Voice Disorders in Athletes, Coaches and other Sports Professionals

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To our families.

Preface

The last few decades have witnessed an increase in sports activities in a growing percentage of the population. It is estimated that one out of four adults in the United States plays at least one type of sport, with younger individuals being more attracted to high-velocity sports while elderly people tend to pursue less volatile, non-competitive sports. The fitness and sports industry, like other occupational industries that require extensive voice use, has a high prevalence of voice disorders among its occupational voice users. Athletes, fitness instructors, and coaches often engage in abusive voice behavior because of the need to project their voices while performing strenuous exercise. This vocal loading is compounded by environmental factors such as background noise, poor environment acoustics, and environmental allergies. Additional individual-related voice risk factors include dehydration, exercise-induced asthma, laryngopharyngeal reflux disease, and the intake of supplements such as anabolic steroids, and other factors. Moreover, athletes are prone to laryngeal trauma, with sports-related laryngeal trauma being common causes of laryngeal injury, in addition to motor vehicle accidents and strangulation. Musculoskeletal injuries may also jeopardize voice given the strong interplay between the phonatory apparatus and musculoskeletal structures. Exercise-induced laryngeal dysfunction, also called paradoxical vocal fold motion, is a significant threat to athletes that warrants consideration given its dramatic impact on quality of life, and that also may result in dysphonia.

Sports lead to numerous voice symptoms and laryngeal pathologies that affect athletes, coaches, and fitness instructors, often leading to absenteeism, abstention from sports, and interference with other normal activities. This book reviews the literature on voice health risk factors in the sports industry. The first four chapters provide core knowledge helpful in understanding voice disorders. This information is included in this book for the convenience of readers who are not otolaryngologists or speech-language pathologists. A fundamental understanding of voice helps readers comprehend sports-related voice dysfunction. These four chapters provide basic information that is common knowledge among laryngologists, and they are modified from prior publications by the author (RTS), with permission. Chapter 1 presents a focused, brief review of anatomy and physiology of phonation. Chapters 2 and 3 explain the medical evaluation (history and physical examination) performed for patients with voice complaints. Many athletes, coaches, and instructors should be considered professional voice users. If a coach cannot be heard from the sidelines, or athletes cannot be heard calling signals to their teammates, their professional performance is impaired. Many voice disorders result in not only alterations in voice quality, but also in loudness and projection. Chapter 4, written in collaboration with Johnathan Sataloff, MD, offers an overview of many medical conditions that may afflict the voice, and of their treatments. These conditions may be seen in any population, including athletes. Chapter 5 provides a comprehensive review of voice health risk factors in sports-occupational voice users, highlighting individual and environmental factors. This review serves as a basis for development of strategies to prevent voice injuries and reduce the risks of laryngeal trauma in athletes and coaches. Chapter 6 discusses voice disorders associated with specific sports activities and highlights behaviors that lead commonly to dysphonia among athletes and coaches participating in specific sports. It also provides understanding of the pathophysiology of dysphonia and the measures that might decrease the prevalence of dysphonia in participants of these athletic endeavors. Chapter 7 provides a concise description of the interplay between musculoskeletal injuries, hyperkinetic body behavior, laryngeal hyperfunction, and voice disorders in athletes and coaches. Chapter 8 summarizes external laryngeal trauma in athletes. Such trauma can lead not only to voice, swallowing, and breathing disturbances, but also to death. The chapter also discusses team- and field-related collisions as causes of sports-related laryngeal trauma and highlights the development of sports-specific rules and equipment that help to minimize the occurrence of such injuries. Chapter 9 offers a comprehensive discussion of exercise-induced laryngeal obstruction in athletes. Also known as paradoxical vocal fold motion (PVFM) and by several other names, this condition is characterized by vocal fold adduction (closing) when the vocal folds should be adducting (opening). This condition can disable athletes, and differential diagnosis and treatment are discussed in detail in this chapter. Chapter 10 summaries sex hormone disturbances in athletes and their effects upon the voice. Related issues have been recognized among young female gymnasts and ballet dancers for many decades, but the implications go far beyond that demographic. Athletes of all ages and genders may be affected by sports-related sex hormone changes and use of related substances such as testosterone to enhance performance. Chapter 11 provides a summary/overview of management of voice health among sports professionals. It considers the information provided in previous chapters, as well as other factors, and offers guidance and strategies for preserving healthy voice while competing in sports at any level, coaching, or participating in any other activity in the sports industry. This chapter stresses the importance of increased awareness of voice hygiene and education, improvement in working environment acoustics when possible, and strategies to minimize the risk of laryngeal fractures.

