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Introduction

Neither the concept for this volume, nor the term "classic" in the context of science is novel. In 1977, Eugene Garfield's essay entitled, "Introducing *Citation Classics:* The human side of scientific papers" was the first to recognize highly-cited manuscripts and their contribution to science (Garfield, 1977). In this essay, published in *Current Contents*, Garfield described his vision for recognizing those investigators who made significant contributions to science in general. In addition, Garfield compiled a list of the 500 most-cited manuscripts published between 1961 and 1975, including Oliver H. Lowry's 1951 paper on protein quantification, the most-cited in the history of science (Lowry et al., 1951). Although the list is interesting, a significant part of the appeal of Garfield's effort was his idea to solicit commentaries from the authors of these landmark papers. Dr. Garfield requested that authors provide insight into "interesting aspects in the development of their techniques, the role played by coauthors or others, and the encouragement received from colleagues." Commentaries included personal anecdotes regarding the scientific process, obstacles encountered, and often, the author's insight into why their paper has been cited so frequently. Garfield's approach in *Citation Classics* was insightful and fundamentally humanistic, bringing out the personalities behind the affectless, impersonal authorial voice typical of scientific papers. In so doing, he explicitly recognized that these seminal contributions to science were made by individuals, encouraged, inspired, constrained, or thwarted by their training, colleagues, mentors, and environment.

With great admiration for Garfield's work and the precedent he set, we present *Classics in Voice and Laryngology*. We recognize that laryngology and voice science represent a small niche within otolaryngology. As such, it is unlikely that seminal works in the advancement of this field will ever be recognized in the context of *science*, in general. However, many publications have significantly altered the way voice production is conceptualized and changed treatment for patients with voice disorders. In fact, in the period covered by this compilation (1967 to 2007), laryngology and voice science have undergone tremendous expansion and change. One recoils from the phrase "paradigm shift," which is used incontinently these days. Yet it obviously and inescapably applies. Laryngology was one of the first medical specialties, brought to life by the development of the laryngeal mirror. Its early practitioners were reviled and not infrequently expelled by the general medical establishment, which found specialization abhorrent. Not only was laryngology an early specialty, but it established the whole concept of specialization in medicine. Then it fell on hard times. The mastery of infectious disease, especially tuberculosis and syphilis, over a very few decades shrank the nonmalignant caseload, and the field atrophied. For a long period, all that was left to it was laryngeal cancer, and it became a minor subdiscipline of head and neck surgery. Its renaissance has been due to the development of surgical endoscopy and microscopic surgical visualization, the resurgence and refinement of framework surgery, stroboscopy, and dramatic and fundamental insights into anatomy and physiology—in fact, by the very authors and papers honored in this volume.

The goals of *Classics in Voice and Laryngology* are three-fold: (1) to recognize great contributions and contributors to the field, (2) to set down in writing aspects of the evolution of voice science and medicine that might fade with time or never be known, and (3) to provide a compilation of landmark manuscripts for both current and future clinician-scientists. As did Garfield, we feel that the author commentaries prepared especially for this volume are as valuable as the papers themselves.

We owe a debt of gratitude to the many leaders in the field that participated in this project. Originally, we hoped to include commentaries from the authors of every manuscript included as a *Classic*. This proved impossible for many reasons. Instead, we attempted to acquire commentaries from a spectrum of investigators, hopefully representing the broad number of research

interests encompassed within voice and laryngology. Undoubtedly, we omitted commentaries from many leaders, for which we sincerely apologize and ask for understanding.

What is a Classic?

