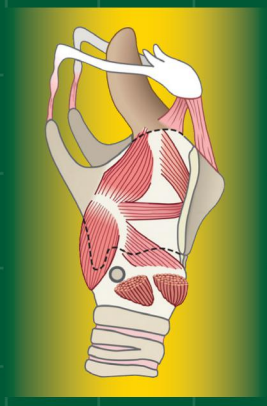
CLINICAL VOICE PATHOLOGY

THEORY AND MANAGEMENT

Sixth Edition



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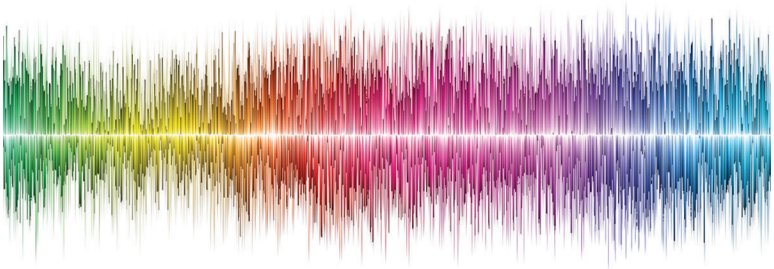

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Contents

Preface

With each new edition of *Clinical Voice Pathology: Theory and Management* comes change, including societal, professional, and educational; this sixth edition is no exception. This is a clinical textbook meant to lay the groundwork for speech-language pathology students to eventually become competent providers for the care and management of patients with voice disorders. As technology rapidly changes, so does our profession evolve: necessary skills are modified and expanded, and research demonstrates new and better methods for evaluation and treatment. Technology has also impacted how students acquire and retain information, and as a result, our teaching approaches must also be modified. To meet these changes, the 6th edition of this text has also been modified to take advantage of technology that will assist both speech-language pathology students and their instructors to build the foundational knowledge necessary to evaluate and treat voice disorders. This knowledge includes the history and common causes of voice disorders, the anatomy and physiology of voice production, pathologies of the vocal mechanism, and an extensive array of evaluation and management approaches.

Changes made to this edition focus on enhancements to instruction and learning, including use of "Call Out" boxes throughout the text to highlight cases, encourage additional thought, and suggest additional readings. There are full color figures and illustrations to enhance learning and understanding of the material as well as a companion website with additional content, including videos of laryngeal pathologies and instructional PowerPoint lectures. In addition to updated references throughout the text to reflect the current state of clinical research in evaluation and treatment of voice disorders, we introduce a new chapter describing the SLP's responsibilities with artificial airways and mechanical ventilation, and an expanded voice therapy chapter, which includes new evidence-based management approaches.

The advances in our field in the past thirty-five years have been extraordinary. However, when one studies the history of our specialty, it is remarkable how much of our past remains constant in terms of assessment and treatment. As an example, with all the available technology to aid in voice evaluation, we would submit that the skilled patient interview remains the most important part of the voice assessment. In the same vein, many of the therapy techniques that we currently use maintain their foundations in skills that were practiced centuries ago to enhance the singing and speaking voices. The advances in our knowledge have significantly enhanced the diagnostic process and have helped confirm whether our chosen treatments are truly effective.

The authors of this text have been privileged to provide clinical services to those with voice disorders, and to contribute to the research for the many

aspects of voice production. While we have had the opportunity to work in interdisciplinary clinical voice centers, side-by-side with our laryngology partners, we fully understand that voice therapy is needed and provided in practically every setting in which speech-language pathologists work. This text is designed to help prepare all clinicians to evaluate and treat voice disorders, and is not limited to only those who specialize in the area of voice. This unique and eclectic population of patients encompasses all ages, across the lifespan, and represents etiologies arising from medical, environmental, social, psychological, and occupational threats to vocal health. Our patients may include typical voice users, occupational voice users, elite vocal performers, individuals with head and neck cancer, and others who suffer with upper airway symptoms. Each patient provides us with a unique diagnostic dilemma: How do we best return the voice to optimal condition?

This text is organized to systematically build the knowledge base and clinical skills necessary to successfully answer this question. We seek to organize, explain, and illustrate the comprehensive hierarchy of knowledge necessary to manage the many types of voice disorders. **Chapter 1** begins with an entertaining history of voice disorders from its ancient foundations to the present. This information clarifies the role speech-language pathologists play in the care of voice-disordered patients and introduces the interdisciplinary background that has permeated our history of successful voice therapy.

The progressive development of essential clinical knowledge areas begins in **Chapter 2,** the anatomy and physiology of voice production. Understanding the structure and function of the laryngeal mechanism is an essential basis for evaluating phonatory function, for examining the larynx and vocal folds, for recognizing the impact of abnormal changes or adaptations on voice production, and for sharing information with our physician partners-in-care. Using enhanced illustrations, this sixth edition updates the descriptions of the three subsystems of voice production, respiration, phonation, and resonance, and expands the discussion of vocal fold histology and DNA microarray gene expression analysis.

Chapter 3 provides a thorough update on the common etiologies of voice disorders, including behavioral, medical, and personality-related etiologies. Common factors associated with the cause and maintenance of voice disorders are discussed in order to understand best options for treatment planning.

Chapter 4 presents the pathologies of the laryngeal mechanism, which are organized according to the *Classification Manual for Voice Disorders-I* developed by Special Interest Division 3 (Voice and Voice Disorders) of the American Speech-Language-Hearing Association (2006). The pathologies are presented in eight major groups: (1) Structural pathologies; (2) Inflammatory conditions; (3) Trauma or injury; (4) Systemic conditions affecting voice; (5) Aerodigestive conditions affective voice; (6) Psychiatric or psychological disorders affecting voice; (7) Neurologic voice disorders and; (8) Other disorders of voice. Many of the pathologies are illustrated with color plates.

Chapters 5 and 6 discuss the objectives and procedures of a systematic diagnostic voice evaluation. Chapter 5 introduces traditional evaluation techniques, including the patient interview, audio-perceptual judgments, patient

self-assessment, determining the cause(s) and maintaining factor(s) of the voice disorder, and educating the patient about these findings to establish a collaborative management plan based on these clinical data. Chapter 6 provides a state-of-the-art overview of the instrumental measures that comprise a comprehensive voice assessment, including the scientific principles that underlie their development, application, and interpretation. In addition to standard measures of acoustics, aerodynamics, electromyography, and stroboscopy, this edition explains the utility of high-speed digital imaging and videokymography tools. The appendix includes instrumental measurement norms and a helpful glossary of terms.

Knowledge of anatomy and physiology, pathologies, etiologies, and the diagnostic process have prepared the reader for **Chapter 7**, which explores an array of voice therapy approaches following the orientations of hygienic, symptomatic, psychogenic, physiologic, and eclectic treatments. Using frequent patient cases to illustrate major insights about voice treatment that we have each gathered from our 30-plus years of clinical experience, we orient the reader to the theories, selection criteria, and clinical methods for specific voice management principles. This treatment framework is appropriate for common, yet diverse, voice complaints due to a variety of laryngeal pathologies and vocal dysfunctions. Finally, we highlight the current clinical evidence that supports popular treatments used in voice therapy.

Because of the exceptional concerns of voice performers, **Chapter 8** introduces the factors that influence clinical management approaches for this artistic population, such as personalities, temperament, performance routines and schedule, and other special considerations needed for their care and treatment. The chapter defines the roles of the expanded interdisciplinary team and identifies the affiliate organizations that represent and support voice performers. In addition to traditional voice therapy considerations, the chapter also discusses nontraditional alternative treatments that are popular with this population.

Chapter 9, "Rehabilitation of the Laryngectomized Patient," serves as a stand-alone manual on the management of this special patient population. This chapter reflects the current "best practice" in voice rehabilitation or restoration in head and neck cancer patients. By outlining the complementary roles of the interdisciplinary treatment team, we understand the multiple management goals: cure the disease, select optimal communication methods, ensure safe swallowing, and address any associated physical, social, and emotional changes that affect each patient. The chapter also contains photographs of the latest communication and airway management devices currently on the market.

Finally, new to this text is **Chapter 10,** written by Tammy Wigginton and Mark Finfrock titled, "Artificial Airway and Mechanical Ventilation." It has been our experience that our colleagues who teach voice disorders are often tasked with also teaching information related to the speech-language pathologist's role in treating tracheostomy and ventilator-dependent patients. With the knowledge that there are limited teaching resources related to this area for our field, these authors, a speech-language pathologist and a respiratory therapist respectively, have prepared an excellent chapter that provides an overview

of the basics of the artificial airway, and the dynamics of mechanical ventilation, as it applies to the practice of speech-language pathology.

Over the past four decades, our chosen specialty of clinical voice pathology has expanded greatly within the field of communication disorders. Nonetheless, this sixth edition of our text retains its original purpose: *to provide students and clinicians with a strong foundation of basic voice science infused with a deep clinical understanding of the best methods for assessing and treating voice disorders*. We hope that you, the reader, will find this text clear, informative, and a worthwhile addition to your professional library.

Text development requires a team, and we are deeply indebted to our team, Angie Singh, Kalie Koscielak, and Valerie Johns, for encouraging and supporting this sixth edition, and to Linda Shapiro, Lori Asbury, and Jessica Bristow on the production side of the text preparation. In addition, we wish to thank our students and colleagues who have suggested ways to improve the text with each new writing. As always, we are most appreciative for the support of our families. Finally, it is our patients who have taught us so much about what is important in the care of their voices, and to whom we are greatly indebted.

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Chapter 10

Voice: A Historical Perspective

INTRODUCTION

Voice, articulation, and language are the major elements of human speech production. When a disorder related to any of these elements is present, the ability to communicate may be impaired. Voice is the element of speech that provides the speaker with the vibratory signal upon which speech is carried. Regarded as magical and mystical in ancient times, today the production of voice is viewed as both a powerful communication tool and an artistic medium. It serves as the melody of our speech and provides expression, feeling, intent, and mood to our daily-articulated thoughts. As it is expressed artistically through the many varieties of vocal performance, voice provides great expression and joy for both the listener and the performer.

Call-Out Box 1–1

You can change the meaning or intent of a phrase by simply changing your vocal expression using vocal pitch, loudness, and inflection. Say the phrase, "My roommate is moving out at the end of the semester," as if you are happy, then sad, then disgusted. See how the manner of voice production influences the meaning of your words.

This text is concerned with the study of both normal and disordered voice production. It is meant to introduce the reader to the science of voice production, the causes of voice disorders, and the pathologies of vocal function. You will explore methods of evaluation of voice disorders and delve into the wide array of management techniques; all are designed to return the

pathologic voice to an improved state of equilibrium. Treating voice disorders is extremely rewarding. The vast majority of patients with vocal difficulties, who follow the prescribed treatment plans, significantly improve their voice quality in a relatively short period of time.

Call-Out Box 1–2

List professions that you think would require a high vocal demand. List professions that would require a lesser vocal demand.

Definition of a Voice Disorder

The historical definition states that a voice disorder exists when a person's quality, pitch, and loudness differ from those of similar age, gender, cultural background, and geographic location.[1–4] In other words, when the perceptual properties of voice are so deviant that they draw attention to the speaker, a voice disorder may be present. We would further suggest that a voice disorder may also exist when the structure and/or function of the laryngeal mechanism no longer meet the voicing requirements established for the mechanism by the speaker. These requirements include vocal difficulties that others do not readily recognize, such as the negative effects of vocal fatigue, or instability in the singing voice, but are reported to be present by the speaker.

The effects of a voice disorder depend on the voicing needs of the individual. Those with a great need for normal voice production, such as professional voice users, may be unusually concerned with the presence of even minor vocal difficulties. Those with low vocal needs may not be greatly concerned with even more severe vocal problems. Identifying the vocal needs of each patient is extremely important in successfully treating voice disorders.[5] Successful management of a voice disorder is dependent on the individual recognizing the problem and accepting the need for improvement.

Role and Skills of the Speech-Language Pathologist

The speech-language pathologist (SLP) plays a major role in the evaluation and management of voice disorders. This role focuses on three major goals: (1) evaluation of laryngeal function using auditory and visual perceptual tasks, acoustic analysis, aerodynamic measures of vocal function, and patient self-assessment;[6] (2) identification and modification, or elimination, of the functional causes that have led to the development of the voice disorder; and (3) developing a therapy plan that will remediate the voice disorder and return the voice to improved function. To accomplish these goals, SLPs must have an extensive understanding and knowledge of the normal anatomy and physiology of the laryngeal mechanism, as well as knowledge of common laryngeal pathologies. They also must understand etiologic factors that lead to the development of voice disorders, as well as appropriate diagnostic techniques and skills for discovering the causes. Finally, based on the previous knowledge, SLPs must develop a bank of clinical management approaches for remediating the voice disorder.

Speech-language pathologists have been involved in the evaluation and management of voice disorders since the beginning of our profession in the

1930s.[7,8] The advent of voice therapy was a unique blend of the knowledge that speech correctionists, as speech-language pathologists were then called, gained from training in the areas of public speaking, oral interpretation, and theater arts. This training was combined with a firm understanding in the areas of anatomy, physiology, psychology, and pathologies of the laryngeal mechanism. In more recent history, voice pathologists (SLPs who specialize in voice disorders are often called voice pathologists; both terms will be used in this text.) have been required to also gain knowledge in other areas such as vocal fold histology, biomechanics of laryngeal tissue, voice acoustics, aerodynamics of voice production, and visual imaging and interpretation of vocal function.[9–13] These years, during which speech-language pathologists have dealt with the remediation of voice disorders, represent only a small segment of time when compared with the total history of the evaluation and treatment of voice disorders. We begin by looking at the past as a means of gaining an understanding and appreciation of the current knowledge of clinical voice pathology.