This book has been written entirely by the three authors in order to optimize consistency and prevent duplication, with a contribution to Chapter 4 by Johnathan B. Sataloff, MD. This is the first book that addresses specifically the interactions between the sports industry and voice health. Dysphonia is extremely common among athletes, coaches, fitness instructors, and other sports professionals. However, it is preventable in most cases and treatable in virtually all cases. The authors hope that this book will provide insights not only for medical voice care professionals, but also for participants in the sports industry that may help them preserve healthy voice for everyone involved in sports.

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Contents

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Chapter 1
Anatomy and Physiology of the Voice

To treat voice patients knowledgeably and responsibly, healthcare providers must understand the medical aspects of voice disorders and their treatment. This requires core knowledge of the anatomy and physiology of phonation. The human voice consists of much more than simply the vocal folds, popularly known as the vocal cords. State-of-the-art voice diagnosis, nonsurgical therapy, and voice surgery depend on understanding the complex workings of the vocal tract. Physicians and other healthcare professionals specializing in the care of voice patients, especially voice professionals, should be familiar with at least the basics of the latest concepts in voice function. The physiology of phonation is much more complex than this brief chapter might suggest, and readers interested in acquiring more than a clinically essential introduction are encouraged to consult other literature [1].

1.1 Anatomy

The larynx is essential to normal voice production, but the anatomy of the voice is not limited to the larynx. The vocal mechanism includes the abdominal and back musculature, rib cage, lungs, pharynx, oral cavity, and nose, among other structures. Each component performs an important function in voice production, although it is possible to produce voice even without a larynx—for example, in patients who have undergone laryngectomy. In addition, virtually all parts of the body play some role in voice production and may be responsible for voice dysfunction. Even something as remote as a sprained ankle may alter posture, thereby impairing abdominal, back, and thoracic muscle function and resulting in vocal inefficiency, weakness, and hoarseness.

The larynx is composed of four basic anatomic units: skeleton, intrinsic muscles, extrinsic muscles, and mucosa. The most important components of the laryngeal skeleton are the thyroid cartilage, cricoid cartilage, and two arytenoid cartilages

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(Fig. 1.1). Intrinsic muscles of the larynx are connected to these cartilages (Fig. 1.2). One of the intrinsic muscles, the *thyroarytenoid muscle* (its medial belly is also known as the vocalis muscle), extends on each side from the vocal process of the arytenoid cartilage to the inside of the thyroid cartilage just below and behind the