Although we recognize that pure objectivity is not possible, we tried to develop a rigorous, yet simple formula to determine which articles to include. The number of citations required to be labeled a classic in various fields is highly variable. In botany, for example, 100 citations are required. However, in larger fields such as molecular biology, 500 citations may be required. Recognizing that voice and laryngology represent extremely small fields, the number of relevant citations was set, after consultation with leaders in the field and a review of the results of various thresholds, at 50. On one hand, we sought to identify truly significant papers, but also cover the compass of the field, something not well achieved at higher cutoff points. For instance, had the number of citations required for inclusion increased to 100, virtually the entire volume would have been composed of papers on laryngopharyngeal reflux, which is evidently the most hotly-discussed topic in the voice literature in the past 40 years. Even at 50, some omissions, detailed below, gave us pause. But the number of papers had grown such that we did not dare to expand the field.

A classic, therefore, is defined as a scholarly manuscript in the fields of laryngology, vocology, and/or voice science that has been cited in other work more than fifty times. The program Scopus® was employed to determine manuscript eligibility for the title of *Classic*. Using Scopus®, the following key words were used to generate a list of all articles published between 1967 and 2007: voice, voice disorder, dysphonia, larynx, vocal fold, and vocal cord. Acknowledging that keywords are not included in some scholarly publications, we then undertook a review of the references from the selected articles in addition to an author name search. For example, the most highly-cited manuscript included in this text, Dr. Koufman's paper on the otolaryngologic manifestations of gastroesophageal reflux disease, does not include keywords, and would therefore have been omitted by simply utilizing Scopus® alone.

We debated whether to include review articles, position papers, and the like. The argument against is obvious: these are not original contributions. The argument in favor rests solely on their import. In the end, we decided these merited a place; as a distillation of the standard of care, the state of the art, what have you, at a particular point in time, these are undoubtedly influential and serve as significant and explicit points of reference for practitioners and investigators.

Once the list of *Classics* was compiled, we then attempted to categorize the articles according to topic. This process led us to the development of 15 imperfect and occasionally overlapping areas of voice and laryngology. Although most articles fit nicely into one category, in some cases it seemed as though we were trying to fit a square peg into a round hole.

Originally, we wished to reprint all of the articles that met the criteria of a *Classic*. We quickly altered that plan, as the size of such a book was obviously not feasible, and chose to present selected papers only. Here we used editorial judgment, for which we accept full responsibility, guided by a few principles and external constraints. Where there were multiple related publications for the same investigative group, we chose what seemed to be the broadest and most representative publication. Almost always, our choice was validated by the citation count, higher for our selection than that of other similar papers. Elsewhere, the choice was more challenging. We preserved our preference for overviews of an investigator or investigating group's work where possible. We also gave preference, where possible, to works by authors who agreed to provide commentaries. It is worth mentioning that not everyone that we approached agreed to do so. We do not attempt to present explications of their reasons here. Throughout the entire task of electing articles to include *in toto*, we preserved our respect and consideration for the citation counts as objective markers of significance.

We were subject to the significant limitation that certain journals demanded exorbitant fees for reproduction, amounting to four figure sums for single articles that effectively excluded articles published between their covers from this volume. We do not hesitate to say that we find this to be an injustice to their authors, incompatible with the mission of an academic journal, and also just plain shortsighted.

What's Missing?

We understand that the method cannot be perfect, and may not be entirely just. Some of this is by design. For

instance, we excluded a few articles that came up in our search that did not specifically address voice, such as papers on laryngeal cancer that did not concern themselves with voice outcomes. More is by accident. Papers published without abstracts or keywords, like the *New England Journal of Medicine* description of the first laryngeal transplantation, did not register on any of our searches, and were discovered on an incidental crosscheck. We performed such crosschecks for many papers whose omission seemed surprising to us. We hasten to add that neither our surprise nor our estimation were sufficient by themselves to include an article; every one had to meet the citation count. Our ignorance, on the other hand, may have by itself resulted in unfair exclusions. Again, we apologize.

We noted with dismay, but no particular shock, that none of our own papers made the cut. However, we are able to guarantee that these omissions at least are not due to any lack of checking.