ANCIENT HISTORY

Folklore Remedies

The earliest accounts of voice disorders, as with other medical information, were handed down orally. These accounts were mainly represented by folk remedies for various recognized disorders. Folklore remedies for disorders of the throat included rubbing liniment derived from centipedes on the neck, gargling the juice of crabs, and inhaling the ashes of a burned swallow. Plant remedies included gargles made from cabbage, garlic, nettles, pennyroyal, and sorrel. Wearing beads of various kinds, or a black silk cord around the throat, was also recommended, as was the excommunication of sore throats in the name of God.[14]

Egyptian Papyri

One of the earliest written histories of a voice disorder was presented about 1600 BC in the Edwin Smith Papyrus. One of many Egyptian papyri discovered in burial tombs, the Edwin Smith Papyrus contained early medical writings. It described 50 traumatic surgical cases, beginning with injuries to the head, and continuing down the body to the thorax. One of these cases was a detailed description of a crushing injury to the neck, which caused the loss of speech. The Egyptian writings contained a hieroglyph portraying the lungs and trachea (Figure 1–1). The larynx

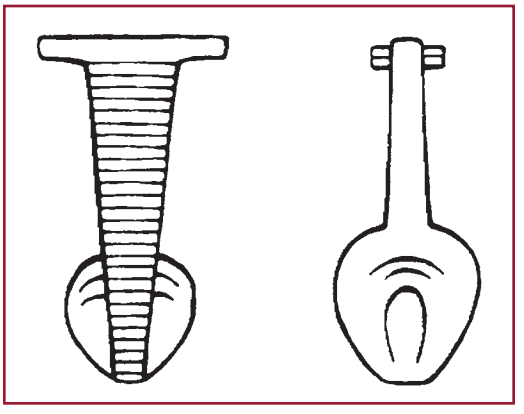

Figure 1–1. Egyptian Hieroglyph of the trachea and lungs.

was not pictured because no organ for voice had yet been identified.[15]

Hindu Writings

The ancient Hindu civilization presented much medical information, including mention of diseases of the throat. The most notable information was presented in the Sanskrit-Atharva-Veda (700 BC). Among the Hindus, surgical achievements included tonsillectomy and rhinoplasty. Nose flaps became a necessity in this civilization because cutting off the nose was the corporal punishment for adultery. Hindu gargles for throat disorders included oils, vinegar, honey, the juices of fruit, and the urine of sacred cows.[16]

Hippocrates

In the fifth century BC, Hippocrates, the "Father of Medicine," (Figure 1–2) was responsible for finally separating medicine from magic. One of Hippocrates' greatest contributions to medicine was his insistence on the value of observation. Hippocrates made many observations regarding diseases associated with the throat and voice, although he, too, failed to identify the source of voice. Several of these observations, as translated by Chadwick and Mann[17] include:

- Aphorism 58: Commotion of the brain, from any cause, is inevitably followed by loss of voice.
- Coan Prognosis 240: Aphonia is of the most serious significance if accompanied by weakness.
- Coan Prognosis 243: Aphonia during fever in the manner of that seen in seizure, associated with a quiet delirium, is fatal.

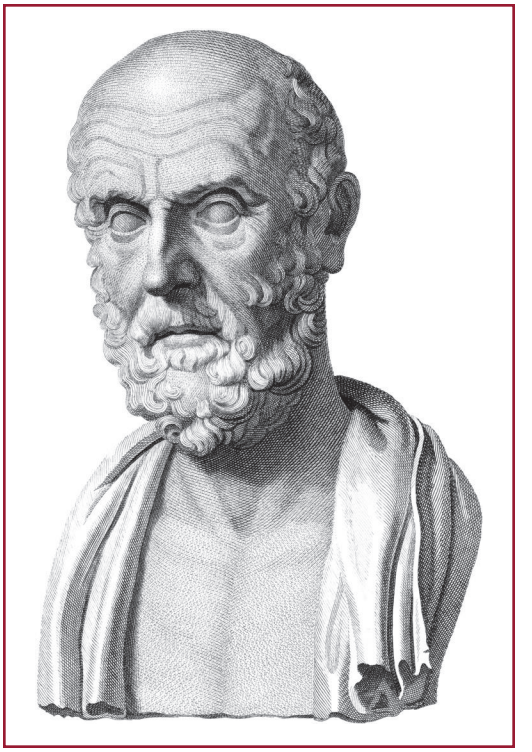

Figure 1–2. Hippocrates, 460–370 BC.

- Coan Prognosis 252: A shrill whining voice and dimness of the eyes denote a spasm.

These examples demonstrate that Hippocrates studied symptoms more than treatments of diseases. Hippocrates was the first person to write that observation of voice quality, whether it be clear or hoarse, is one means by which a physical diagnosis may be reached.[17] Observation of voice quality remains a powerful diagnostic tool to this day.

Aristotle

Aristotle (Figure 1–3) was the first writer to refer to the larynx as the organ from which the voice emanates. In his *Historia Animalium*,[18] written in the late fourth century BC, he stated that the neck was

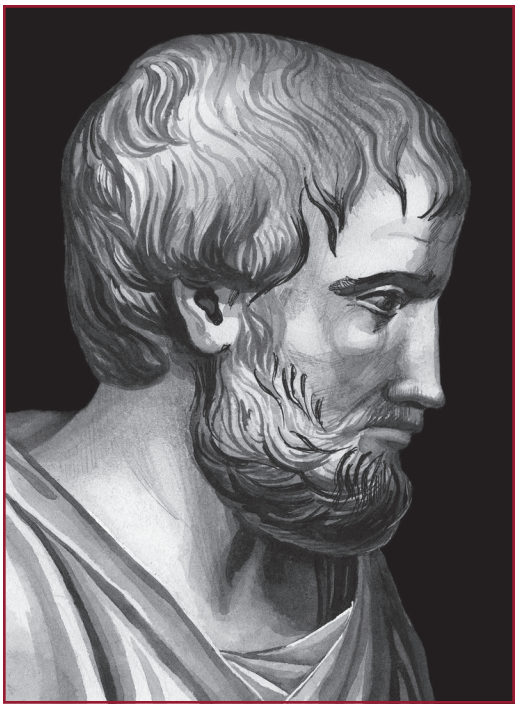

Figure 1–3. Aristotle, 384–322 BC.

the part of the body between the face and the trunk, with the front being the larynx and the back, the gullet. He further stated that phonation and respiration took place through the larynx and the windpipe.

Claudius Galenus

Aristotle's understanding of voice production lay dormant until five centuries later when the first true anatomist, Claudius Galenus (Figure 1–4), was born in Asia Minor in 130 AD. Galen derived his knowledge of anatomy from the dissection of animals. He greatly advanced the knowledge of the upper air passages and the larynx and described the warming and filtering functions of the nose. He also distinguished six pairs of intralaryngeal muscles and divided them

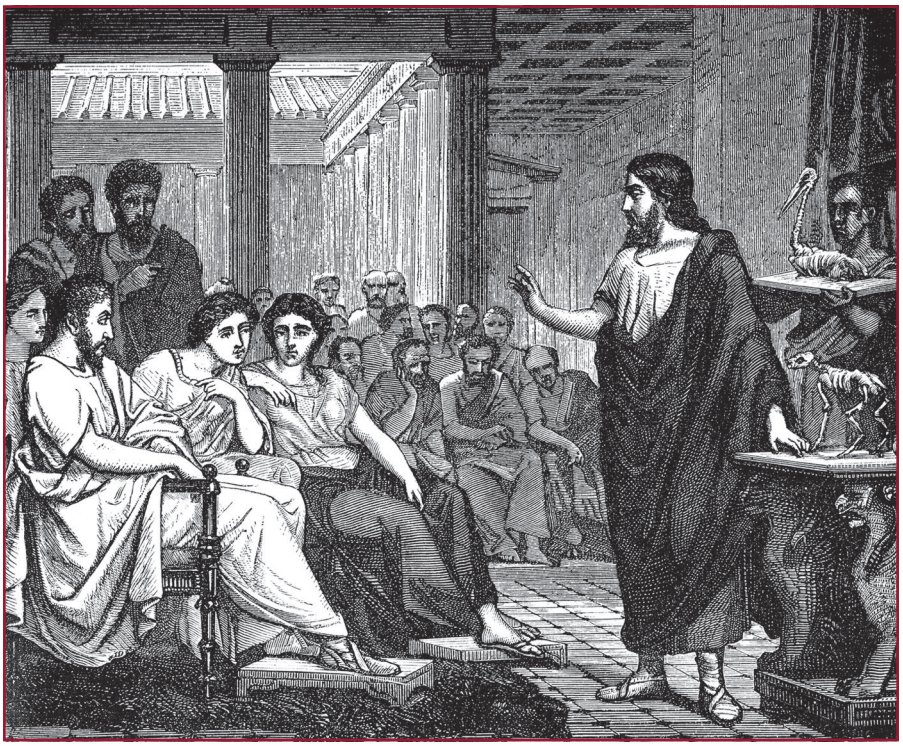

Figure 1–4. Claudius Galenus (Galen), 130–210 AD.

into abductor and adductor muscles. The thyroid, cricoid, and arytenoid cartilages were described, as was the activity of the recurrent laryngeal nerves.[14]

In experiments with pigs, Galen demonstrated that pigs would always cease making squealing sounds when the recurrent laryngeal nerve was severed. This led him to conclude that muscles move certain parts of the body on which breathing and voice depend, and that these muscle movements are dependent on nerves from the brain. Galen, therefore, proved that the larynx was the organ of voice, thus disproving that the "voice was sent forth by the heart,"[14] which was still a popular belief.

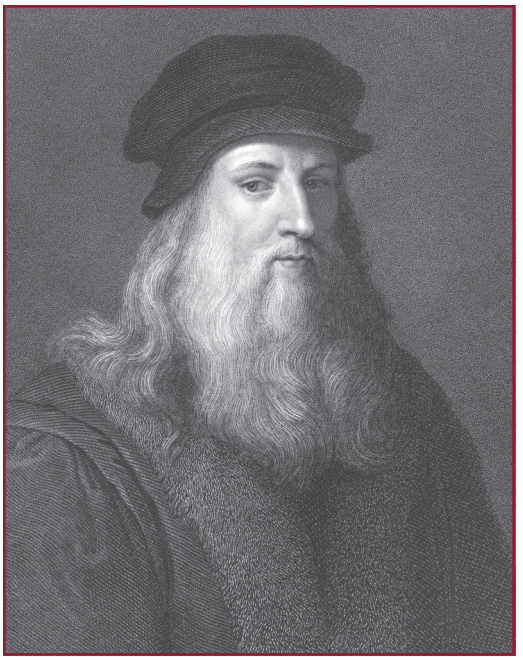

Figure 1–5. Leonardo da Vinci, 1452–1519.

THE RENAISSANCE

Galen did much to further medical progress, but his theories and views, which were by no means totally accurate, were blindly accepted for 1500 years as the world went through the Dark Ages. This historical period of intellectual and artistic stagnation was finally broken in the late 14th and early 15th centuries AD with the invention of the printing press, the astronomic discoveries of Copernicus and Galileo, and the discovery and exploration of the Western Hemisphere. With these and other discoveries, the world began the great growth period known as the Renaissance.

A genius of the Renaissance, the bold artist Leonardo da Vinci (1452–1519; Figure 1–5) did not hesitate to exchange his painting brush for a dissection scalpel to explore the human anatomy. Andreas Vesalius (1514–1564; Figure 1–6) reformed the knowledge of anatomy. In his 1542 publication, *De*

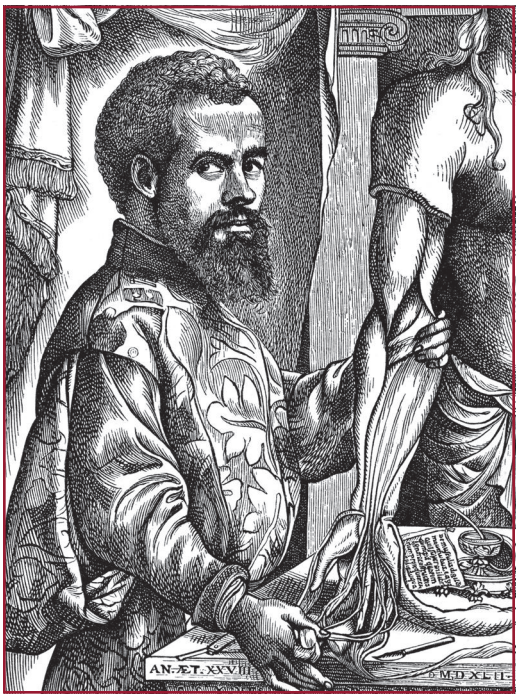

Figure 1–6. Andreas Vesalius, 1514–1564.

Humani Corporis Fabrica,[19] this 29-year-old anatomist and artist corrected many of the age-old errors of Galen. He clarified the laryngeal anatomy and presented the function of the epiglottis. Vesalius' work was considered to be the anatomic classic of his time.[14]

During this time period, Bartolomeus Eustachius (1520–1574; Figure 1–7) was one of the first anatomists to accurately describe the structure, course, and relations of the eustachian tube. More interesting were his descriptions and carvings of the anatomy of the larynx, which were not discovered until the 18th century in the Vatican Library, and are even more detailed and accurate than those of Vesalius. Fabricius, of Padua, Italy, authored the first monograph of the larynx (1600) entitled, *De Visione Auditu*.[20] In his monograph, Fabricius named the posterior cricoarytenoid muscles and described the action of the other laryngeal muscles.

Figure 1–7. Bartolomeus Eustachius, 1520–1574.

THE 17TH TO 19TH CENTURIES

The discoveries of anatomy, physiology, and pathology of the laryngeal mechanism continued, highlighted by descriptions of the laryngeal ventricles by the Italian anatomist Giovanni Morgagni (1682–1771); further clarification of the purpose of the epiglottis by Francois Magendie (1783–1855) of Paris, France; the functions of the laryngeal cartilages and muscles in the production of voice by Robert Willis in Cambridge in 1829; and, finally, in Frederick Ryland's (1837) publication titled, *Treatise on the Disease and Injuries of the Larynx and Trachea*.[20] This important publication clearly described the diseases of the larynx (Figure 1–8) as they were understood before the use of the laryngeal mirror.

THE LARYNGEAL MIRROR

Since the time of Aristotle, many minds had considered the idea of examining the larynx in living humans. It was not until 1854, however, that a Spanish singing teacher named Manuel Garcia (1804–1906; Figure 1–9) made the discovery that ushered in what became known as the modern era of laryngology.