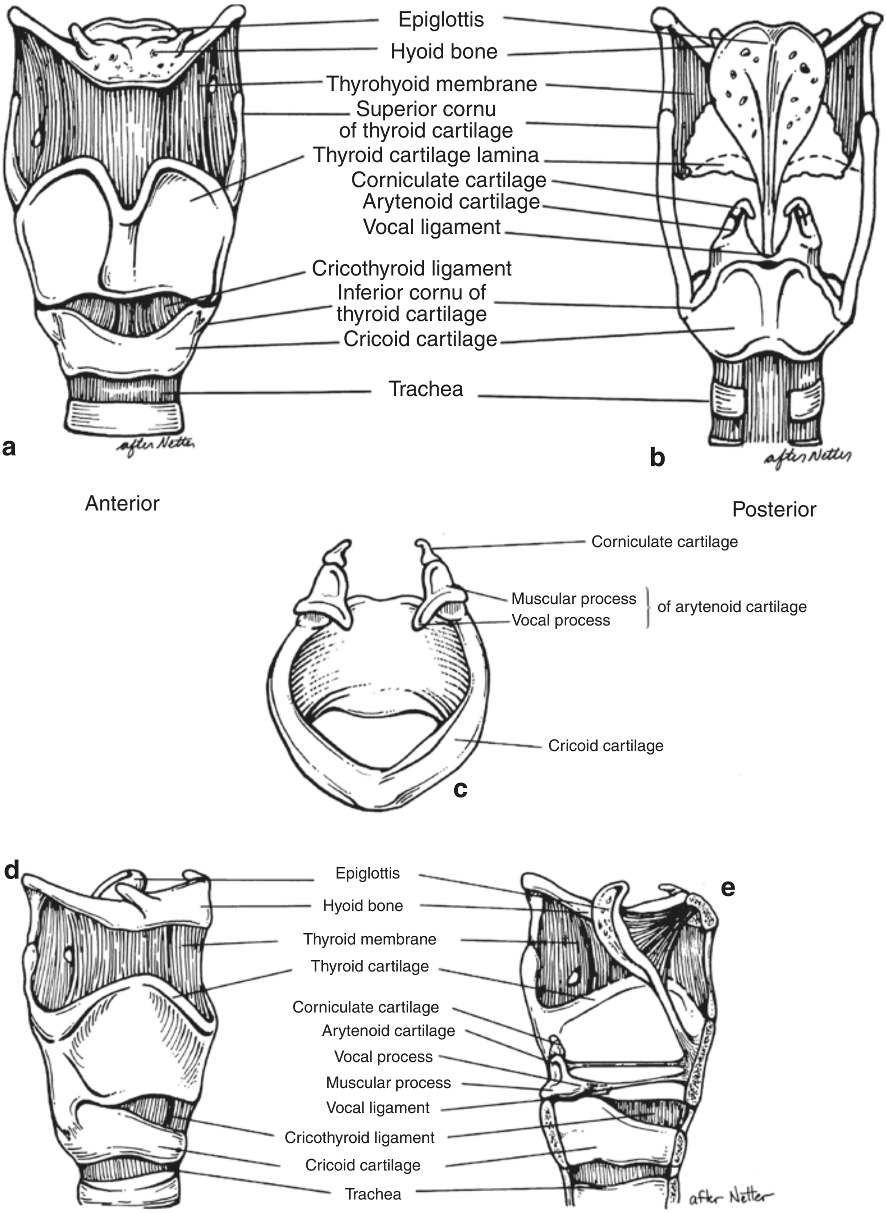
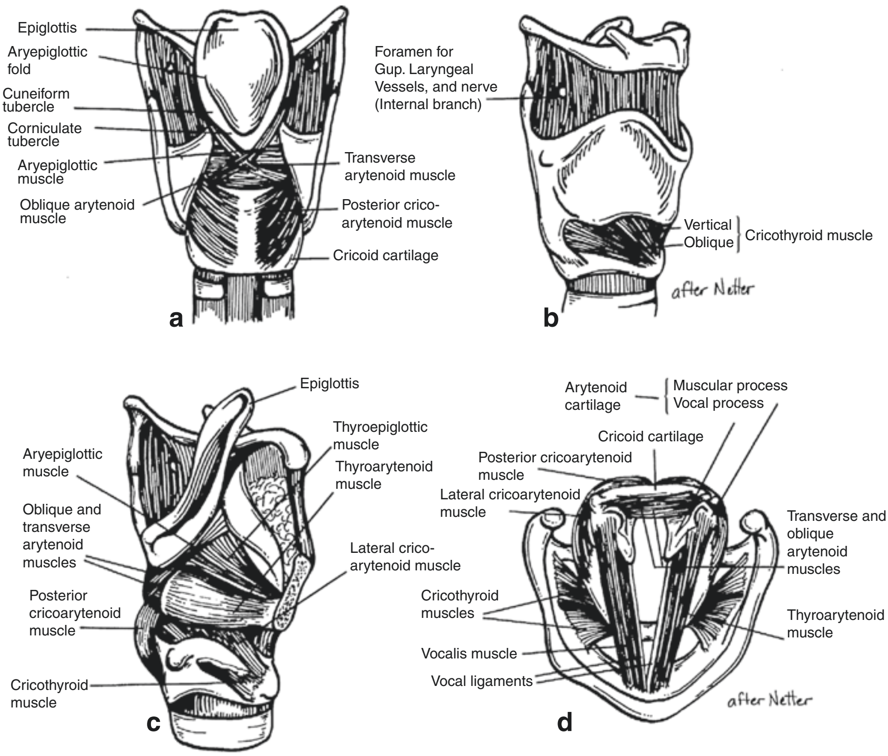


Fig. 1.1 Cartilages of the larynx



Intrinsic muscles of the larynx.

Fig. 1.2 Intrinsic muscles of the larynx

thyroid prominence ("Adam's apple"), forming the body of the vocal folds. The vocal folds act as the *oscillator* or *voice source* of the vocal tract. The space between the vocal folds is called the *glottis* and is used as an anatomic reference point. The intrinsic muscles alter the position, shape, and tension of the vocal folds, bringing them together (adduction), moving them apart (abduction), or stretching them by increasing longitudinal tension (Fig. 1.3). They are able to do so because the laryngeal cartilages are connected by soft attachments that allow changes in their relative angles and distances, thereby permitting alteration in the shape and tension of the tissues suspended between them. The arytenoid cartilages on their eliptoid cricoarytenoid joints are capable of motion in multiple planes, permitting complex vocal fold motion and alteration in the shape of the vocal fold edge associated with intrinsic muscle action (Fig. 1.4). All but one of the muscles on each side of the larynx are innervated by one of the two *recurrent laryngeal nerves*. Because this nerve runs in a long course (especially on the left) from the neck down into the chest and then back up to the larynx (hence, the name "recurrent"), it is injured easily by trauma, neck surgery, and chest surgery. Injury may result in vocal fold paresis or paralysis.