By definition, the roster generated for this project is dynamic–the body of classics is constantly shifting by small increments. As time goes on, new publications cite their predecessors, and more papers make the grade. Anyone who wishes to repeat this project in a few years will find either that the resulting volume must be thicker or that the benchmark number of citations will have to change. As a corollary, it takes some maturity and seasoning to be included. Recent developments, such as the angiolytic lasers, at the forefront of discourse now, are invisible in this work. Time will decide whether they are passing fashions or . . . well, classics.

The omission of some topics was puzzling. Microlaryngoscopic surgery—bimanual, magnified endoscopic surgery which takes into account the microanatomic details revealed in recent years—is very poorly represented, for instance. On reflection, though, it becomes clear, no matter how seminal Kleinsasser's book *Microlaryngoscopy and Endolaryngeal Microsurgery*, that these techniques are very poorly represented in the peer-reviewed literature. There are case series justifying its use in various patient groups, papers quibbling over mini-, micro-, and probably nanoflaps, and pieces introducing various pieces of equipment, but none of these are widely cited. Is this because the justification of the technique rests elsewhere, specifically in the paper by Hirano and Sato included in this volume, or because, as we would like to think, the superiority of microlaryngoscopy is so self-evident that it has become the standard of treatment virtually without debate?

Along a similar thread, there are no single reports regarding the efficacy of voice therapy techniques with the exception of Dr. Ramig's LSVT. Given the recent proliferation of high-level behavioral intervention, it is troubling that the literature is essential void of good quality efficacy data. It is also interesting that, in the absence of a single efficacy study, Drs. Ramig and Verdolini provide a comprehensive review of the efficacy data, a true classic manuscript. We hypothesize two potential explanations for this finding. The first is that, until only recently, translational research was unheard of. Communication and collaboration between the ivory tower and the clinic was rare. Looking at the authors on the current list of classics, you can sense the tide of change. Secondly, and perhaps a more persistent issue, is the lack of fundamental metrics by which therapeutic success is determined. The list of classics is relatively sparse on the identification of clinically-viable measures by which to directly or indirectly quantify voice production and the potential for change related to intervention. The reasons are left for another forum; for now, we note the omission.

Obtaining and Assembling Manuscripts

Once the list of articles was compiled and the articles were placed, sometimes awkwardly, into categories, we began the tedious and sometimes disappointing task of obtaining permissions. We wish to acknowledge the many journals and publishers who supported this project and provided permissions for either no charge or for a reasonable rate. A list of these supportive journals and publishing houses is provided below. There are obvious omissions from this list. It is unfortunate that some did not share our vision to recognize those individuals who have shaped our field.

Acta Otolaryngolica
Taylor and Francis Group

Annals of Otology, Rhinology, and Laryngology
Annals Publishing Group

Archives of Otolaryngology-Head and Neck Surgery
American Medical Association

Folia Phoniatricia
Karger Publishing

Journal of Speech, Language and Hearing Research
Journal of Speech and Hearing Research
American Speech, Language, and Hearing Association

Laryngoscope
Lippincott, Williams, & Wilkins

New England Journal of Medicine
Massachusetts Medical Society

Journal of Voice
Otolaryngology-Head and Neck Surgery
American Journal of Medicine
Neuroscience and Biobehavioral Reviews
Elsevier Ltd.

We also wish to thank those individuals who saw merit in the concept of *Classics* for our field and supported it in various ways. Robert T. Sataloff, MD DMA, in his capacity of Editor-in-Chief of *Journal of Voice* and senior statesman in laryngology, intervened with the publisher of several journals to break an impasse in reproduction rights and fees. Tom Murry, PhD provided advice and guidance, and in many respects served as godparent to the project. Last, but in many respects most important, we wish to thank the Singhs and their team at Plural Publishing for their support and encouragement of our vision.