Strolling through the gardens of Palais-Royal on a bright September day, Garcia observed the flashing sun in the windowpanes of the quadrangle buildings:

Figure 1–8. Polyps of the larynx. *Source:* From F. Ryland. *Treatise on the Diseases and Injuries of the Larynx.* London, England: Longmans; 1837.

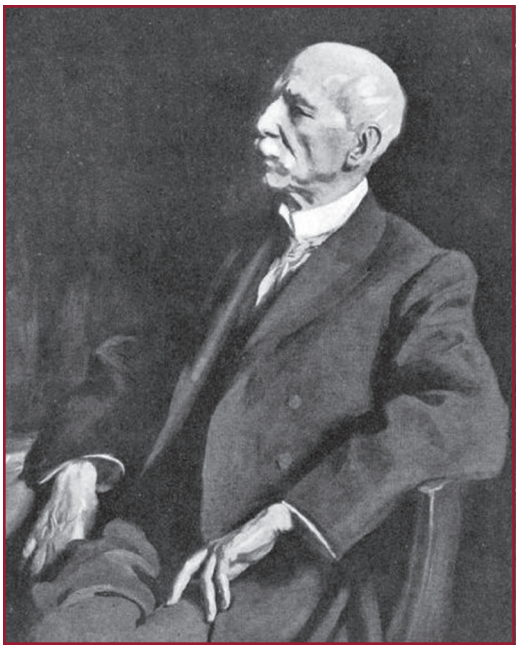

Figure 1–9. Manuel Garcia at age 100 years.

> Suddenly I saw the two mirrors of the laryngoscope in their respective positions, as if actually present before my eyes. I went straight to Charriere, the surgical instrument maker, and asking if he happened to possess a small mirror with a long handle, was informed that he had a little dentist's mirror, which had been one of the failures of the London exhibition of 1851. I bought it for six francs. Having also obtained a hand mirror, I returned home at once, very impatient to begin my experiments. I placed against the uvula the little mirror (which I heated in warm water and carefully dried), then flashing upon its surface with the hand mirror a ray of sunshine, I saw at once, to my great joy, the glottis, wide and open before me, and so fully exposed that I could perceive a portion of the trachea. When my excitement had somewhat subsided, I began to examine what was passing before my eyes. The manner in which the glottis silently opened and shut and moved in the act of phonation, filled me with wonder.[21] M. Garcia

FURTHER ADVANCEMENTS

The use of the laryngeal mirror (Figure 1–10) was taken up quickly in the major medical centers of the world, with the major improvement of artificial illu-

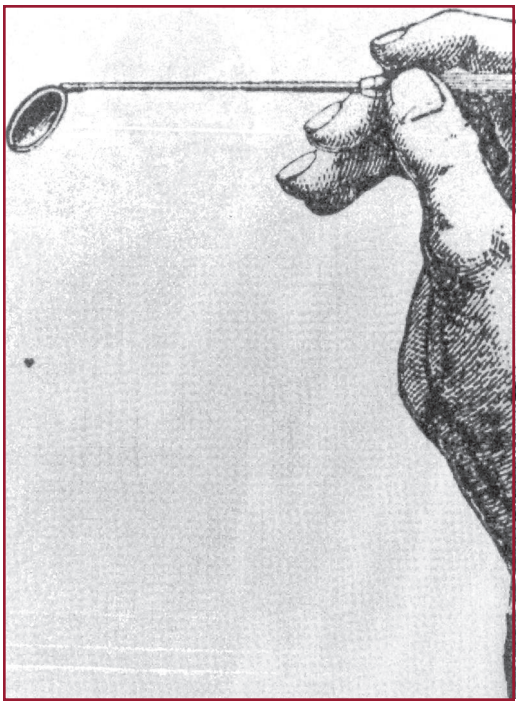

Figure 1–10. The position of the hand with the laryngeal mirror.

mination made in Budapest by Johann Czermak in 1861.[22] The laryngeal mirror was first introduced in the United States in 1858 by Ernst Krakowizer, but credit for the development of laryngology as a specialty in the United States was given to Louis Elsberg of New York, and J. Dobs Cohen of Philadelphia. Elsberg taught laryngoscopy in the University Medical School of New York in the 1860s, and Cohen published the first American textbook on diseases of the throat in 1872. Cohen also performed the first total laryngectomy in the United States.[14]

Other laryngeal examination techniques followed, including stroboscopy (1878), direct laryngoscopy (1895), and ultrahigh-speed photography developed at the Bell Telephone Laboratories in 1937.[23,24] These techniques are further described in Chapters 5 and 6 of this text. Medical treatment of laryngeal pathologies has advanced greatly just in the past 30 years. The philosophy of surgical intervention has changed from one of lesion excision to a philosophy of vocal conservation. Indeed, a subspecialty in otolaryngology was developed, known as phonosurgery, which is defined as surgery to improve voice quality.[25] Special microsurgical instruments have been designed specifically for the purpose of permitting laryngologists to excise laryngeal lesions while maintaining the integrity of the vocal fold mucosa, and thus voice quality. Phonosurgical techniques have also been applied to problems associated with vocal fold closure, such as paralysis and bowing, in an effort to improve voice quality. New procedures and techniques are rapidly developing, leading to improved voice production for a variety of voice disorders.

VOICE THERAPY

The evaluation and treatment of voice disorders remained the province of the medical profession until about 1930. It was at this time that a few laryngologists, as well as singing teachers, instructors in the speech arts, and a fledgling group of speech correctionists became interested in retraining individuals with vocal disorders.[26] Using drills and exercises borrowed from training manuals designed to enhance the normal voice, these specialists attempted to modify the production of the disordered voice. Enterprising teachers created many of these rehabilitation techniques and tailored them to individual students'

needs. The techniques, however, were not based on scientific principles of laryngeal, respiratory, and resonatory physiology. Nonetheless, it is particularly interesting how many of these techniques remain with us today, as testimony to the insight and creativity of early speech pathologists.

In the 1930s, the study and practice of voice therapy were greatly advanced with the publication of two books, *The Rehabilitation of Speech* by West, Kennedy, and Carr,[8] and Charles Van Riper's *Speech Correction Principles and Methods*.[7] In their chapter related to voice disorders, West, Kennedy, and Carr concentrated on the organic problems of voice and diseases related to laryngeal dysfunction. These authors understood that when the voice is disordered, there is always a reason, and if properly studied, the reason will be discovered. Causes of the disorder may be neuropathologic, emotional, or the result of improper vocal habits and structural pathology. To rehabilitate voice, the authors suggested techniques including: (a) ear training, (b) breathing exercises, (c) relaxation training, (d) articulatory compensations, (e) emotional retraining, and (f) special drills and exercises to be used with cleft palate and velopharyngeal insufficiency.

Van Riper stressed remedial measures to be used specifically by speech correctionists. He was the first author to suggest that voice disorders could be classified under the major headings of disorders of pitch, loudness, and quality. Van Riper advocated that voice therapy should follow a medical examination, to rule out organic pathology, and a detailed evaluation of pitch, loudness, and quality. His description of therapy techniques was the most elaborate of the time, and included several general therapy approaches:

- Recognition of the problem by the patient
- Production of a new, more appropriate sound
- Stabilization of the new vocal behavior in many contexts
- Habituation of the new voicing behavior in all situations

These early foundations of voice rehabilitation have evolved into several general voice management orientations. These orientations may be classified as:

- Hygienic voice therapy
- Symptomatic voice therapy
- Psychogenic voice therapy
- Physiologic voice therapy
- Eclectic voice therapy

In short, hygienic voice therapy concentrates on discovering the behavioral causes of the voice disorder, and focuses on modifying or eliminating these causes. Symptomatic voice therapy modifies the deviant vocal symptoms identified by the voice pathologist, such as breathiness, low pitch, glottal attacks, and so on. The focus of psychogenic voice therapy is on the emotional and psychosocial status of the patient, which led to and maintained the voice disorder. The physiologic orientation of voice therapy relies on direct modification of respiration, phonation, and resonance to improve the balance of laryngeal muscle effort to the supportive airflow, as well as the correct focus of the laryngeal tone. Finally, the eclectic approach to voice therapy is the combination of any and all of the previous voice therapy orientations. Indeed,

none of these philosophical orientations is pure. Much overlap is present, often leading, of course, to the use of an eclectic voice therapy approach.

CLINICAL VOICE PATHOLOGY

The role of the speech-language pathologist has expanded significantly in the evaluation and management of voice disorders. Indeed the "voice pathologist" has become an integral part of a team responsible for treating individuals with such disorders. This team is composed primarily of the laryngologist and voice pathologist, with other team members including relevant medical specialists, vocal coaches, and singing instructors. Never before in the history of the treatment of voice disorders have patients had the opportunity for such integrated multidisciplinary care. The physician's medical expertise, combined with the speech-language pathologist's knowledge of speech and voice processes and behavioral management, have significantly improved the accuracy of diagnosis and the management care of patients.

Artistic and Scientific Ingredients of Voice Pathology

This text is designed to introduce and integrate the artistic nature of voice care with the scientific areas of knowledge that are necessary for the development of a "voice pathologist." Voice analysis and treatment is, indeed, a unique blend of art and science. The *artistic nature* of voice care involves sensitive human interactions. The vocal mechanism is quite strong and resilient physiologically, but sensitive psychologically. The voice pathologist must develop a caring compassion, empathy, and understanding for the patient and the problems that the voice disorder creates.

These interaction skills require that a person have the ability to listen to not only the characteristics of the voice quality, but also to what the patient says. In turn, gathering appropriate information related to the voice disorder is dependent on the interview skills of the voice pathologist. Despite many integral parts of a diagnostic voice evaluation, the patient interview remains the most valuable tool in the assessment and remediation of a voice disorder.

Considering the strong relationship between voice production and the emotional state of the patient, the voice pathologist must also develop effective counseling skills. It is common for patients with voice disorders to share personal information regarding their thoughts, feelings, and relationships. Often, this information must be discussed in depth as it relates to the voice problem. The role of the voice pathologist demands that professionals can discuss and consider sensitive issues related to voice. The voice pathologist must also be aware of the potential need to refer emotional concerns to other mental health care professionals, as needed.

Finally, developing and maintaining patient motivation is the "art" of clinical intervention. Motivational skill is the ability to instill action for change. Although many patients come to the voice pathologist highly motivated to

improve voice production, some patients do not. The voice pathologist must have not only the ability to motivate the somewhat noncompliant patient, but also the creativity and perseverance to maintain motivation in those who proceed through the sometimes difficult tasks of therapy. In our experience, the ability to monitor progress through objective measures and laryngeal imaging procedures has significantly improved patient compliance and motivation.

The *scientific nature* of voice care involves a broad knowledge base including:

- normal anatomy and physiology
- laryngeal pathologies
- etiologic correlates
- diagnostic methods including:
  - perceptual assessment
  - vocal acoustics
  - vocal aerodynamics
  - laryngeal imaging techniques
  - patient self-assessment
- therapy methods

The voice pathologist must be completely familiar with the anatomy and physiology of the normal laryngeal mechanism, respiratory system, and supraglottic structures. Based on the specific physiologic needs of the patient, voice management approaches may be planned and implemented. The voice pathologist must learn to recognize various laryngeal pathologies, including their causes, signs, symptoms, and typical management approaches. Laryngeal pathologies encompass a broad range, from tissue lining changes of the vocal fold cover to neurologically induced, psychologically induced, or functionally induced changes in voice production.

The many causes of laryngeal pathologies must also be well understood by the voice pathologist. These causes include behavioral origins, medical etiologies, or psychologically based onset. The voice pathologist who recognizes the critical etiologic correlates will likely be very successful in discovering specific causes of voice disorders, which is the first step in successful remediation.

The ability to objectively measure many aspects of voice production has added important clinical tools in voice evaluation and management. Along with these tools comes the need to develop additional knowledge bases, including knowledge related to the science of voice acoustics, aerodynamics, and laryngeal imaging. Many commercial instruments are available that provide multitudes of measures related to voice production. It is the responsibility of the voice pathologist to understand the science of the specific measures, and to utilize the measures as only one part of the diagnostic voice evaluation. The clinical ear remains the most valuable perceptual assessment tool.

SUMMARY AND CONCLUDING REMARKS

The practice of clinical voice pathology has a deep, rich, and interesting history that continues to rapidly evolve at this writing. By combining the speech-language pathologist's natural artistic abilities related to human interaction skills, an expertise in our knowledge of the upper airway, a strong scientific base, and expertise in behavioral management, the voice pathologist has emerged as a specialist in the treatment of voice disorders. Improved patient care is the ultimate result.

Call-Out Box 1–3

Considering the knowledge base necessary to practice successful voice evaluation and therapy, what foundational coursework has prepared you for this voice disorders course?

Our study of voice production begins in Chapter 2, with the anatomy and physiology of the mechanisms of voice. A complete understanding of this area of knowledge is an essential foundation in the preparation of the clinical voice pathologist.

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Anatomy and Physiology

Knowledge of the anatomy and physiology of the laryngeal mechanism is paramount to understanding voice disorders, and is a foundation for examining the larynx, evaluating phonatory function, and recognizing the impact of abnormal changes or adaptations on voice production. A solid understanding of the normal structure and function of the larynx is the basis for interpreting evaluative findings and developing appropriate voice treatment plans.

ANATOMY

The larynx is essentially a cartilaginous tube that connects inferiorly to the respiratory system, (trachea and lungs), and superiorly to the vocal tract and oral cavity. This orientation in the body is important because it exploits the interactive relationship between these three subsystems of speech: the pulmonary power supply, the laryngeal valve, and the supraglottic vocal tract resonator. When considering the "vocal mechanism," it is common to emphasize the complex and intricate structures of the larynx and vocal folds, but this limited perspective is flawed if it fails to include the broader contributions of subglottic breath support and supraglottic vocal tract resonance. Indeed, vocal function of the larynx relies heavily on the integration of this three-part system: respiration, phonation, and vocal tract resonance (Figure 2–1).