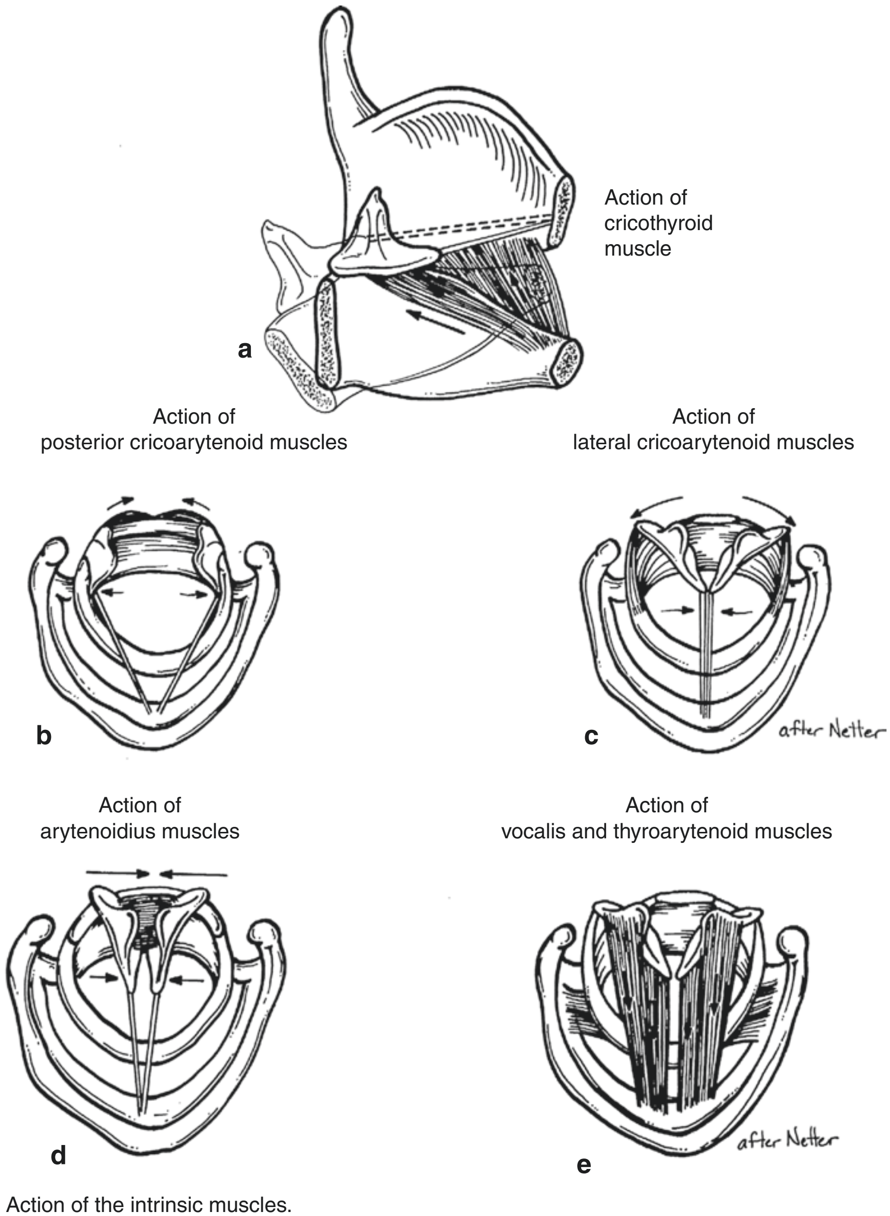


Fig. 1.3 Action of the intrinsic muscle

The remaining muscle (*cricothyroid muscle*) is innervated by the superior laryngeal nerve on each side, which is especially susceptible to viral and traumatic injury. It causes changes in longitudinal tension that are important in voice projection and pitch control. The "false vocal folds" are located above the vocal folds and, unlike

