, the patient must phonate in this method. Hence, this method cannot be applied when an operation is carried out under general anesthesia or when the voice is too hoarse to drive a laryngostroboscope well. On the other hand, this new method permits us to observe stroboscopically a wavelike motion on the vocal fold membrane, even without the patient’s phonation. In the case of vocal fold with mass such as polyp and cyst, it has been clarified how the existence of the mass affects the wavelike motion on the normal membrane surrounding mass nor how the wavelike motion on the mass itself is observed.

The purpose of this study is to observe the externally induced vibration patterns on the normal membrane surrounding the abnormal region with mass and in the abnormal region itself as well as to examine the patterns of the externally induced vibration on the normal membrane.

Materials and Methods

Fig. 1 shows the study underway.

Fig. 2 shows the vibrator which we designed for clinical use with cooperation of the Nagashima Medical Instrument Company. Vibration frequency stood at 100 Hz and amplitude at less than 5 mm. The externally induced vibration on the fold was observed under stroboscopic illumination. The stroboscope is manually synchronized with the vibrator frequency.

In the case of the vocal fold with mass such as polyp, this observation was made while the patient was under general anesthesia with a direct laryngoscope inserted, or
in other words under almost the same condition as laryngomicrosurgery performance. Under this condition, the vibrator was slightly pushed over the thyroid cartilage in the anterior neck. As a follow up, frequency of luminescence was changed to synchronize with the vibration of the vibrator.
The wavelike motion on the vocal fold was observed on a TV monitor screen and videotaped for further study. Later, some points on the vein of the vocal fold were randomly selected as marks and their movements were analyzed frame by frame. In order to clarify the physical condition of the membrane, two dimensional movements were traced at each point. And the transition of distance between the two points was

Fig. 3 One cycle of the externally induced vibration in the case of the polyp.
analyzed by a microcomputer.

**Results**

1) Result of the wavelike motion of vocal polyp

Fig. 3 indicates six out of 23 frames in one vibration cycle in the case of vocal polyp degeneration.

![Image](image.png)

Fig. 4 One cycle of the externally induced vibration in the case of the polypoid degeneration.
Fig. 5  The result of analysis in the polypoid degeneration.

A:  Point “1” movement along X axis.
B:  Point “1” movement along Y axis.
C:  Point “2” movement along X axis.
D:  Point “2” movement along Y axis.
E:  The change of the distance between 2 points. Both points move periodically in X and Y directions and the periodical shortening and lengthening of the distance between two points are also seen.
polyp. So far it has been difficult to assess the flexibility of polyp itself with the use of laryngostroboscope. With the new method, however, cavities and polyp itself projecting on the surface can be detected which in turn means the flexibility of the polyp can be assessed.

2) Result of the wavelike motion of polypoid vocal fold

Fig. 4 shows frames of one vibratory cycle obtained in the case of polypoid vocal fold. Here, the black points represent the targets used for frame by frame analysis. The phasic movement of these points was traced in two dimensions. Result of this procedure are shown in Fig. 5.

Fig. 5.—Here, X axis is shown in horizontal movement and Y axis, in vertical movement. Fig. 5—(A) indicates the movement of point “1” along axis X. (B), point “1” movement along axis Y. (C), the point “2” movement along axis X, and (D), point “2” movement along axis Y. (E), the change of distance, shortening and lengthening, between two points. Both points move periodically, shortening and lengthening,
Fig. 7 The result in the case of the cyst.
F: Point "3" movement along X axis.
G: Point "3" movement along Y axis.
H: Point "4" movement along X axis.
I: Point "4" movement along Y axis.
J: The change of the distance between 2 points.
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in X and Y directions. The amplitude in this case is larger than that in the normal case. The periodical change in the distance between the two points is also seen in this figure.

3) Result of the wavelike motion of the cyst

Fig. 6 shows the single frame from the cyst. In Fig. 7, the analyses of the vibration at the points in the normal membrane near the cyst (point “3”) and those far from the cyst (point “4”) can be seen here. Both points “3” and “4” indicate the same periodical movement in X and Y directions. The regular shortening and lengthening of the distance between the two points was observed to be the same as that in the normal case. There were no periodical cavities seen in the membrane of the cyst itself.

Discussion

Many studies have been reported in the past on observations of vocal fold vibration. These were mainly classified into two groups depending on the instruments used—one group by stroboscope and the other by ultrahigh speed camera. Saito developed an X-ray stroboscope that enable front view observation of the vocal fold vibration. With this apparatus, Isogai studied the vocal fold vibration and claimed that the principle of the vocal fold vibration was the traveling wave. And Tsuzuki reported that the muscle layer as a vibratory organ did not play an important role in producing sound. The laryngostroboscope can not be applied in an operation performed under general anesthesia or when the voice is too hoarse to drive a laryngostroboscope well.

Hence, Fukuda developed this new method by which the vibrator forces the larynx to vibrate and simultaneously forces the vocal fold to vibrate. This vibration of the vocal fold is observed through a VTR monitor with a laryngostroboscope. The vocal fold flexibility can be assessed by this wavelike motion pattern. The present new method permits us to stroboscopically observe a wavelike motion of the vocal fold membrane even without the patient’s phonation. And it is also applicable to the patient under general anesthesia and thus enable us to observe the vibrations much longer than with the hitherto ordinary methods.

For phonosurgery, obviously it is important to maintain the flexibility of the vocal fold. In the case of stiff vocal fold such as scar formation and early stage carcinoma, the voice quality is too poor to obtain stroboscopic vibration. By clearly spotting the stiff areas of the vocal fold, the extension of tumor is determined more precisely. Fukuda reported that this method would be a valuable aid in performing laser surgery on vocal fold cancer under general anesthesia, and that the vibrations observed would help to determine which part of the vocal fold should be vaporized by laser. He also stated that it was evident and notable that the distance between the two points remained
unchanged in the case of vocal fold cancer while the distance between the two points in the case of vocal polyp changed regularly. That is, the regular change of the distance between two points signify the membrane's flexibility. The flexibility was measured by the distance variation between the two points. Large variation of the distance indicates considerable flexibility. The new method revealed that there was periodical change of distance between the points on polypoid degeneration and movements of each point were amplified. That is, the flexibility of polypoid degeneration had increased.

In the case of vocal fold with mass, we studied to see if the mass had any effect on the externally induced vibrations of the normal area. Therefore, we carried out an experiment to find out if the existence of cyst had any effect on the wavelike motion patterns of normal membrane around cyst. It turned out that the distance between two points on the normal membrane around cyst exhibited regular variation. That is, by the new method, the flexibility of the normal membrane around the mass was assessed and the mass was proven to have hardly affected the wavelike motion pattern of the normal membrane around the mass.

**Conclusion**

This vibration method is effective in observing the flexibility of the vocal fold with mass such as polyp, cyst or polypoid degeneration. Furthermore, the mass hardly affects the wavelike motion of the normal vocal fold membrane around the mass.

**References**

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