Classics and the Future

As we write, laryngology is gelling into a solid, well-recognized subspecialty in which the clinical and the basic sciences are in communication and in synch to a greater degree than in most other fields of medicine. Various intellectual threads, all represented between these covers, have joined over the past few decades to form an integrated cloth of investigation and patient care. We are excited to be part of it and have found a resonance for our enthusiasm in the many contributors with whom we have interacted in this project. We hope that *Classics in Voice and Laryngology* conveys not only the substance of their contribution, but also some of the intellectual curiosity, process and excitement that has created the momentum that we are benefiting from today. It is certainly a reminder of how far we have come in a very short time, and we hope a touchstone and inspiration for continued advances for the benefit of our patients.

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Commentary

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The original paper[1] was submitted for publication in 1973 and published in 1974. Our studies on the structure and vibration of the vocal fold continued until the end of 1996 when the author retired from his chair as Professor of Otolaryngology. This commentary presents our most recent study results and models.

Morphological Structure of the Human Vocal Fold

The vocal fold comprises the vocalis muscle and mucosa. The mucosa, in turn, is made up of the epithelium and lamina propria. The lamina propria consists of superficial, intermediate and deep layer.

The superficial layer of the lamina propria (Lps), referred to as Reinke's space, is composed chiefly of an amorphous substance and is loose and pliable. The intermediate layer (Lpi) is primarily consists of elastic fibers and the deep layer (Lpd), collagenous fibers. Lps is clearly delineated from Lpi. The border between Lpi and Lpd is not distinct. They together form the vocal ligament. The fibers of Lpd go into the vocalis muscle. Around the edge of the vocal fold, the elastic and collagen fibers in the vocal ligament, as well as the muscle fibers in the vocalis muscle, run roughly parallel to the edge, facilitating vibratory movements.

The findings mentioned above indicate that the vocal fold should be regarded as, at least, a double-layered vibrator consisting of a body made up of the vocalis muscle and the vocal ligament, and the cover consisting of the epithelium and Lps.

Physiological Variations

The mechanical properties of the vocal fold, such as position, shape, mass, tension, and elastic constant, are determined by the intrinsic and extrinsic laryngeal muscles. Among these muscles, the most important in determining the relationship between the body and the cover of the vocal fold are the vocalis and the cricothyroid muscles.

Four typical laryngeal adjustments in terms of the relationship between the body and the cover are proposed in Figure 2 of the reprinted work, which presents schematically frontal sections of the vocal fold during vibration. The vocal fold is deformed to a great extent from the rest state. The first three, Figures 2a, 2b, and 2c, represent condition of heavy or modal register, which is

associated with a more or less marked wavelike movement of the mucosa, or mucosal wave, having up-and-down movements. Two ripples in these pictures present the so-called upper and lower lips, respectively.

In Figire 2a, contraction of both the vocalis and cricothyroid muscles is very weak. This occurs in soft phonation at low pitch levels. The elastic constant of both the body and the cover is small because there is little tension in or on the vocal fold. Both the body and the cover are very flexible, and are almost equally involved in the deformation.

In Figure 2b, the vocalis muscle contracts much more powerfully than the cricothyroid. This happens in loud heavy voice at medium pitch levels. The body is stiff and has a high elastic constant. The cover is slackened and associated with a small elastic constant. Deformation during vibration occurs mainly in the cover, especially the wavelike movement involves only the cover.

Figure 2c represents a group of conditions where contraction of the vocalis muscle is a little more dominant than that of the cricothyroid, that is, conditions between Figures 2a and 2b. This is supposedly the case with most phonation in heavy or modal register. Deformation of the vocal fold, especially the wavelike movement, involves both the body and the cover, but more markedly the cover.

Figure 2d represents conditions for light register or falsetto. The vocals muscle is not active or only slightly active, whereas the cricothyroid contracts powerfully. Both the body and the cover are passively stretched and made tense. Both are associated with a high elasticity constant. In this condition, changes in shape during vibration are smaller than in modal register, and the wavelike movement does not appear.

Needless to say, the expiratory force is one of the most important factors which determine the mode of changes in the vocal fold shape during vibration. Figure 2 shows conditions where the expiratory force is at its optimum.