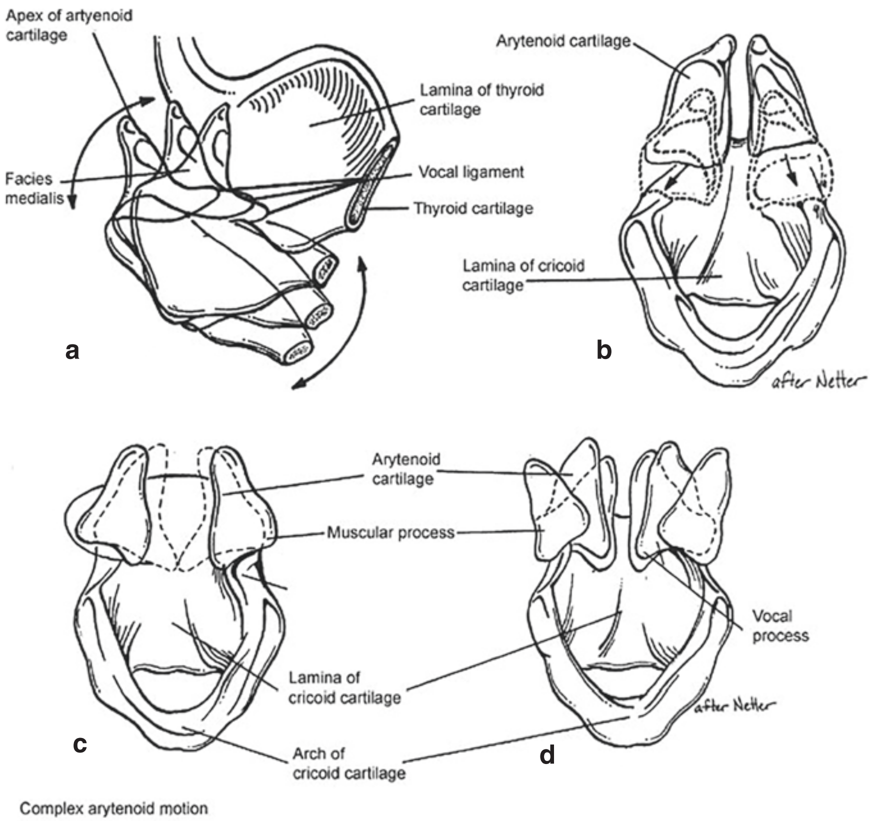


Fig. 1.4 Complex arytenoid motion

the true vocal folds, usually do not make contact during normal speaking or singing [1]. The neuroanatomy and neurophysiology of phonation are extremely complicated and only partially understood. As the new field of neurolaryngology advances, a more thorough understanding of the subject is becoming increasingly important to clinicians. Readers interested in acquiring a deeper, scientific understanding of neurolaryngology are encouraged to consult other literature [2] and the publications cited therein.

Because the attachments of the laryngeal cartilages are flexible, the positions of the cartilages with respect to each other change when the laryngeal skeleton is elevated or lowered. Such changes in vertical height are controlled by the extrinsic laryngeal muscles, the strap muscles of the neck. When the angles and distances between cartilages change because of this accordion-like effect, the resting length of the intrinsic muscle changes. Such large adjustments in intrinsic muscle condition interfere with fine control of smooth vocal quality. Classically trained singers generally are taught to use the extrinsic muscles to maintain the laryngeal skeleton at a relatively constant height regardless of pitch. That is, they learn to avoid the natural tendency of the larynx to rise with ascending pitch and fall with descending pitch, thereby enhancing unity of sound quality throughout the vocal range through effects on both resting muscle condition and supraglottic vocal tract posture.

The soft tissues lining the larynx are much more complex than originally thought. The mucosa forms the thin, lubricated surface of the vocal folds, which makes contact when the two vocal folds are approximated. Laryngeal mucosa might look superficially like the mucosa which lines the inside of the mouth, but it is not. Throughout most of the larynx, there are goblet cells and pseudostratified ciliated columnar epithelial cells designed for producing and handling mucous secretions, similar to mucosal surfaces found throughout the respiratory tract. However, the mucosa overlying the vocal folds is different. First, it is stratified squamous epithelium, which is better suited to withstand the trauma of vocal fold contact. Second, the vocal fold is not simply muscle covered with mucosa. Rather, it consists of five layers as described by Hirano [3]. Mechanically, the vocal fold structures act more like three layers consisting of the *cover* (epithelium and superficial layer of the lamina propria), *transition* (intermediate and deep layers of the lamina propria), and *body* (the vocalis muscle).

The *supraglottic vocal tract* includes the pharynx, tongue, palate, oral cavity, nose, and other structures. Together, they act as a *resonator* and are largely responsible for vocal quality or timbre and the perceived character of all phonated sounds. The vocal folds themselves produce only a "buzzing" sound. During the course of vocal training for singing, acting, or healthy speaking, changes occur not only in the larynx but also in the muscle motion, control, and shape of the supraglottic vocal tract and in aerobic, pulmonary, and bodily muscle function.

The *infraglottic vocal tract* (all anatomical structures below the glottis) serves as the *power source* for the voice. Singers and actors often refer to the entire power source complex as their "support" or "diaphragm." The anatomy of support for phonation is especially complicated and not completely understood. Yet, it is quite important because deficiencies in support frequently are responsible for voice dysfunction.

