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Laryngeal Gestures during Air Trapping

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Abstract

The basic function of the larynx is to close the airway. Laryngeal closure has three functions;(1) to prevent aspiration;(2) to enable phonation; and (3) trap exhaled air inside the thoracic cavity (air trapping). Air trapping thus immobilizes the points of origin of the arm muscles that arise from the chest wall, and also increases abdominal pressure. Many studies have been done from the physiological and pathological standpoints concerning swallowing and phonation, but very little has been done on air trapping. One reason for this is the difficulty of observing the larynx during body movement.

In this paper, we describe the development of an endoscope capable of observing the larynx during various body movements, and observation of the laryngeal state during these movements. The endoscope was complemented by a 3m light guide and an endoscopic camera was designed to be worn by the subject. Using this system, we were able to observe the larynx even during extreme body movements.

Introduction

The study of the larynx was revolutionized in 1854, when Manuel Gracia observed his own larynx. Since then, the indirect laryngoscopy using a flat mirror has been utilized widely. It can be said that modern laryngeal research started with the discovery of the indirect laryngoscope.

More recently, in the clinical setting, direct laryngoscopy and the laryngeal endoscopic fiberscope are also used to observe the larynx. All have their good points and their shortcomings, and are chosen according to the purpose. Indirect laryngoscopy is simple and easy to do, and moreover, produces a non distorted image. Thus it is the most popular method. But, the image is very difficult to record, and since the mirror has to be inserted inside the mouth, there are certain restrictions. Direct laryngoscopy has many constraints because it requires oral-pharyngeal anesthesia and, neck extension. It is advantageous for laryngeal operations, but is unfit for observing the larynx in a normal state.

The fiberscope was designed to observe the in its normal state, with minimal invasiveness. It consists of a light guide to illuminate the larynx, and an image guide to observe the larynx. The image guide is made from fine glass fibers lined up in an orderly fashion. Each of the fibers represents an image pixel, and the resolution is defined by the numbers and density of these fibers. The fiberscope used in our experiment had 20,000 of these fibers. In comparison to the other methods of observing the larynx, the fiberscope has a limit on its resolution. But, because of the flexibility of the scope, and because of its small outer diameter, it can be inserted through the nose and has the following advantages.

1) Observation without relation to the movement of the vocal tracts

Because other endoscope observe the larynx through the mouth, it is only possible to observe the larynx while the mouth is open. Since the fiberscope is inserted through the nose, observations can be made without regard to movement of the vocal tract. Thus, with the development of the fiberscope, the state of the larynx during normal phonation could be examined for the first time, and research in speech pathology and experimental phonetics could be done more easily.

2) Observation without regard to the state of the subject

Clinically, this is an important aspect. It is now possible to observe the larynx of an infant, or a patent in coma, who is uncooperative. Also, it can be used on a subject who has a sensitive pharynx.

3) Body movement within the length of the light guide

Glass fibers are used to guide the illumination from the light source to the larynx. Since the light guide is also flexible, the subject is able to move during the observation, limited only by the length of the light guide.

The basic function of the larynx is the protection of the airway which is essential for existence. From a phylogenetic point of view, the primitive larynx can be seen in the lungfish. It appears as a sphincter, ventral to the gastrointestinal tract. This constricts during swallowing, preventing the influx of food into the respiratory tract (aspiration). In mammals, aspiration is prevented by upward movement and closure of the larynx. This closure of the larynx could be called the basic function of the organ. Another function of the larynx is phonation. During phonation, the larynx closes, and the aerodynamics of the expiratory flow and the viscoelasticity of the tissue generate vibration of the vocal folds. The resulting intermittent expiratory flow becomes the laryngeal fundamental frequency. As noted previously, these functions are both related to closure of the larynx.

Previous studies of the larynx focused on swallowing, respiration, and the phonation. Studies concerning air trapping have been published only by Negus[1]. One reason that this field has not been explored is that, since air trapping is related to body movement, observation of the larynx is difficult to say the least. To advance the study of laryngeal movement during air trapping, a system that could record laryngeal gestures during body movement was needed. In this study, describe a special endoscope and camera that we developed to achieve these goals.

This instrumentation has a number of potential clinical applications. For example, a non-functioning larynx (a bilateral recurrent nerve paralysis), a tracheotomy, or a laryngectomy could affect air trapping. Although papers by Tsukerberg[2] and Gilchrist point to physical power being reduced after laryngectomy, very few experiments have been conducted on this area.

Other clinical applications include evaluation of voice therapy. The pushing exercise is a voice therapy technique designed to reduce glottal inefficiency by increasing glottal closure by means of upper arm exercises. This therapy takes advantage of air trapping to increase glottal resistance, but as Yamaguchi noted in 1993[3], "data documenting how the technique works. ....is scarce or nonexistent".

Methods

(1)Requirements of the observation system

Before designing the system, the following specifications for the observation system were decided upon;

a) Movement should be only minimally restricted during the observations.
b) The observed image would have to be stable during movement, especially head movement. The subject would have to be able to behave naturally. This is an important point, necessary to

achieve normal air trapping and to minimize discomfort for the subject.
c) The image would be recorded with video, and image resolution would have to be high.
d) Simultaneous recording with other data sources (i.e., electromyography) would have to be possible. This is because electromyographic data from the various muscles would be needed to analyze the motor function.

(2) Construction of the endoscope

To satisfy the above requirements, a fiberoptic laryngeal endoscope widely used in the clinical field was modified The light guide was extended to 3m. This is because movement would consist mainly of upper limb movement, and the extent of action was perceived to be under 3m.