The lungs function as the power supply by providing aerodynamic (subglottal) tracheal pressure that blows the vocal folds apart and sets them into vibration. This vocal fold oscillation provides the sound source for phonation. As the tissues open and close in repeated cycles, the vocal folds modulate subglottal pressure and transglottal flow as short pulses of sound energy. The vocal tract serves as the resonating cavity, which shapes and filters the

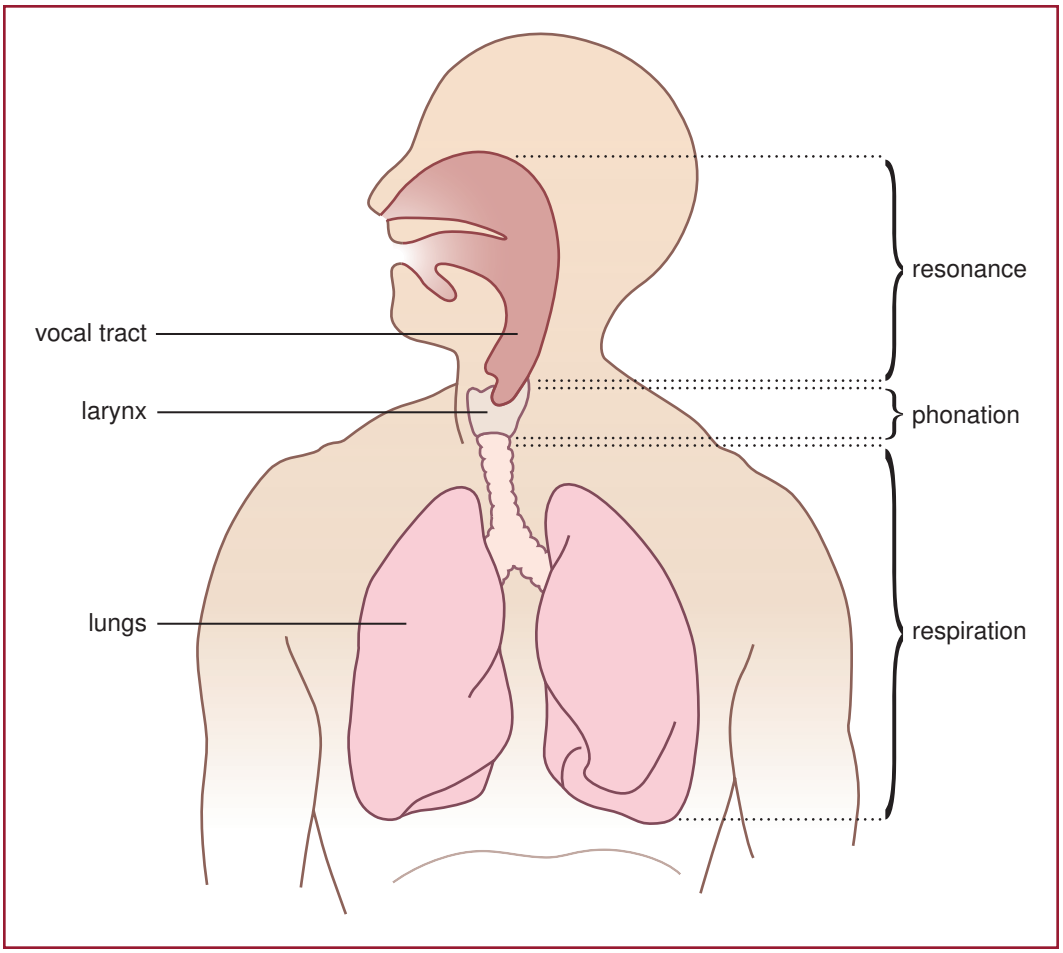


Figure 2–1. Orientation of the larynx in the body, at the juncture between the subglottic trachea and lungs and the supraglottic pharyngeal and oral cavities. These structures form the three subsystems of voice: respiration, phonation, and resonance.

acoustic energy to produce the sound we recognize as human voice.[1–7]

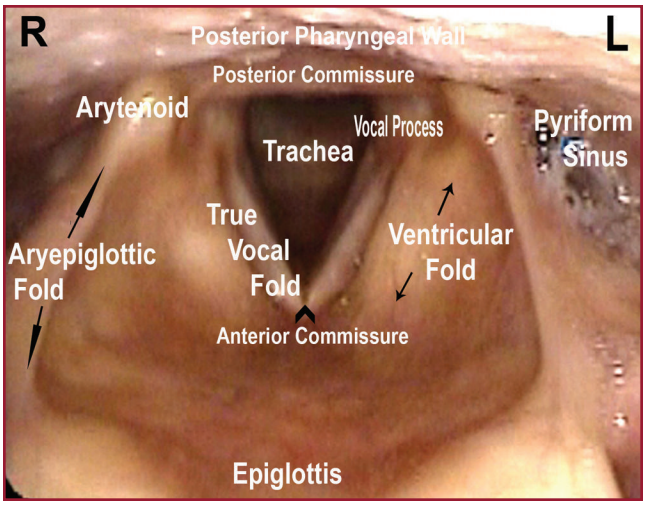
Differential diagnosis of voice disorders requires careful assessment of these three components. Obviously, laryngeal health and vocal function will influence the quality of voice production, but respiratory support and supraglottic resonance will also affect the speech product. For example, adequate or insufficient lung pressure can either maximize or limit vocal fold vibration, respectively. A patient with weak or compromised lung capacity may be unable to generate sufficient subglottal pressure required to produce normal vocal loudness or quality. Similarly, altering the shape and size of the vocal tract can either improve or diminish vocal resonance by enhancing or constricting the phonatory sound source generated by the vocal folds. The loss of either of the subglottal or supraglottal contributions could violate the potential for normal voice quality.[6–7] Indeed, the resulting voice product radiated from

the lips is a truly interactive result of these subsystems: respiration, phonation, and resonance.

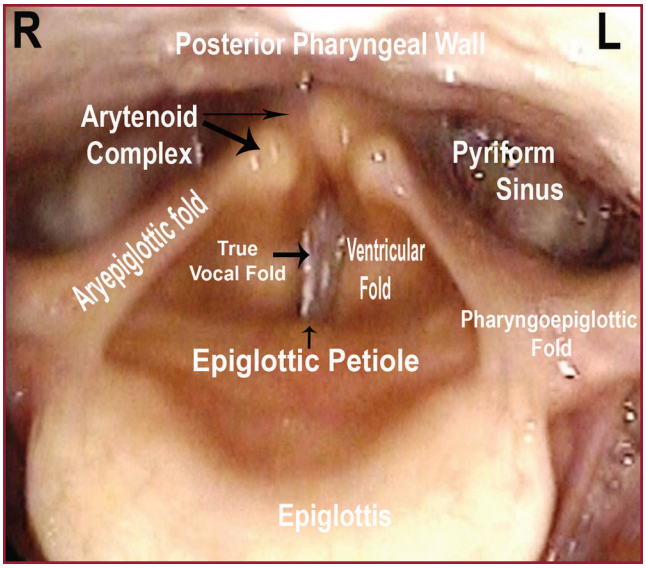
The Laryngeal Valve

The larynx consists of a complex arrangement of cartilages, muscles, connective tissues, and mucosa that allows wide degrees of variation in position, movement, and tension to support three basic functions: airway preservation (opening) for ventilation, airway protection (closing) to block or repel environmental infiltrates, and phonation (vocal fold vibration) for communication and singing. The laryngeal valve achieves these three functions through three levels of "folds" that are best appreciated from an endoscopic view of the larynx (Figure 2–2). Endoscopy permits visualization of internal structures from outside of the body, and it is this view of the larynx that often forms the basis of clinical judgments related to the normalcy of anatomical structure and physiological function. This view of the endolarynx (and surrounding anatomy) shows the vocal folds in their fully open position (A) or closed position (B), and also illustrates the location of each of the three sets of folds (from most superior to most inferior):

1. Aryepiglottic folds connect the anterior attachment of the epiglottis cartilage to the arytenoid cartilages to form the superior border of the circular laryngeal column (Figure 2–3). The upper rim of the larynx is formed by the aryepiglottic folds, which are strong fibrous membranes that connect the lateral walls of the epiglottis to the left and right arytenoid cartilage complexes. When the epiglottis cartilage folds posteriorly and inferiorly over the laryngeal vestibule, it separates the pharynx from the larynx and offers the first line of defense for preserving the airway.[1,2,8,9]
2. Ventricular (or false) folds lie superior and parallel to the true vocal folds just above the ventricles. The ventricular folds form the second sphincter. They are not normally active during phonation but may become hyperfunctional or more prominent during effortful speech production, or extreme vegetative closure. The ventricular folds are directly superior to the ventricles, which function as variable pockets of space above the true vocal folds. The ventricular folds form a "double layer" of medial closure, if needed. The principal function of this sphincter is to increase intrathoracic pressure by blocking the outflow of air from the lungs. For example, the ventricular folds compress tightly during rapid contraction of the thoracic muscles (eg, coughing or sneezing) or for longer durations when building up subglottic pressure to stabilize the thorax during certain physical tasks (eg, lifting, emesis, childbirth, or defecation). The ventricular folds also assist in airway protection during swallowing.[1,2,8,9]
3. True vocal folds open for breathing, close for airway protection, and vibrate to produce sound. The third and final layer of this folding mechanism is the true vocal folds. For speech communication, the vocal folds provide a vibrating source for phonation. They also close tightly for nonspeech and vegetative tasks, such as coughing, throat clearing,



A



B

Figure 2–2. Endoscopic view of the larynx and surrounding structures as observed from above with the vocal folds in the fully open (**A**), and closed (**B**) positions. R = right, L = left.

and grunting, by functioning as a variable valve, modulating airflow as it passes through the vibrating vocal folds during phonation, closing off the trachea and lungs from foods and liquids during swallowing actions, and providing resistance to increased abdominal pressure during effortful activities. The angles of true vocal fold closure are multidimensional and include the potential for valving in both hori-

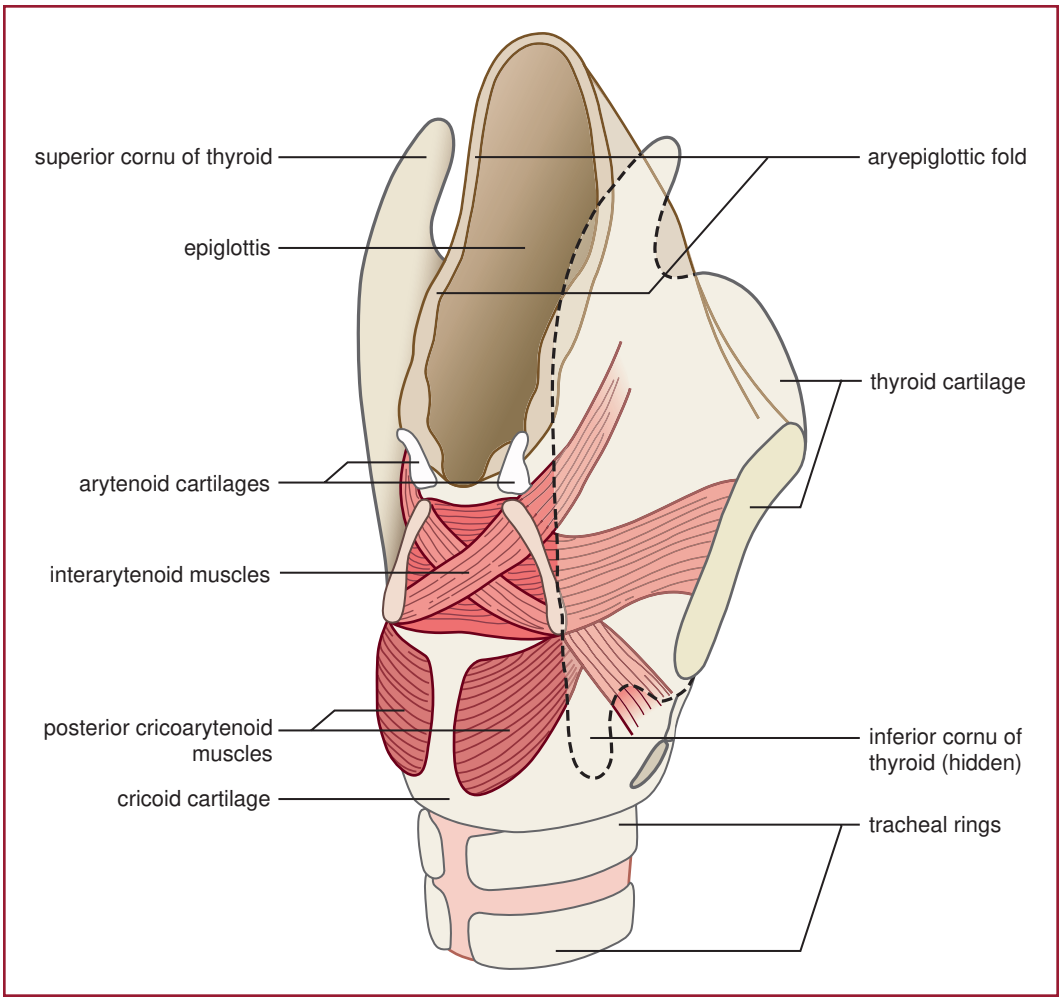


Figure 2–3. Oblique view of the larynx.

zontal and vertical planes, depending on the variable shape, tension, and compression of the medial edge. Communicative maneuvers include narrow and rapid opening and closing gestures to produce momentary phonetic contrasts for voiced and voiceless speech sounds, as well as sustained vocal fold closing to produce vibration for phonation.[1,2,8,9]

All three of these folding structures—the epiglottis, ventricular folds, and true vocal folds—exhibit variable shape, tension, and position to accomplish these communicative and vegetative functions in the body. Together, these three levels of airway preservation and protection perform constant adjustments in the airway aperture (Figure 2–4).