The purpose of the support mechanism is to generate a force that directs a controlled airstream between the vocal folds. Active respiratory muscles work in concert with passive forces. The principal muscles of inspiration are the diaphragm (a dome-shaped muscle that extends along the bottom of the rib cage) and the external intercostal muscles (located between the ribs). During quiet respiration, expiration is largely passive. The lungs and rib cage generate passive expiratory forces under many common circumstances such as after a full breath.

Many of the muscles used for active expiration also are employed in "support" for phonation. Muscles of active expiration either raise the intra-abdominal pressure, forcing the diaphragm upward, or lower the ribs or sternum to decrease the dimensions of the thorax, or both, thereby compressing air in the chest. The primary muscles of expiration are "the abdominal muscles," but internal intercostals and other chest and back muscles also are involved. Trauma or surgery that alters the structure or function of these muscles or ribs undermines the power source of the voice, as do diseases, such as asthma, that impair expiration. Deficiencies in the support mechanism often result in compensatory efforts that utilize the laryngeal muscles, which are not designed for power functions. Such behavior can result in impaired voice quality, rapid fatigue, pain, and even structural pathology such as vocal fold nodules. Current expert treatment for such vocal problems focuses on the correction of the underlying malfunction rather than surgery whenever possible.

1.2 Physiology

The physiology of voice production is extremely complex. The volitional production of voice begins in the cerebral cortex (Fig. 1.5).

The command for vocalization involves complex interactions among brain centers for speech, as well as other areas. For singing, speech directives must be integrated with information from the centers for musical and artistic expression, which are discussed elsewhere [1]. The "idea" of the planned vocalization is conveyed to the precentral gyrus in the motor cortex, which transmits another set of instructions to the motor nuclei in the brainstem and spinal cord. These areas send out the complicated messages necessary for coordinated activity of the larynx, thoracic and abdominal musculature lungs, and vocal tract articulators, among other structures. Additional refinement of motor activity is provided by the extrapyramidal and autonomic nervous systems. These impulses combine to produce a sound that is transmitted not only to the ears of the listener but also to those of the speaker or singer. Auditory feedback is transmitted from the ear through the brainstem to the cerebral cortex, and adjustments are made within milliseconds that permit the vocalist to match the sound produced with the sound intended, integrating the acoustic properties of the performance environment. Tactile feedback from the throat and other muscles involved in phonation also is believed to help in fine tuning vocal output, although the mechanism and role of tactile feedback are not understood fully. Many trained singers and speakers cultivate the ability to use tactile feedback effectively because of expected interference with auditory feedback data from ancillary sound such as an orchestra or band.

Phonation, the production of sound, requires interaction among the power source, oscillator, and resonator. The voice may be compared to a brass instrument such as a trumpet. Power is generated by the chest, abdominal, and back musculature, and a high-pressure air stream is produced. The trumpeter's lips open and close against the mouthpiece producing a "buzz" similar to the sound produced by vocal folds when they come together and move apart (oscillate) during phonation. This sound then passes through the trumpet, which has acoustic resonance characteristics that shape the sound we associate with trumpet music. If a trumpet mouthpiece is placed on a French horn, the sound we hear will sound like a French horn, not a trumpet. Quality characteristics are dependent upon the resonator more than on the oscillatory source. The non-mouthpiece portions of a brass instrument are analogous to the supraglottic vocal tract.