Pathological Variations

Several pathologic conditions are associated with typical changes in mechanical properties of the vocal fold. The changes, in turn, are reflected as variations in the mode of vibration. A slight or moderate degree of edema in Lps results in a decrease in the elastic constant of the cover. This is recognized as a pronounced wavelike movement under a stroboscopic light or in an ultra-high-speed film. The deformation of the vocal fold during vibration seems to involve the cover to a greater extent than the body.

A carcinomatous lesion of the vocal fold, which is first developed in the cover and invades the body later, causes an increase in the elastic constant of the tissue. This usually results in immobility of the affected portion during phonation. A similar state is also caused by papilloma or hyperkeratosis. It is usually developed from the epithelial layer of the cover.

In recurrent laryngeal nerve paralysis, the vocalis muscle does not contract. Because the cricothyroid muscle is not innervated by the recurrent laryngeal nerve but by the superior laryngeal nerve, a condition similar to that in an adjustment for falsetto may result. In typical cases of recurrent laryngeal nerve paralysis, the wavelike movement is not observed, unless there are no other pathologies, such as edema. When the paralysis persists for a long time, the vocals muscle becomes atrophied, the muscular tissue is replaced by fibrous tissue, and the vocal fold becomes thin. The vocal fold presents a movement similar to that of a flag flapping in the wind. When reinnervation of the vocalis muscle begins (at first, usually in only a fraction of the entire motor units of the muscle), gradual recovery of the wavelike movement is observed.

Summary

Histological findings of the human vocal fold indicate that it can be regarded as a double-structured vibrator that consists of a body and a cover. The mechanical properties of the two structures can vary according to different laryngeal adjustments or pathological conditions. This is reflected by changes in the vibratory mode and consequent variations in the acoustical properties of the glottal sound.

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Morphological Structure of the Vocal Cord as a Vibrator and its Variations

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Various models which simulated vibrating vocal cords have been proposed by several investigators [1, 2, 8, 9, 11]. The degree of similarity of such a model to the real human vocal cord should depend on the purpose of the model. From the physiological or clinical point of view, we need a model which has variable parameters essential to simulate different conditions produced by different laryngeal adjustments or by pathological variations.

In this paper, we will discuss (1) how the morphological structure of the vocal cord should be interpreted, (2) how the mechanical properties of the vocal cord can vary under different laryngeal adjustments, and (3) how the mechanical characteristics of the vocal cord are affected by pathological changes. The discussion is based mainly upon our electromyographic, ultra-high-speed cinematographic and stroboscopic data [3–7] and also upon some previous reports by other investigators [10, 12].

Morphological Structure of the Vocal Cord

Figure 1 presents the histological structure of a human vocal cord in a frontal section. The main part of the vocal cord consists of the vocalis muscle. The vocalis muscle is a stratified, voluntary muscle innervated by the recurrent laryngeal nerve, a branch of the vagus nerve. Its mechanical character varies according to the degree of contraction. The more forceful the degree of contraction becomes, the greater the elasticity constant of the muscle.

Received: February 7, 1973; accepted: August 8, 1973.