Respiration for Phonation

Vocal fold vibration is the sound source that produces phonation and provides the speech signal. Phonation relies on the pulmonary respiratory power, sup-

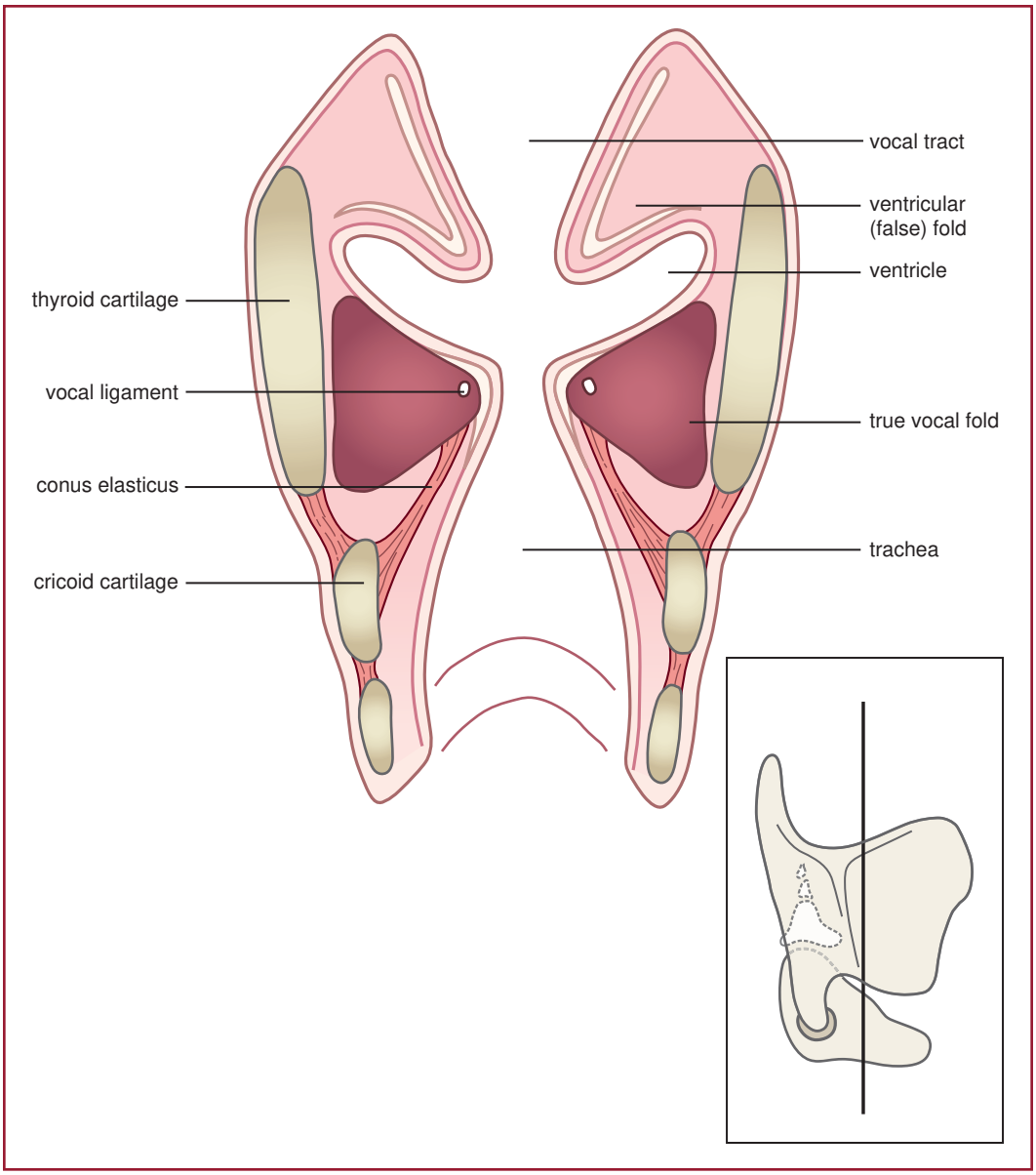


Figure 2–4. Coronal view of the ventricular and true vocal folds. (insert: Coronal plane of Figure 2–5).

ported by the abdominal and thoracic musculature. The lungs are housed within the rib cage in the thorax and separated from the viscera (digestive organs in the abdomen) by a large, dome-shaped muscle called the diaphragm. The bottoms of the lungs are attached to the top of the diaphragm by a double-walled pleural lining. During inhalation, the diaphragm contracts (flattening downward in the body), compressing the viscera, and simultaneously pulling the lungs downward, thereby expanding the lung volume. As

this lung volume expands, air is drawn passively into the lungs. During exhalation, the diaphragm relaxes and rises back up to its resting position, as passive elastic recoil pushes air out of the lungs and upward through the vocal folds and vocal tract. During quiet exhalation, the vocal folds are abducted (opened) in the paramedian position (approximately 60% of the full glottal aperture), so no sound is generated. To exhale for speech, however, the vocal folds adduct (close) at midline, constricting the airflow stream as it exits the lungs. This aerodynamic breath stream builds up pressure below the adducted vocal folds until they are blown apart and set into oscillation, creating the vibratory sound source of phonation.[10–12] Without this airflow, no sustained phonatory sound source can be achieved. The interactive relationship between the subglottal air pressure buildup and transglottal airflow rate passing through the vibrating vocal fold valve influences the overall pitch, loudness, and quality of phonation.[4,5,10–14]

VOCAL TRACT RESONANCE

As sound waves generated by the vocal folds travel through the supraglottic air column into the pharynx, oral and nasal cavities, and across articulatory structures such as the velum, hard palate, tongue, and teeth, the excitation of air molecules within this space creates a phenomenon called resonance. Resonance occurs when sound is reinforced or prolonged as acoustic waveforms reflect off another structure. The model of acoustic energy (phonation) traveling through a filter (vocal tract) modified in variable shape, size, and constriction characteristics (articulatory gestures) is the basis for Fant's *Acoustic Theory of Speech Production*.[15] This theory underlies our understanding of the three components of the acoustic speech product: *glottal sound source* provided by the vibrating vocal folds, coupled with the supraglottic contributions of *vocal tract filtering*, and *resonant characteristics*.[15,16]

The fluctuating dimensions of the vocal tract cross-sectional area, cavity shape, and points of articulatory contact (eg, tongue, teeth, and lips), each have a direct influence on the quality and strength of the acoustic product radiated from the lips, and perceived by listeners. The sound of vocal fold vibration without the supraglottic resonating cavity (for example, in intraoperative conditions or in excised larynx studies) reveals a flat, atonal buzz, devoid of any "ring" and completely unrecognizable as human voice. The contribution of this resonating filter is essential to creating the perceptual attributes of voice, including pitch, loudness, nasality, and quality. Manipulating resonance characteristics by changing the vocal tract shape and oral posturing has been the study of vocal pedagogues, actors, and singers for several centuries.[5,7,11,13–16] Modifying resonance has also been applied directly to voice treatment methods for disordered speakers and professional voice users.[17–20]

STRUCTURAL SUPPORT FOR THE LARYNX

Hyoid Bone

The larynx is composed of a complex system of mucosa, connective tissues,

muscles, and cartilages, all suspended from a single semicircular bone, the hyoid. The hyoid bone marks the superior border of the laryngeal complex of muscles and cartilage. It articulates with the superior cornu of the thyroid cartilage and attaches to the thyroid through the thyrohyoid membrane. Although the hyoid serves as the muscular attachment for many extrinsic muscles of the larynx, it is notable as the sole bone in the body that does not articulate with any other bone. This has an important benefit clinically because chronic elevation of the hyoid can reflect excessive tension of the muscular sling that supports the larynx. Speech-language pathologists and vocal pedagogues may palpate the neck to assess hyoid positioning and monitor vocal tension in patients or performers (Figure 2–5).[1,2,9,10]

Laryngeal Cartilages

There are nine laryngeal cartilages that extend from just below the hyoid bone superiorly to the first tracheal ring inferiorly. Together, these cartilages attach to muscles and connective tissues to form the surrounding columnar housing for the vocal folds. The three largest cartilages are (from most superior to inferior) the epiglottis, thyroid, and cricoid. Additionally, there are three smaller pairs of cartilages that form the posterior wall of the laryngeal column; they are (from most inferior to superior)

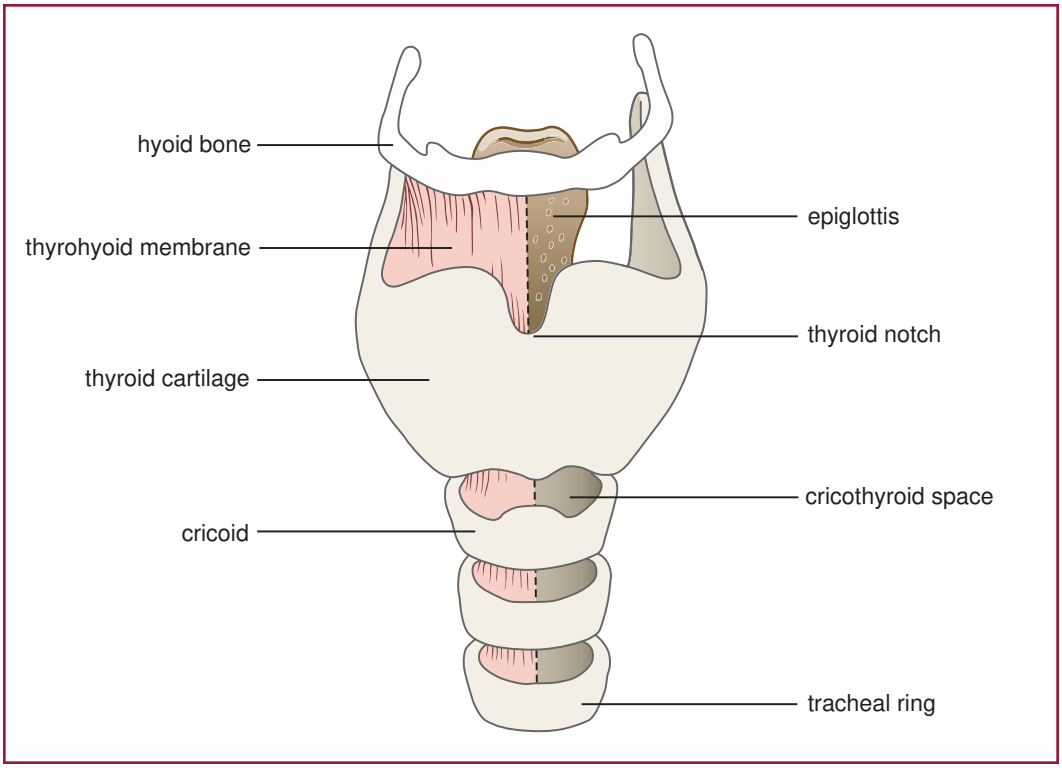


Figure 2–5. Anterior view of the hyoid bone and laryngeal cartilages.

the arytenoid, corniculate, and cuneiform cartilages.

epiglottis

The epiglottis cartilage is shaped like a long leaf, with its narrow base (petiole) attached to the inner portion of the anterior rim of the thyroid cartilage. This attachment allows the blade of the epiglottis cartilage to fold along its midline and move forward and back, closing down inferiorly and posteriorly over the laryngeal vestibule. Although the position of the epiglottis may influence vocal tract resonant properties, the epiglottis normally has no direct role in phonation or communication. Its primary role is airway protection, as it forms the top level of the three tiers of a sphincteric folding mechanism to divert particles of food or liquid away from the glottis during swallowing. Unlike other laryngeal cartilages, the epiglottis is composed of elastic cartilage and, therefore, does not ossify, or harden, with age. This composition is important because this structure must remain flexible throughout life to allow a pliable free edge to assist in closing the airway (Figures 2–6 and 2–7).[1,2,9,10]

Thyroid

The thyroid cartilage is a three-sided saddle-shaped curve that creates the anterior border of the airway column. The thyroid cartilage attaches the true

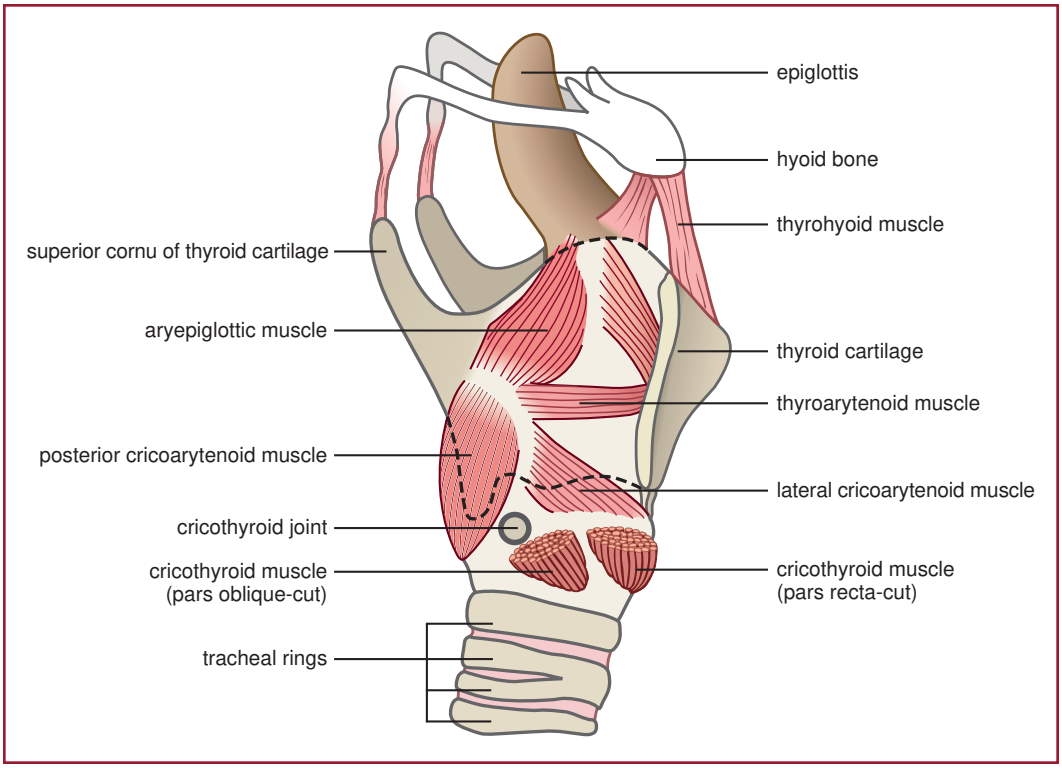


Figure 2–6. Lateral view of the larynx.