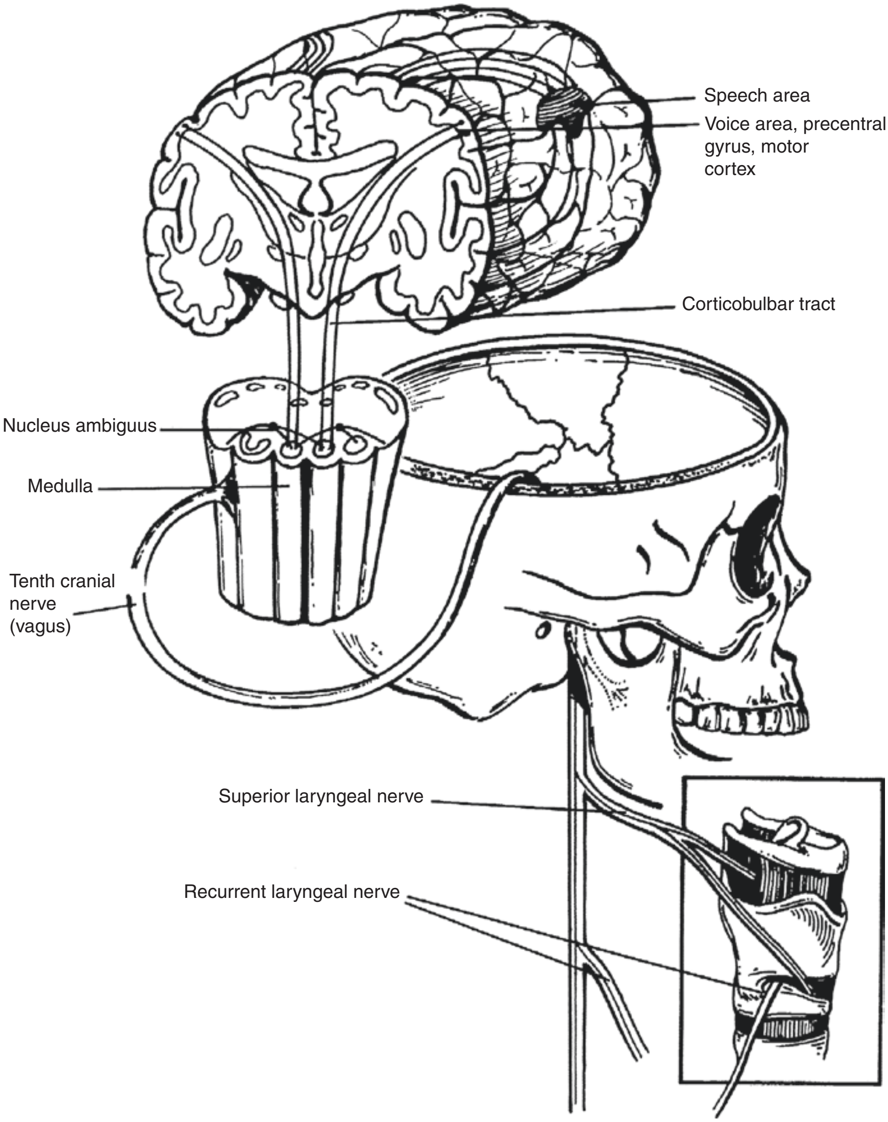


Fig. 1.5 Simplified summary of pathway for volitional phonation

During phonation, the infraglottic musculature must make rapid, complex adjustments because the resistance changes almost continuously as the glottis closes, opens, and changes shape. At the beginning of each phonatory cycle, the vocal folds are approximated, and the glottis is obliterated. This permits infraglottic air pressure to build, typically to a level of about 7 cm of water for conversational speech. At that point, the vocal folds are convergent (Fig. 1.6a). Because the vocal folds are closed, there is no airflow. The subglottic pressure then pushes the vocal folds progressively