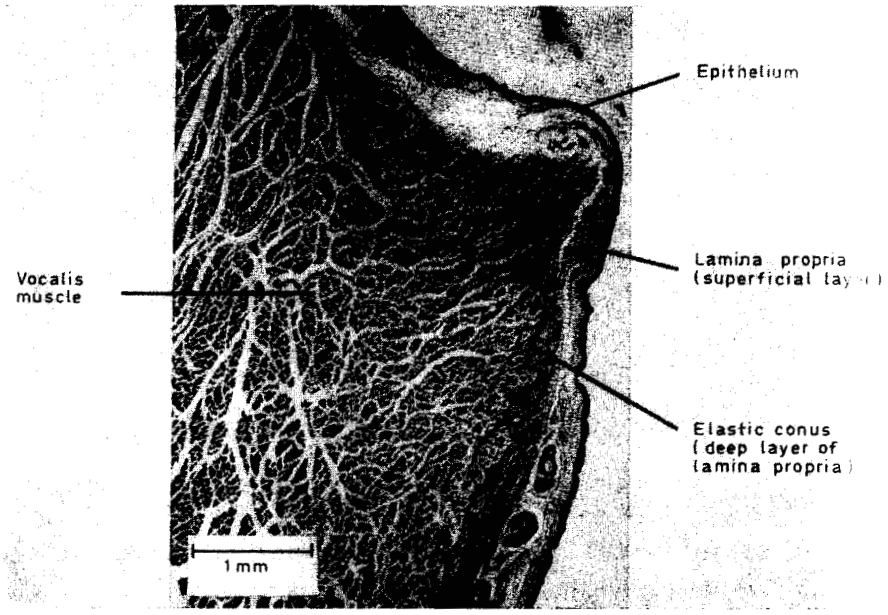

Fig. 1. Histological structure of a human vocal cord. Frontal section. Note that fibers of the elastic conus go into the vocalis muscle, resulting in tight connection of the elastic conus and the vocalis muscle. Note also that the elastic conus and the superficial layer of the lamina propria are connected loosely with each other. The tissue, especially the mucous membrane, should be shrunk by formalin. HE.

The vocalis muscle is covered with the elastic conus. The elastic conus is markedly thick near the edge of the vocal cord. This part is called the vocal ligament. The elastic conus is composed of dense fibrous tissue which in turn consists of collagen and elastic fibers as shown in figure 1. It is important to realize that the fibers of the elastic conus go into the vocalis muscle at many places and merge in the connective tissue between bundles of the muscle fibers. In other words, the elastic conus is tightly connected with the vocalis muscle. Therefore, these two structures appear to move as one unit during vibration.

Superficial to the elastic conus lies the mucous membrane (mucosa) which consists of the very thin epithelial layer and the lamina propria; the latter contains loose connective tissue. The mucous membrane is connected loosely to the elastic conus. Therefore, it can be moved in a different manner from the elastic conus during vibration.

The findings mentioned above indicate that the vocal cord should be regarded as, at least, a double-structured vibrator consisting of a body made up of the vocalis muscle and the elastic conus, and a cover consisting of the mucous membrane.

In many anatomy or laryngology textbooks, the description of vocal cord structure is misleading: the elastic conus is described as a part of the mucous membrane. Although from a histological point of view, the elastic conus might be a part of the mucous membrane, it should be considered as a structure separate from the superficial layer of the mucous membrane when one looks at the vocal cord as a vibrator.

Physiological Variations

The mechanical properties of the vocal cord – such as position, shape, mass, tension, and elastic constant – are determined by the intrinsic and extrinsic laryngeal muscles. Among these muscles, the most important in determining the relationship between the body and the cover of the vocal cord are the vocalis and cricothyroid muscles.

Four typical laryngeal adjustments in terms of the relationship between the body and the cover are proposed in figure 2 which presents schematically frontal sections of the vocal cord during vibration; the vocal cord is deformed to a great extent from the rest state. The first three (fig. 2a, b, c) represent conditions of heavy or modal register which is associated with a more or less

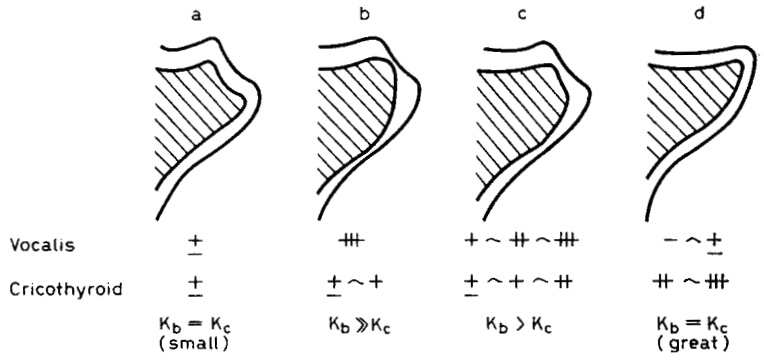

Fig. 2. Four typical laryngeal adjustments in physiological condition which are determined mainly by combinations of different activities of the cricothyroid and the vocalis muscles. K_b = elasticity constant of body; K_c = elasticity constant of cover.

marked wave-like movement of the mucous membrane having an up-and-down movement. Two ripples in these pictures represent the so-called upper and lower lips, respectively.