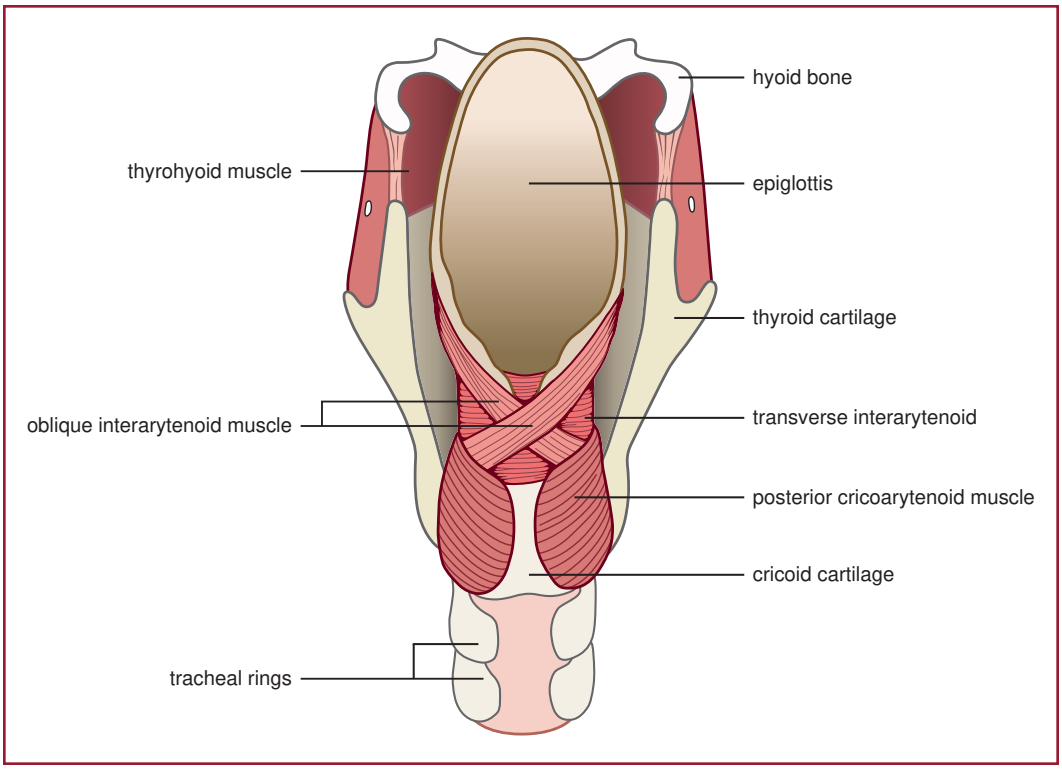


Figure 2–7. Posterior view of the larynx.

vocal folds to the internal rim of the anterior curve. Posteriorly are two superior cornu, or "horns" that extend upward to articulate with the hyoid bone, and two inferior cornu that articulate with the cricoid cartilage below it.[1,2,9,10] The thyroid is composed of hyaline cartilage that ossifies and limits flexibility with age.[21] The lateral walls form quadrilateral plates, called laminae, that attach at the anterior midline in a thyroid notch or prominence. In newborns, these laminae form a curve of about 130°, and the angle becomes more acute with age. A fully matured thyroid angle will be more acute for adult males (90°) than for adult females (110°).[9] In males, the thyroid notch will become more prominent anteriorly, resulting in the characteristic male "Adam's apple." This thyroid notch can be seen or palpated at the front of the neck. Clinically, malposition or aberrant movement of the thyroid notch can signal extrinsic laryngeal muscle hyperfunction, or voice misuse.[18–20]

Cricoid

Below the thyroid cartilage is the cricoid, another hyaline cartilage. It is the only circular cartilage and its shape is described as a "signet ring," with a narrow anterior curve and broad posterior back.

The cricoid sits above the first tracheal ring and provides a stable round entry to the pulmonary airway. The cricoid has two sets of paired facets, or flat surfaces that articulate with the thyroid

Call-Out Box 2–1

In clinical circles, it is quite common for patients to complain of pain and/or discomfort in specific regions of the laryngeal framework. This pain is often a symptom of overactivity of the extrinsic laryngeal muscles. This overactivity may be causal, concomitant, or a consequence of the persistent dysphonia. In fact, during the diagnostic session, many clinicians will palpate the larynx to identify the location and extent of muscle tenderness and pain (see Chapter 5). These sites typically include the major horns of the hyoid bone (bilaterally), within the thyrohyoid space, and over the superior cornu of the thyroid cartilage. Try to identify these sites on your own larynx, and then recruit some of your fellow students, (or friends) and see if you can identify these anatomical landmarks/sites across a variety of larynges. This exercise will help you to appreciate the variation in larynges across people of different genders and body types.

and arytenoid cartilages. The cricothyroid joints connect the lateral facets of the cricoid to the inferior cornu of the thyroid cartilage above it, thus allowing the thyroid cartilage to rock forward from its vertical position. The convex facets on top of the posterior cricoid rim are where the concave pyramidal bases of the paired arytenoid cartilages rest to form the cricoarytenoid joint.[1,2,9,10] Both the cricothyroid and cricoarytenoid joints are lined with a synovial membrane, which provides a connective tissue cushion supplied with secretions for lubrication, blood supply, adipose cells, and lymph tissue. Both articular joint surfaces and the synovial joint membranes do display normal age-related deterioration, although no gender differences have been noted (Figure 2–8).[21–22]

Arytenoids, Corniculates, and Cuneiforms

The three-paired cartilages are the arytenoid, corniculate, and cuneiform cartilages. The arytenoid cartilages are pyramid-shaped, with three quasitriangular surfaces: the anterior, lateral, and medial sides. The arytenoids have a pointed apex on top and a concave base. The anterior points of the arytenoid base project farther forward than the lateral and median sides to form the vocal processes. The bilateral vocal processes form the cartilaginous portions of the vocal fold, and are the posterior points of attachment for the membranous left and right true vocal folds. The arytenoids are composed of hyaline cartilage, except for these vocal processes, which have elastin cartilage at their tips. The lateral arytenoid angles are called the muscular processes because two different intrinsic laryngeal muscles attach in separate locations. When these muscles contract, they move the bilateral vocal processes laterally, to open (abduct), or medially to close (adduct), the vocal folds. The medial arytenoid angle faces its arytenoid pair, forming an even surface for midline glottic closure (Figure 2–9).[1,2,9,10]

The base of the arytenoid cartilage is a concave cylinder, allowing it to articulate smoothly with the convex superior surface of the posterior cricoid cartilage. The arytenoid base fits neatly over the posterior cricoid similar to an empty half cylinder resting over a rounded bar. The movement of the

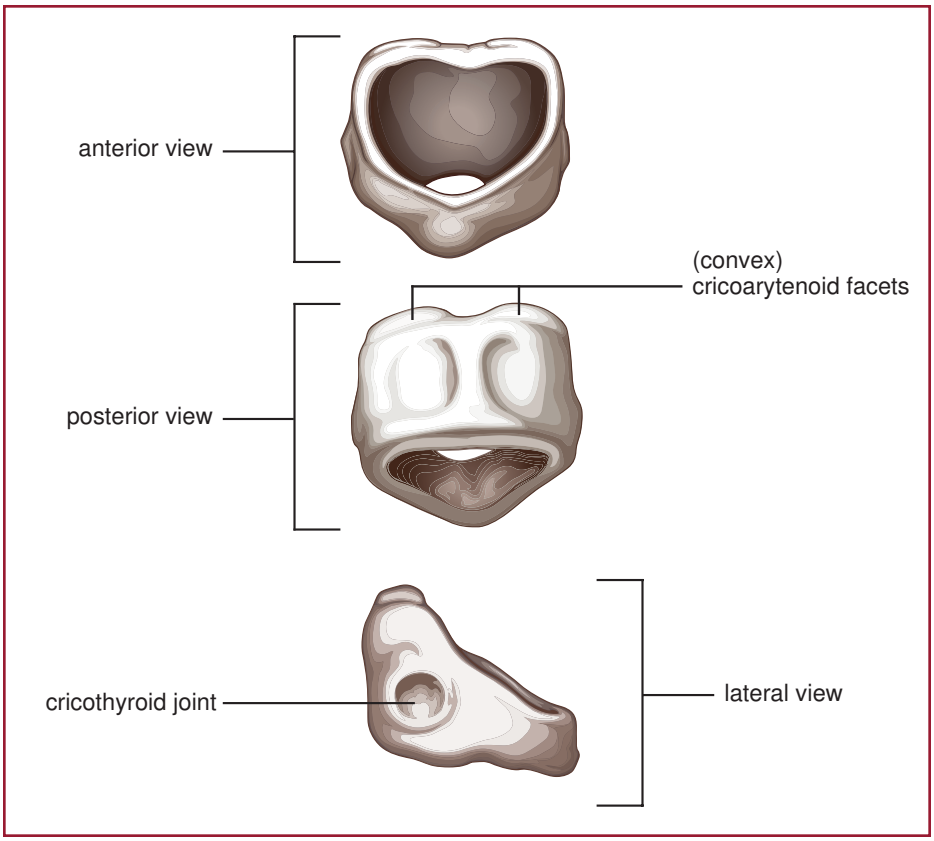


Figure 2–8. Cricoid cartilage: anterior, posterior, and lateral views.

cricoarytenoid joint is complex and has been the subject of discovery and clarification over many years. When the tips of the vocal processes are directed medially (facing each other), normal vocal folds meet at midline and are closed (adducted). When vocal process tips are pointed laterally, the vocal folds are drawn open (abducted). Formerly, these arytenoid movements were thought to rotate on an axis because a superior view of the vocal process tips (that attach to the membranous vocal folds) confirms that the vocal process tips appear to twist medially and laterally. However, that oversimplified presumption is inaccurate. In fact, these movements are not accomplished by simple rotation, but rather, by two separate types of arytenoid motion: rocking and sliding. To understand these degrees of movement, first consider that the concave base (empty half-cylinder) of the arytenoid allows it to rock anteriorly and posteriorly over the superior convex cylindrical cricoid rim (bar). Second, the cricoid rim slopes downward laterally and anteriorly along its circular curve, allowing the arytenoid cartilage to slide in the same lateral and anterior direction to produce these rocking and sliding motions.[1,2,9,10,23,24]

Three different muscles attach to the lateral or posterior facets of the arytenoid base. Their discrete contractions adjust the position of the arytenoid

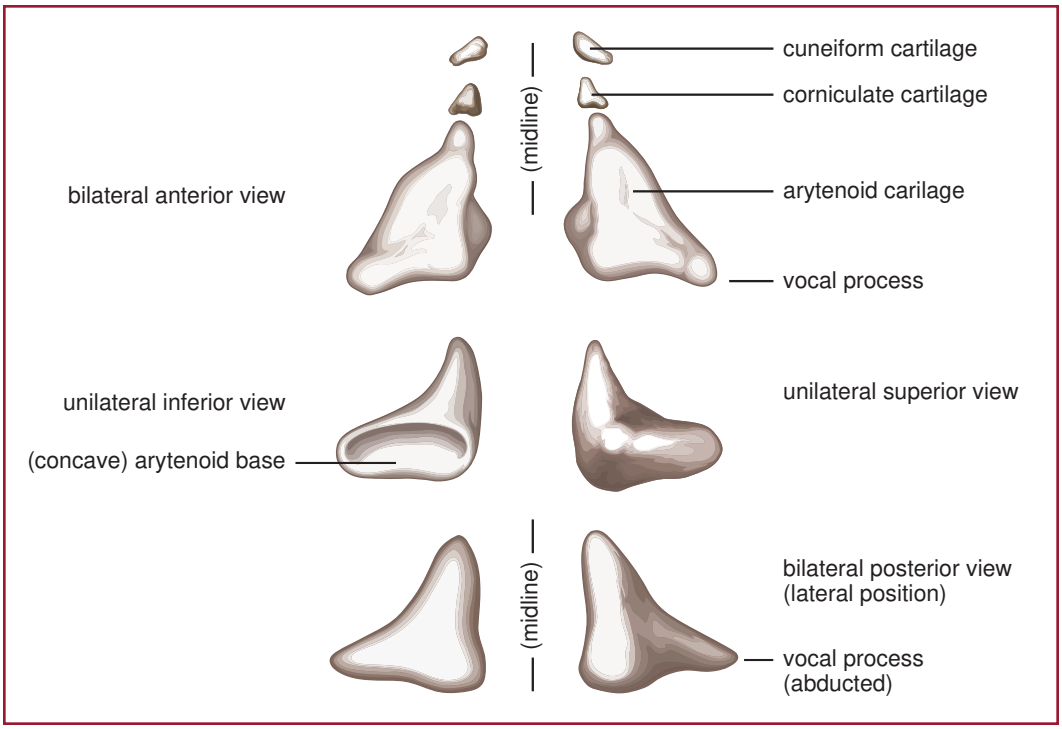


Figure 2–9. Arytenoid cartilage complex: arytenoid, corniculate, and cuneiform cartilages.

base on the cricoid rim and direct the vocal process tips to orient the membranous vocal folds into varying degrees of fully opened, (abducted), to fully closed, (adducted). During this rocking and sliding, the vocal process tips can achieve both the medial and lateral angle orientations needed to adduct or abduct the membranous vocal folds and, consequently, to alter the shape and size of the glottis.[22–24]

The corniculate cartilages, (also called the cartilages of Santorini), are attached by a synovial joint to the superior tips of the arytenoids. The cuneiform cartilages, (also known as the cartilages of Wrisberg), do not articulate with other cartilages, but are embedded in the muscular complex superior to the corniculates. Both of these tiny cartilages consist of hyaline cartilage. They provide no clear function, but may add structure and stability to preserve the airway by extending the column of muscular tissue superiorly to form the posterior border of the aryepiglottic fold.[22–24]

MUSCLES

Muscles for Respiration: Inspiration and Exhalation

The muscles of respiration are divided functionally into muscles of inspiration and expiration. These muscles respond differently in quiet breathing versus respiration for phonation. The muscles of inspiration are (Figure 2–10):