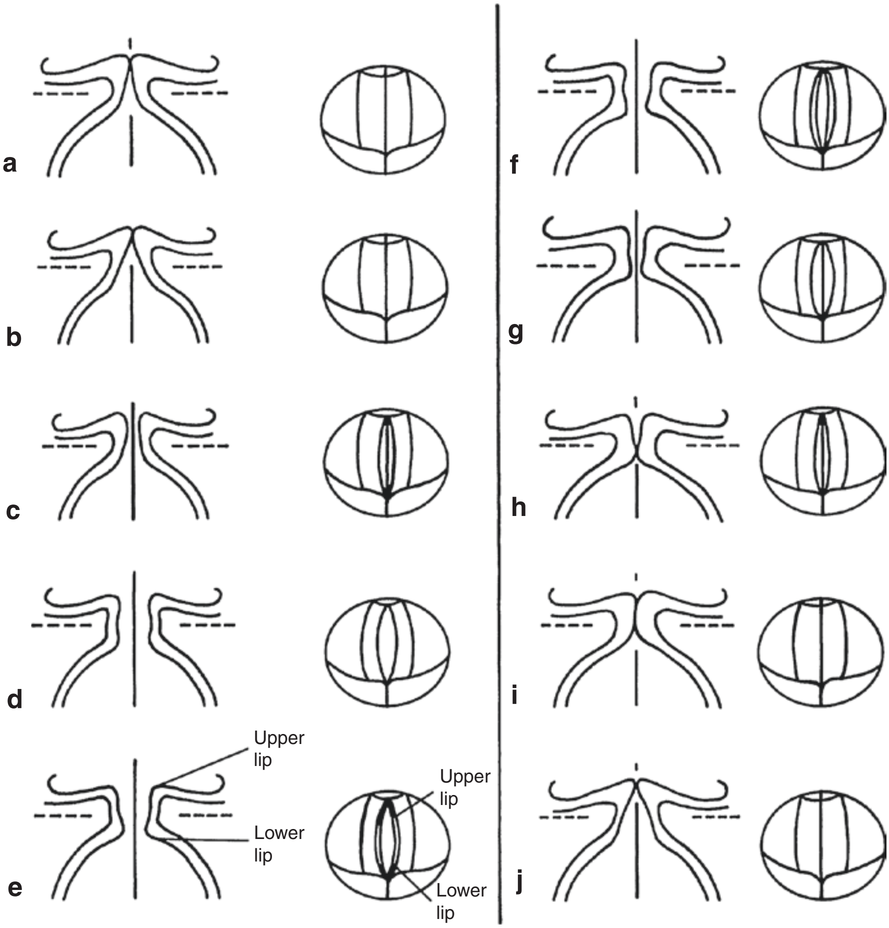


Fig. 1.6 Frontal view (left) and view from above (right) illustrating the normal pattern of vocal fold vibration. The vocal folds close and open from the inferior aspect of the vibratory margin upward and from posterior to anterior

farther apart from the bottom up and from the back forward (Fig. 1.6b) until a space develops (Fig. 1.6c, d) and air begins to flow. The Bernoulli force created by the air passing between the vocal folds combines with the mechanical properties of the folds to begin closing the lower portion of the vocal folds almost immediately (Fig. 1.6e–h) even while the upper edges are still separating. The principles and mathematics of the Bernoulli force are complex. It is a flow effect more easily understood by familiar examples such as the sensation of pull exerted on a vehicle when passed by a truck at high speed or the inward motion of a shower curtain when the water flows past it.

The upper portion of the vocal folds has elastic properties that also tend to make the vocal folds snap back to the midline. This force becomes more dominant as the upper edges are stretched and the opposing force of the air stream diminishes because of approximation of the lower edges of the vocal folds. The upper portions of the vocal folds are then returned to the midline (Fig. 1.6i), completing the glottic cycle. Subglottal pressure then builds again (Fig. 1.6j), and the events repeat. Thus, there is a vertical phase difference. That is, the lower portion of the vocal folds begins to open and close before the upper portion. The rippling displacement of the vocal fold cover produces a mucosal wave that can be examined clinically under stroboscopic light. If this complex motion is impaired, hoarseness or other changes in voice quality may cause the patient to seek medical evaluation. The frequency of vibration (number of cycles of openings and closings per second, measured in hertz [Hz]) is dependent on the air pressure and mechanical properties of the vocal folds, which are regulated in part by the laryngeal muscles. Pitch is the perceptual correlate of frequency. Under most circumstances, as the vocal folds are thinned and stretched and air pressure is increased, the frequency of air pulse emissions increases, and pitch goes up. The myoelastic-aerodynamic mechanism of phonation reveals that the vocal folds emit pulses of air, rather than vibrating like strings.

The sound produced by the oscillating vocal folds, called the voice source signal, is a complex tone containing a fundamental frequency and many overtones, or higher harmonic partials. The amplitude of the partials decreases uniformly at approximately 12 dB per octave. Interestingly, the acoustic spectrum of the voice source is about the same in ordinary speakers as it is in trained singers and speakers. Voice quality differences in voice professionals occur as the voice source signal passes through their supraglottic vocal tract resonator system (Fig. 1.7).

The pharynx, oral cavity, and nasal cavity act as a series of infinitely variable interconnected resonators, which are more complex than that in our trumpet example or other single resonators. As with other resonators, some frequencies are attenuated, and others are enhanced. Enhanced frequencies are radiated with higher relative amplitudes or intensities. Sundberg [4] showed long ago that the vocal tract has four or five important resonance frequencies called *formants* and summarized his early findings in a book that has become a classic. The presence of formants alters the uniformly sloping voice source spectrum and creates peaks at formant frequencies. These alterations of the voice source spectral envelope are responsible for distinguishable sounds of speech and song. Formant frequencies are determined by vocal tract shape, which can be altered by the laryngeal, pharyngeal, and oral cavity musculature. Overall, the vocal tract length and shape are individually fixed and determined by age and sex (females and children have shorter vocal tracts and formant frequencies that are higher than males). Voice training includes conscious physical mastery of the adjustment of vocal tract shape.

Although the formants differ for different vowels, one resonant frequency has received particular attention and is known as the “singer’s formant.” This formant occurs in the vicinity of 2300–3200 Hz for all vowel spectra and appears to be responsible for the “ring” in a singer’s or trained speaker’s (“speaker’s formant”) voice. The ability to hear a trained voice clearly even over a loud choir or orchestra is dependent primarily on the presence of the singer’s formant [1]. Interestingly, there is little or no significant difference in maximum vocal intensity between