Also, to only minimally restrict the actions of the subject, the endoscope and the camera were fixed on the subject's body. This was achieved by placing the endoscope and camera on a helmet and placing it on the subject's head. The helmet used was an ordinary motorcycle helmet sold to the general public.

(3) Description of the endoscope

Total weight (includes CCD camera) 800g
Image guide;
effective length (insertable length);350mm
outer diameter ; 4.1mm
number of fibers ; App.20,000
Light guide;
effective length ; 3m

The developed fiberscope's light guide was extended to 3m to broaden the area of activity of the subject. In principle, it is possible to extent more, but 3m was chosen as the most practical and economical.

(4) Usage

The endoscope with the CCD camera was attached to the helmet that was fixed on top of the subject's head. The image guide was immobilized with adhesive plaster on the nose.

(5) Observation of the larynx

To evaluate the validity of this system, observations during the below movements were made.

1)Rotation of the head (left- light movement)
2)Pull-ups
3)Pole climbing using the upper limbs
4)Brachiation (swinging horizontally from one fixed bar to another)
5)Ken'do(Japanese fencing)
6)Tennis (striking a tennis ball with a tennis racquet)
7)Horizontal bar exercises
8)Vault horse exercises
9)Pushing up against a horizontal bar

Results

The larynx was constantly observable during these movements. The observed larynx is displayed in figures 1 and 2. Figure 1 shows the false cords strongly adducted and closing the glottis. In figure, the glottis is opened the trachea can be seen through the open vocal folds. The laryngeal closure was almost always seen during sudden maximum power movements of the upper limbs. On the other hand, during constant power movements (pull-ups), the state of the larynx varied. Respiration and awareness were thought to have effects during this period. More observations are needed to characterize this state.

During pushing up a horizontal bar, it was confirmed that more power could be extracted during laryngeal closure.(fig.) Since the helmet was attached to the subject's head, it was predicted that the subject would feel the weight of the system, but in the actual experiment, the subject ceased to feel the weight after 10-15 minutes. It was then possible to observe the larynx in the unstressed moving subject. The observation time for each subject was approximately one to two hours. In no cases was it necessary to stop the experiment during the observations, due to any trouble from this system.

Discussion

The concept that air trapping is an important function in life seems to be generally accepted. Air trapping is used as one way to elevate thoracic and abdominal pressure in defecation, labor, urination, coughing and vomiting. Also, from the comparative anatomy point of view, by fixing the thorax, the efficiency of the upper limbs improves.

The relation between upper limb movement or body movement and the larynx is not only important physiologically, but is important medically. From our results, we can predict that laryngetomy patients, bilateral recurrent nerve paralysis patents, and tracheotomy patents would have difficulty in producing maximum force in a short period, and have lower maximum output force. This is consistent with the report by Tsukerberg, who reported a 3-5% decrease in the maximum weight lifted by patients when he measured the weight lifted before and after laryngectomy.

Also, in the pushing exercise, patients who have incomplete vocal folds has not been known. Based on our observations, pushing exercise would have the best results when repeatedly producing maximum force suddenly.

This instrumentation has potential for the study of other areas in the field of vocal therapy, as well. For example, relaxing the muscles of the body on vocal fold tension are not well understood.

Observation of the larynx during body movement would be useful in many clinical areas, as shown above.

The technique and equipment used in this experiment could also be used in the observation of the larynx during normal vocal processes, such as singing, and other instances where normal body movement is especially needed during laryngeal observations.

References

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2) Tsykerberg, L.I.: On the Capacity for Work after Laryngectomy. Probl. Onclo. 6, 820-826, 1960

3) Yamaguchi, H., Yotsukura, Y., Sata, H., Watanabe,Y. et al.: Pushing Exercise Program to Correct Glottal Incompetence. Jour. of Voice,7,250-256, 1993

Figure 1

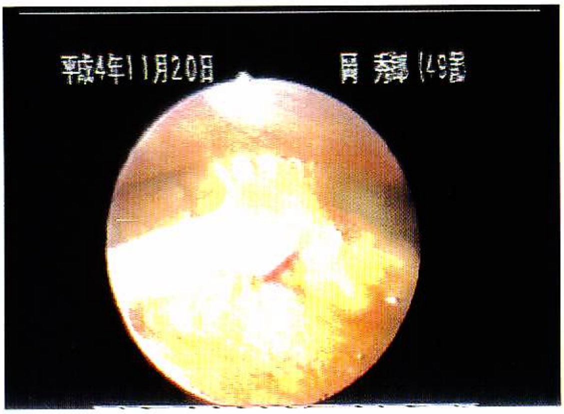

Figure 2

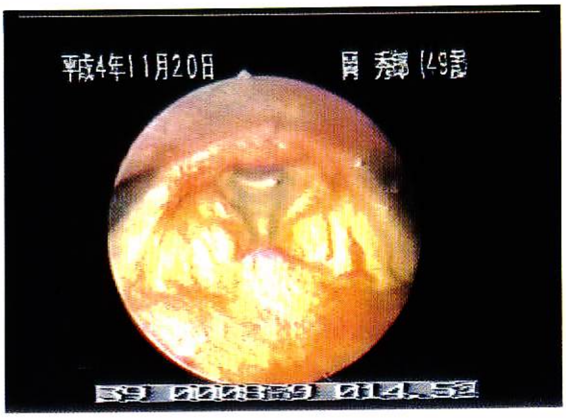

Figure 3