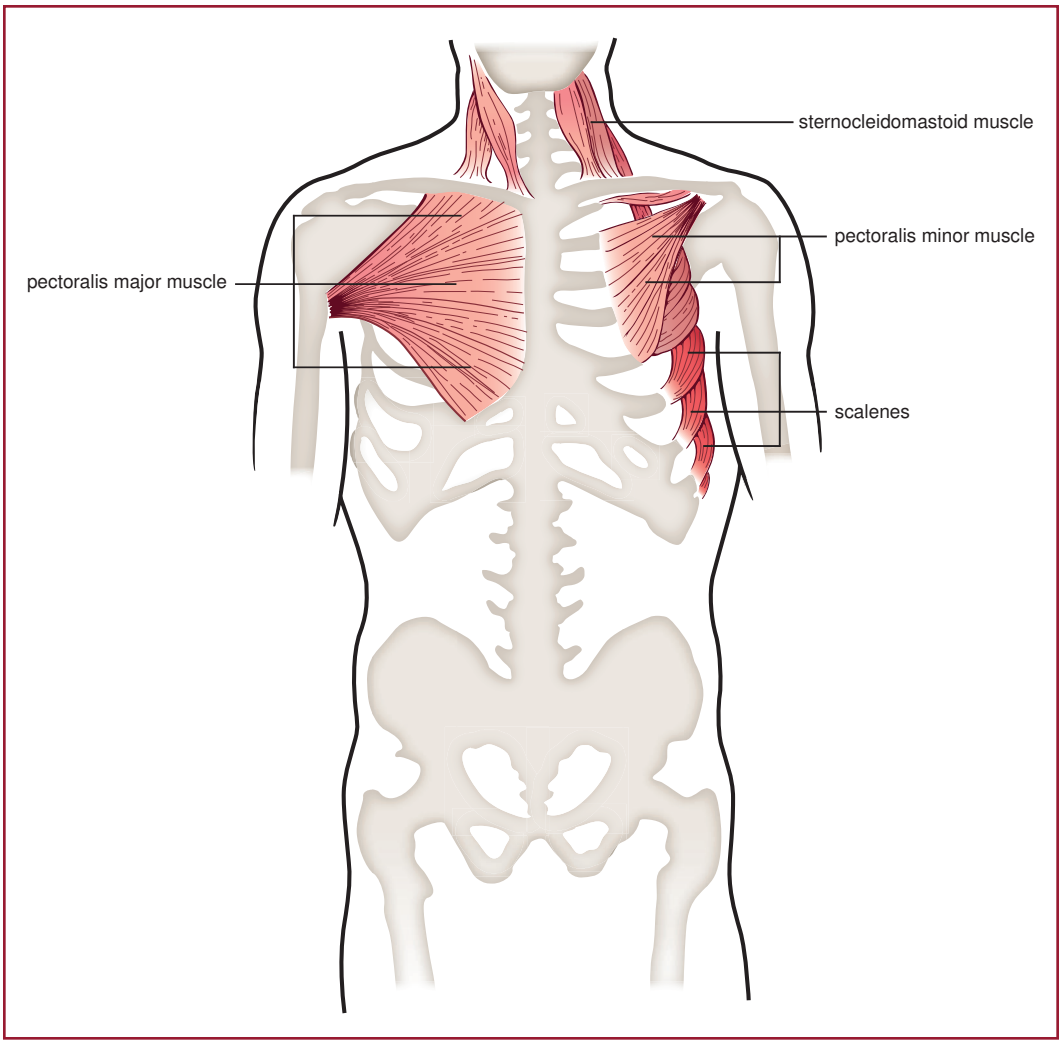


Figure 2–10. Muscles of inspiration.

- Diaphragm: a dome-shaped muscle that attached to the inferior border of the rib cage, active in both quiet and speech breathing. When it contracts, it depresses the abdomen and increases the vertical dimensions of the lungs and thoracic cavity.
- External intercostals: a series of muscles situated between each of the ribs, originating from the inferior surface of one rib and coursing down and medially to attach to the superior surface of the rib below. These muscles are active in both quiet and speech breathing; when they contract, the external intercostals elevate the rib cage and increase the transverse and anteroposterior dimensions of the thoracic cavity.
- Sternocleidomastoid: a major accessory muscle of inspiration that attaches at its upper end to the mastoid process of the skull and at its lower end to the sternum and clavicle,

active only during deep breathing. When it contracts, it elevates the sternum and rib cage.

- Scalenes: three muscle pairs that originate at the cervical vertebrae (C2–C7) and attach to the first and second ribs. They are active during forced inspiration; when they contract, they elevate the rib cage.
- Pectoralis major and pectoralis minor: two accessory muscles of inspiration. Pectoralis major originates in the sternum and attaches to the humerus; pectoralis minor originates in the costal cartilages and attaches to the scapula. They are active only during the final phase of maximal inspiration; when they contract, they elevate the rib cage.

The muscles of expiration work in concert with the passive forces of torque, tissue elasticity, and gravity. At the end of a normal inspiratory cycle, the muscles of inspiration relax and passive recoil decreases the thoracic cavity dimensions. This decrease occurs as a result of: (1) gravity pulling downward on the rib cage; (2) tissue elasticity pulling the rib cage downward and inward; (3) the diaphragm moving upward into its normal, relaxed position; and (4) the torque on the twisted ribs causing them to lower. During speech breathing, expiratory muscles assist these passive forces by compressing the abdominal viscera, to force the diaphragm upward and depress the lower ribs, to decrease thoracic cavity size and thereby sustain pulmonary pressure. The muscles that support expiration (Figure 2–11) are:

- Internal intercostals: a series of muscles situated between each of the ribs, originating from the inferior surface of one rib and coursing down and laterally to attach to the superior surface of the rib below. They are active in speech breathing; when they contract, the internal intercostals depress the rib cage to reduce dimensions of the thoracic cavity.
- Rectus abdominis: long, vertical muscle that covers the central abdomen, originating at the pubis and attaching to the sternum and lower ribs. It is active during speech breathing; when it contracts, it compresses the abdomen.
- Transverse abdominis: broad muscle that originates at the posterior vertebral column and fans anteriorly to attach to the abdomen at various points from the diaphragm down to the pubis. It is active during speech breathing; when it contracts, it compresses the abdomen.
- Internal obliques: upward fanlike muscle that originates at the iliac crest and attaches to the cartilage of the lower ribs. It is active during speech breathing; when it contracts, it lowers the rib cage.
- External obliques: downward fanlike muscle that originates at the lower ribs and attaches at abdominal points and the iliac crest. When contracting for speech breathing, it lowers the rib cage and compresses the abdomen.

Laryngeal Muscles

There are two logical groupings of the laryngeal muscles: extrinsic and intrinsic. Extrinsic laryngeal muscles are so named because they attach to both a site in the larynx and to an external point, such as the hyoid bone, sternum, mandible, or skull base. The intrinsic muscles have both ends attached to a laryngeal cartilage. When contracted, all muscles

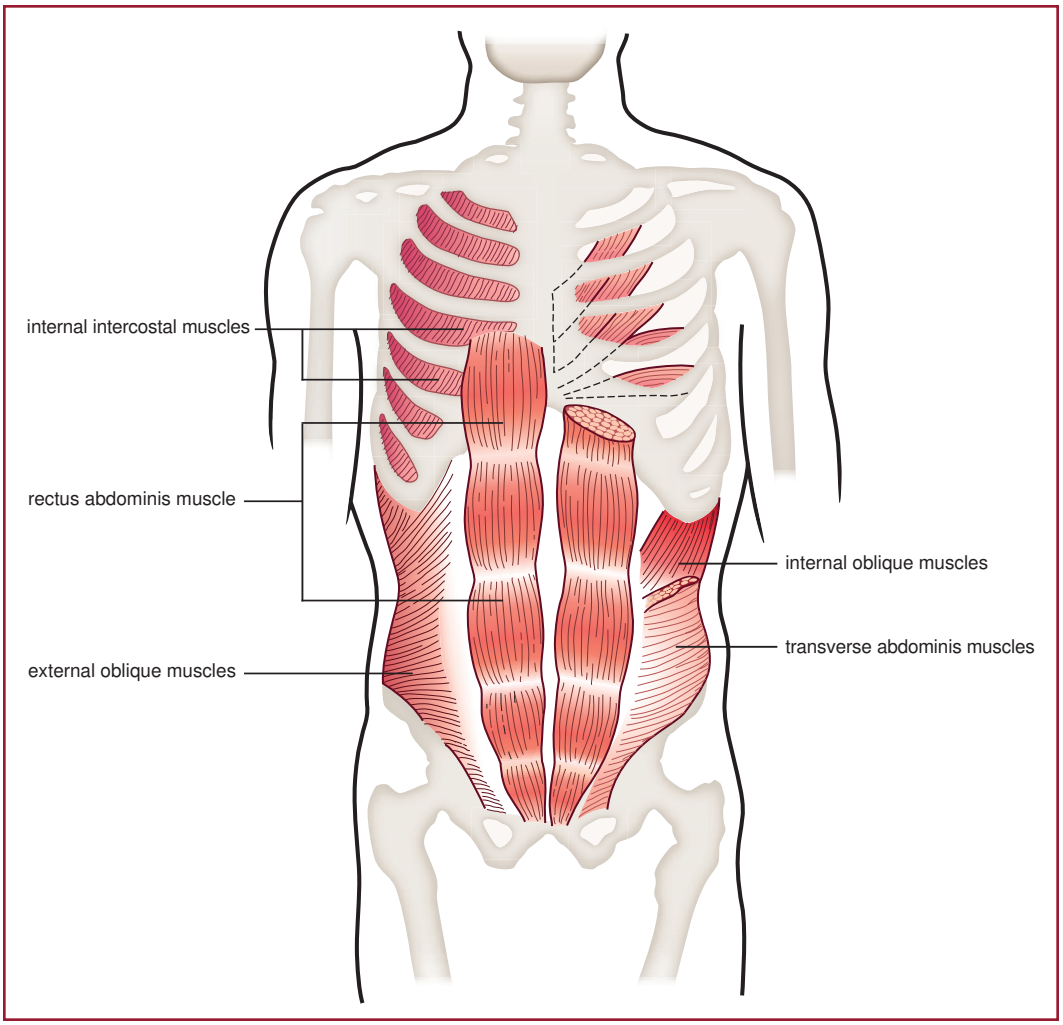


Figure 2–11. Muscles of expiration.

increase tension and shorten, providing a "pull" between the attachments. The primary function of the extrinsic muscles is to influence overall laryngeal height or position in the neck. For example, the larynx moves vertically (superiorly and inferiorly) and horizontally (anteriorly and posteriorly) as a whole for lifting, swallowing, phonating, and many vegetative acts. Extrinsic muscle manipulations also alter the shape and filtering characteristic of the supraglottic vocal tract, which modifies vocal pitch, loudness, and quality. The primary function of the intrinsic laryngeal muscles is to alter the shape and configuration of the glottis by modifying the position, tension, and edge of the vocal folds. These intrinsic laryngeal manipulations consist of adduction (closing), abduction (opening), and modifications in vocal fold length, tension, and thickness. Both intrinsic and extrinsic muscle groups are necessary to accomplish the

many vital and complex movements required for ventilation, airway protection, and communication, and all are integral to maintaining a functioning laryngeal valve.[1,2,9,10,25]

Extrinsic Laryngeal Muscles

The many extrinsic muscles of the larynx (Figure 2–12) can be divided into two regional groupings: the suprahyoid above the hyoid bone and infrahyoid below the hyoid bone (Table 2–1). The muscles' locations can usually be identified based on their names, which describe the structural attachments. By knowing the attachments, one can predict the effect of individual muscle contraction (shortening) between those sites. For example, the thyrohyoid attaches to the hyoid bone superiorly and the thyroid cartilage inferiorly. When contracted, this muscle draws these structures closer together. The sternocleidomastoid, although not technically an extrinsic laryngeal muscle, forms a broad sheath in the neck that extends from the sternum to the mastoid, without attaching directly to the larynx. Nonetheless, it is an accessory muscle for respiration and contributes to head and neck movements and stability.

Suprahyoid Muscles. The suprahyoid muscles generally raise the larynx by pulling the hyoid bone upward. This action is particularly important during a swallow, when laryngeal elevation can help protect the airway from aspiration. Clinically, laryngeal elevation during phonation may be a sign of excessive extrinsic laryngeal muscle tension

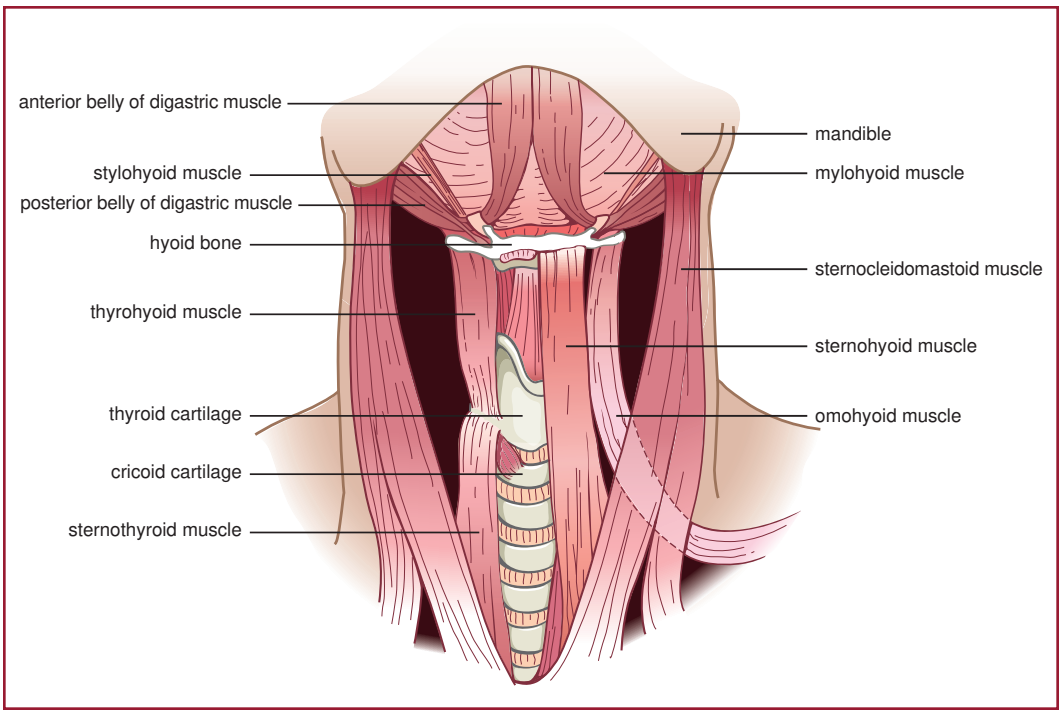


Figure 2–12. Extrinsic laryngeal muscles.