In figure 2a, contraction of both the vocalis and cricothyroid muscles is very weak. This occurs in soft phonation at low pitch levels. The elastic constant of both the body and the cover is small, since there is little tension in or on the vocal cord. Both the body and the cover are very flexible, and are almost equally involved in the deformation.

In figure 2b, the vocalis muscle contracts much more powerfully than the cricothyroid. This happens in loud heavy voices at medium pitch levels. The body is stiff and has a high elastic constant. The cover is slackened and associated with a small elastic constant. Deformation during vibration occurs mainly in the cover, especially the wave-like movement involves only the cover. This appears to be the condition described by SCHÖNHÄRL [10] based on stroboscopic investigation.

Figure 2c represents a group of conditions where contraction of the vocalis muscle is a little more dominant than that of the cricothyroid – that is, conditions between figure a and b. This is supposedly the case with most phonation in heavy or modal register. Deformation of the vocal cord, especially the wave-like movement, involves both the body and the cover, but more markedly the cover.

The last illustration, figure 2d, represents conditions for light register or falsetto. The vocalis muscle is not active or only slightly active, whereas the cricothyroid muscle contracts powerfully. Both the body and the cover are passively stretched and made tense; both are associated with a high elasticity constant. In this condition, changes in shape during vibration are smaller than in the modal register, and the wave-like movement does not appear.

Needless to say, the expiratory force is one of the most important factors which determine the mode of changes in the vocal cord shape during vibration. Figure 2 shows conditions where the expiratory force is at its optimum.

Pathological Variations

There are several pathological conditions associated with typical changes in mechanical properties of the vocal cord which are, in turn, reflected as variations in the mode of vocal cord vibration.

A slight or moderate degree of edema in the superficial layer of the lamina propria of the mucous membrane results in a decrease in the elastic constant

of the vocal cord cover. This is recognized as a pronounced wave-like movement under a stroboscopic light or in an ultra-high-speed film [6, 7, 10]. The deformation of the vocal cord during vibration seems to involve the cover to a greater extent than the body.

A carcinomatous lesion of the vocal cord, which is first developed in the cover and invades the body later, causes an increase in the elastic constant of the tissue. This usually results in immobility of the affected portion during phonation [6, 7, 10]. A similar state is also caused by papilloma or hyperkeratosis. It is usually developed from the epithelial layer of the cover.

In recurrent laryngeal nerve paralysis, the vocalis muscle does not contract. Since the cricothyroid muscle is not innervated by the recurrent laryngeal nerve but by the superior laryngeal nerve, a condition similar to that in an adjustment for falsetto may result. In typical cases of recurrent laryngeal nerve paralysis, the wave-like movement is not observed, unless there are no other pathologies, such as edema [5–7, 10]. When the paralysis persists for a long time, the vocalis muscle becomes atrophied, the muscular tissue is replaced by fibrous tissue, and the vocal cord becomes thin. The vocal cord presents a movement similar to that of a flag flapping in the wind [7]. When reinnervation of the vocalis muscle begins (at first, usually in only a fraction of the entire motor units of the muscle), gradual recovery of the wave-like movement is observed [10, 11].

Summary

Histological findings of the human vocal cord indicate that it should be regarded as a double-structured vibrator which consists of a body and a cover. The mechanical properties of the two structures can vary according to different laryngeal adjustments or pathological conditions. This is reflected by changes in the vibratory mode and consequent variations in the acoustical properties of the glottal sound.

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