Table 2–1. Extrinsic Laryngeal Muscles

Muscle	Attachments	Function
	Suprahyoid Muscles	
Stylohyoid	Temporal bone (styloid process) to hyoid	Raises hyoid bone posteriorly
Mylohyoid	Mandible to hyoid	Raises hyoid bone anteriorly
Digastric	Two compartments: anterior and posterior	
Anterior	Mandible to hyoid	Raises hyoid bone anteriorly
Posterior	Temporal bone (mastoid process) to hyoid	Raises hyoid bone posteriorly
Geniohyoid	Mandible to hyoid	Raises hyoid bone anteriorly
	Infrahyoid Muscles	
Thyrohyoid	Thyroid to hyoid	Brings thyroid cartilage and hyoid bone closer together
Sternothyroid	Sternum to thyroid	Lowers thyroid cartilage
Sternohyoid	Sternum to hyoid	Lowers hyoid bone
Omohyoid	Scapula to hyoid	Lowers hyoid bone
	Regional	
Sternocleidomastoid	Sternum and clavicle to mastoid process of the temporal bone	Rotates the neck

and is often an accurate indicator of hyperfunctional voice use.[2,8,9,18,19] The suprahyoid extrinsic laryngeal muscles include the stylohyoid, the mylohyoid, the digastric (anterior and posterior bellies), and the geniohyoid (not seen). All elevate the hyoid bone and larynx in the neck, but the specific repositioning of other structures depends on the muscular attachments. For example, both the geniohyoid and the stylohyoid muscles move the hyoid posteriorly. The digastric may depress the mandible; the mylohyoid may elevate the tongue.

infrahyoid Muscles. The infrahyoid muscles include the thyrohyoid, the sternothyroid, the sternohyoid, and the omohyoid. In general, the infrahyoid muscles pull the hyoid bone and larynx to a lower position in the neck. The sternothyroid depresses the thyroid cartilage and the thyrohyoid contracts the distance between the hyoid and the thyroid, as mentioned previously.

intrinsic Laryngeal Muscles

There are five intrinsic laryngeal muscles (Table 2–2), each of which attaches to cartilages in the larynx to modify the cricothyroid and cricoarytenoid joint relationships, and thereby affect the position, length, and tension of the

Table 2–2. Intrinsic Laryngeal Muscles

Muscle	*Attachments*	*Innervation*
Cricothyroid (CT)	Cricoid to thyroid	External branch of the superior laryngeal nerve
Two compartments:		
Pars recta	Cricoid to inferior border of the thyroid lamina	
Pars oblique	Cricoid to inferior cornu of the thyroid	
Thyroarytenoid (TA)	Thyroid to arytenoid vocal process	Recurrent laryngeal nerve
Two compartments:		
Thyromuscularis	Lateral portion of the TA	
[Thyro]vocalis	Medial portion of the TA	
Lateral cricoarytenoid (LCA)	Lateral cricoid to the arytenoid muscular process	Recurrent laryngeal nerve
Interarytenoid	Joins the left and right muscular processes of the arytenoids	Recurrent laryngeal nerve
Two compartments:		
Transverse	Unpaired muscle sheath attaching to the lateral laminae of the left and right arytenoids; runs horizontally	
Oblique	Paired muscles coursing from the base of one arytenoid upward and across to the apex of the other, forming an X-configuration	
Posterior cricoarytenoid (PCA)	Posterior medial aspect of the cricoid to the lateral arytenoid muscular process	Recurrent laryngeal nerve

vocal folds. Specifically, these intrinsic muscles create three critical effects:

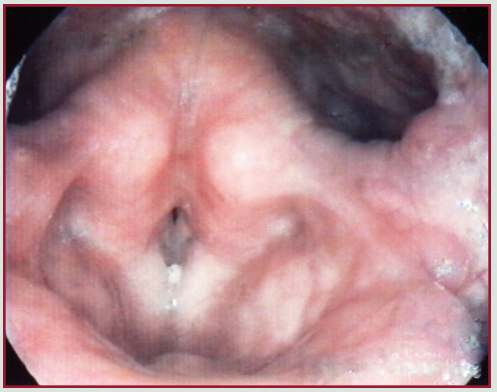
1. Changes the position of the cartilage framework that houses the vocal folds,
2. Alters the length, tension, and shape of the vocal fold edge, and
3. Changes the shape of the glottal opening between the vocal folds.

As with the extrinsic muscles, the intrinsic muscles of the larynx are also identifiable by their names, which describe the cartilaginous attachments. Intrinsic laryngeal muscles are skeletal muscles, predominantly Type IIA, which are fast acting and fatigue resistant. Moreover, there are multiple muscle fiber inputs to each motor unit, suggesting high capacity for fine motor control.[9,10]

Call-Out Box 2–2

Take a look at the following laryngoscopic figures. Both figures were acquired from the same patient during sustained vowel production. However, Figure A was acquired before treatment and Figure B was acquired immediately following voice therapy designed to relax the extrinsic laryngeal muscles. In Figure A, the ventricular folds almost completely obliterate the view of the true vocal folds below; however, after successful treatment, the ventricular folds return to their normal position. Discuss with your colleagues what muscles or groups of muscles might be contracting to produce this kind of supraglottic (ventricular fold) constriction. Are there any muscles in the ventricular folds that are sufficient to create this kind of strong adductory force? If not, how is such ventricular compression possible?

A. Before Treatment



B. Immediately Posttreatment

Cricothyroid. The cricothyroid is a broad, fan-shaped muscle that attaches inferiorly to the anterior arch of the cricoid cartilage and courses superiorly and laterally to the anterior rim of the thyroid cartilage. The cricothyroid is the only intrinsic laryngeal muscle that is not innervated by the recurrent laryngeal nerve; rather, the cricothyroid is innervated by the external branch of the superior laryngeal nerve. When the cricothyroid muscle contracts, it decreases the distance between these two cartilages, simultaneously stretching, lengthening, and creating longitudinal tension that stiffens the entire membranous vocal fold and thins the medial vibrating edge. This vocal fold lengthening is achieved as the thyroid cartilage is pulled inferiorly, as the cricoid is pulled superiorly, or by a combination of these movements. The cricothyroid muscle has been described traditionally as having two distinct compartments: pars rectus (vertical) and pars oblique (angled). However, a third "horizontal" belly has also been recently identified. The exact function of these muscle bellies is not clear, but studies suggest that the pars recta and pars oblique function in vari-

able patterns for different speakers and at different portions of the fundamental frequency range.[26] Regardless, cricothyroid contraction always reduces the vibrating mass of the vocal fold by separating the vocal folds slightly to prevent tight adduction, increasing overall stiffness, and limiting the vibratory wave to the thinnest portion of the vocal fold, located at the medial edge. Therefore, the cricothyroid serves as a major contributor to fundamental frequency control, especially in higher tones (Figure 2–13).[1,2,9,10,26]

Thyroarytenoid. The thyroarytenoid is attached anteriorly to the internal angle of the thyroid cartilage and posteriorly to the vocal process of the arytenoid (Figure 2–14). The thyroarytenoid is innervated by the recurrent laryngeal nerve. The thyroarytenoid usually contains two muscle compartments arranged in parallel. The lateral belly is called the thyromuscularis; the medial belly is the thyrovocalis, or simply, the vocalis. Often, the general name, thyroarytenoid (reflecting both compartments), and vocalis are used interchangeably.

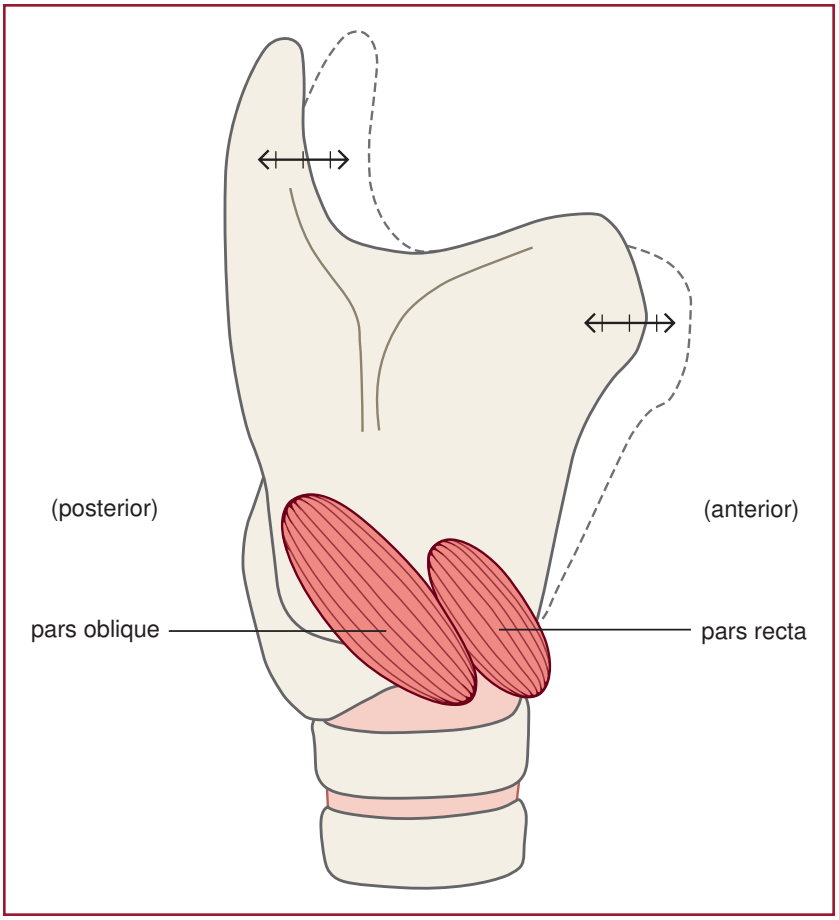


Figure 2–13. Lateral view of cricothyroid muscle contraction, which pulls the thyroid anteriorly.

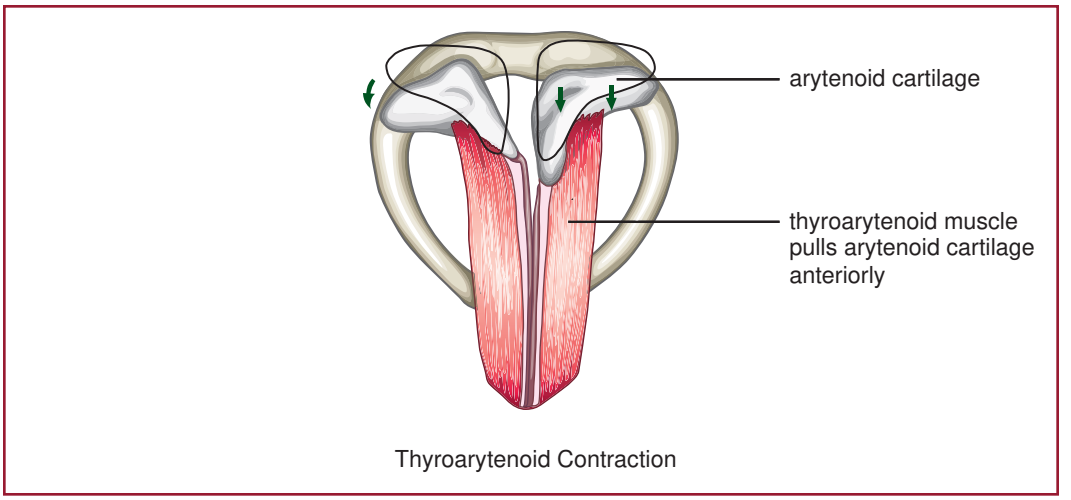


Figure 2–14. Superior view of thyroarytenoid muscle contraction, which shortens and rounds the vocal folds.

The thyroarytenoid muscle is the actual "body" of the vocal fold. When contracted, it shortens the fold length and lowers its vertical level in the larynx by drawing the arytenoid cartilages anteriorly. This muscle also influences the vocal fold shape and glottic closure patterns because thyroarytenoid contraction thickens and rounds the vocal fold by increasing the mass of the vibrating medial edge. As the vocal fold body stiffens, the superficial cover and transition become looser, allowing greater vocal fold closure and larger vibratory amplitude. Thus, the thyroarytenoid contributes directly to lowering fundamental frequency, increasing loudness, and tighter glottic closure.[1,2,9,10,25] Historically, the thyromuscularis (lateral portion) was thought to contribute more to vocal fold adduction, due to its high concentration of fast twitch muscle fibers, whereas the thyrovocalis, which has predominantly slow-twitch fibers, was thought to exert greater control over phonation.[27]

Lateral Cricoarytenoid. The lateral cricoarytenoid is another broad, fan-shaped muscle that attaches to the lateral superior rim of the cricoid and to the lateral arytenoid muscular process (Figure 2–15). The lateral cricoarytenoid is innervated by the recurrent laryngeal nerve. When the lateral cricoarytenoid contracts, it rocks the arytenoids anteriorly and slides the muscular processes laterally. This movement redirects the tips of the vocal processes medially, bringing the membranous vocal folds to midline adduction and lowering the vocal folds. The lateral cricoarytenoid serves as one of the strongest vocal fold adductors (closers) by closing the glottis and creating medial compression for loud voice and strong vegetative closure, as in coughing, grunting, throat clearing, and Valsalva maneuvers.[1,2,9,10]

interarytenoid. The interarytenoid muscles attach the left and right arytenoid cartilages (Figure 2–16). When they contract, the medial walls of the carti-