Principles and Practices of LARYNGEAL ELECTROMYOGRAPHY

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Preface

Laryngeal electromyography (LEMG) is an important method that detects the status of electrophysiological activity of the laryngeal muscles during various physiological activities such as phonation, breathing, and swallowing, studying the electrical activity of the laryngeal nerve and its innervated muscles. It provides a scientific basis for the diagnosis, treatment, and prognosis of laryngeal immobility such as organic (neuromuscular paralysis or cricoarytenoid joint abnormalities), swallowing disorders, spasmodic dysphonia, and other laryngeal neuromuscular pathologies. Due to the difficulties of clinical application of LEMG, such as the need for a certain electrophysiological basis for its operation and diagnosis, and the need for neurologist assistance, this technique has not yet been widely used in clinical practice. Therefore, otolaryngologists urgently need to master standardized examination and diagnostic interpretation methods to improve the level of diagnosis and treatment of laryngeal neuromuscular dysfunction.

As an original monograph on LEMG, it contains over 36,000 words and 167 original clinical pictures, including a large number of electromyogram and stroboscopic laryngoscopy photos, which are illustrated in detail. Besides, it is supplemented by 18 selected interesting clinical cases, demonstrating the fundamentals of LEMG and its clinical experience thoroughly. It mainly involves two parts: (a) basis of LEMG; (b) abnormal LEMG characteristics and case studies.

- **Basis of laryngeal electromyography**: It includes applied anatomy and physiology of the larynx, electromyographic recorders and electrodes, introduction to needle-electrode electromyography and the parameters of its evaluation, basic principles and basic operations of LEMG, examination of laryngeal nerve conduction function, other electrophysiological tests (including repetitive nerve stimulation and single-fiber electromyography), as well as the principles and precautions of electromyography.

- **Abnormal laryngeal electromyographic manifestation and case study**: It may help you to grasp LEMG vividly and three-dimensionally in vocal fold paralysis, vocal fold paralysis combined with lower cranial nerve injuries, mechanical movement disorders of the vocal folds, laryngeal myopathy, myasthenia gravis, spasmodic dysphonia, and functional dysphonia, from the dimensions of both clinical features and case studies.

This book is clinically instructive, combining electrophysiological theories and techniques with clinical practice for the majority of otolaryngological specialists, physicians, primary care physicians, postgraduate students, and other related electrophysiologic professionals with a concise and clear text. It provides a concise and practical reference book for clinical LEMG.

Acknowledgment

The final completion of this book is the result of the guidance of our predecessors, the exploration of colleagues, and our practice for more than 20 years. First, I would like to express my gratitude to Professor Zhenming Tian from the former Air Force General Hospital for his teaching, which enabled our work on laryngeal electromyography to begin. I am deeply grateful to our team members for their unwavering efforts and perseverance, and I would also like to extend my sincere thanks to the team at the Department of Neurology at Beijing Tongren Hospital, Capital Medical University for their invaluable collaboration and assistance. Liyu Cheng, MD; Yuhong Lin, MD; Rong Hu, MD; Xueyan Li, MD et al. did a lot of meticulous work, and Anqi Zhao, MD drew a part of schematic diagrams. In addition, we also received professional guidance and selfless help from Professor Hui Qiao from Beijing Tiantan Hospital, Capital Medical University, and Beijing Neurosurgical Institute. I hereby express my deep gratitude. Finally, I would like to express my gratitude to the colleagues at the Department of Otorhinolaryngology – Head and Neck Surgery, Beijing Tongren Hospital, Capital Medical University for their strong support, and to Professor Demin Han (Professor, Academician of the Chinese Academy of Engineering, Director of ENT Center, Beijing Tongren Hospital, Capital Medical University, China) for his wisdom, advice, and enlightenment throughout the years.

PART I
Basis of Laryngeal Electromyography

Due to the deep location and complex physiological functions of the larynx and pharynx, it is necessary to choose some special methods to evaluate their functional changes in structure and physiology. Before the examination of the laryngopharynx, the medical history of the patient should be obtained in detail, then the symptoms should be analyzed, and the general condition should be paid more attention to as well. Laryngoscopy is the basis for making a diagnosis of laryngopharyngeal diseases, including indirect laryngoscopy, flexible laryngoscopy, electrolaryngoscopy, strobolaryngoscopy, narrow-band imaging endoscopy, and direct laryngoscopy. Clinical evaluation of vocal function mainly includes subjective and objective assessment and measurement of voice quality, voice-related quality of life, assessment of the vocal fold vibration, laryngeal electromyography, aerodynamic assessment, laryngopharyngeal reflux (pH monitoring), etc.

Laryngeal electromyography (LEMG) objectively detects the bioelectrical activity of laryngeal muscles during different physiological activities, such as phonation, respiration, and swallowing. LEMG determines the function of laryngeal nerves and muscles so as to provide the basis for the diagnosis, treatment, and prognosis of laryngeal neuromuscular disorders. This part begins with a brief introduction of laryngeal anatomy and physiology, and then the essential knowledge of electromyography and characteristics of LEMG are further elaborated.

Chapter 1
Anatomy of the Larynx

The larynx is found in vertebrates that breathe through the lungs. It is located in the middle of the anterior neck and below the hyoid bone. It opens into the laryngopharynx and continues into the trachea. The upper end of the larynx is the upper edge of the epiglottis, the lower end is the lower border of the cricoid cartilage, the anterior is the infrahyoid strap muscles, the posterior is the pharynx and the cervical vertebrae, and it projects ventrally between the great neurovascular bundles of the neck and the lateral lobes of the thyroid gland. The larynx is a conical lumen organ formed by a series of cartilages as the skeletal framework, interconnected by ligaments, fibrous membranes, and a few muscles. The larynx lies opposite the third to sixth cervical vertebrae in adult males, about 8 cm high, and it is somewhat higher in children and adult females.

1.1 Laryngeal Muscles

The muscles of the larynx are striated muscles, which are divided into extrinsic and intrinsic laryngeal muscles. Except for the single transverse arytenoid muscle, they all exist in pairs (Sataloff 2017).

The role of the extrinsic laryngeal muscles is to elevate or lower the larynx, as well as to fix the larynx and to assist swallowing and phonation. Suprahyoid muscles, such as the middle pharyngeal constrictor muscles, allow the larynx to rise with the hyoid bone. During phonation, under the combined action of the sternothyroid muscle, the hyoid bone is fixed, and the thyroid cartilage is tilted forward and downward, increasing the tension of the vocal folds (Sataloff 2017).

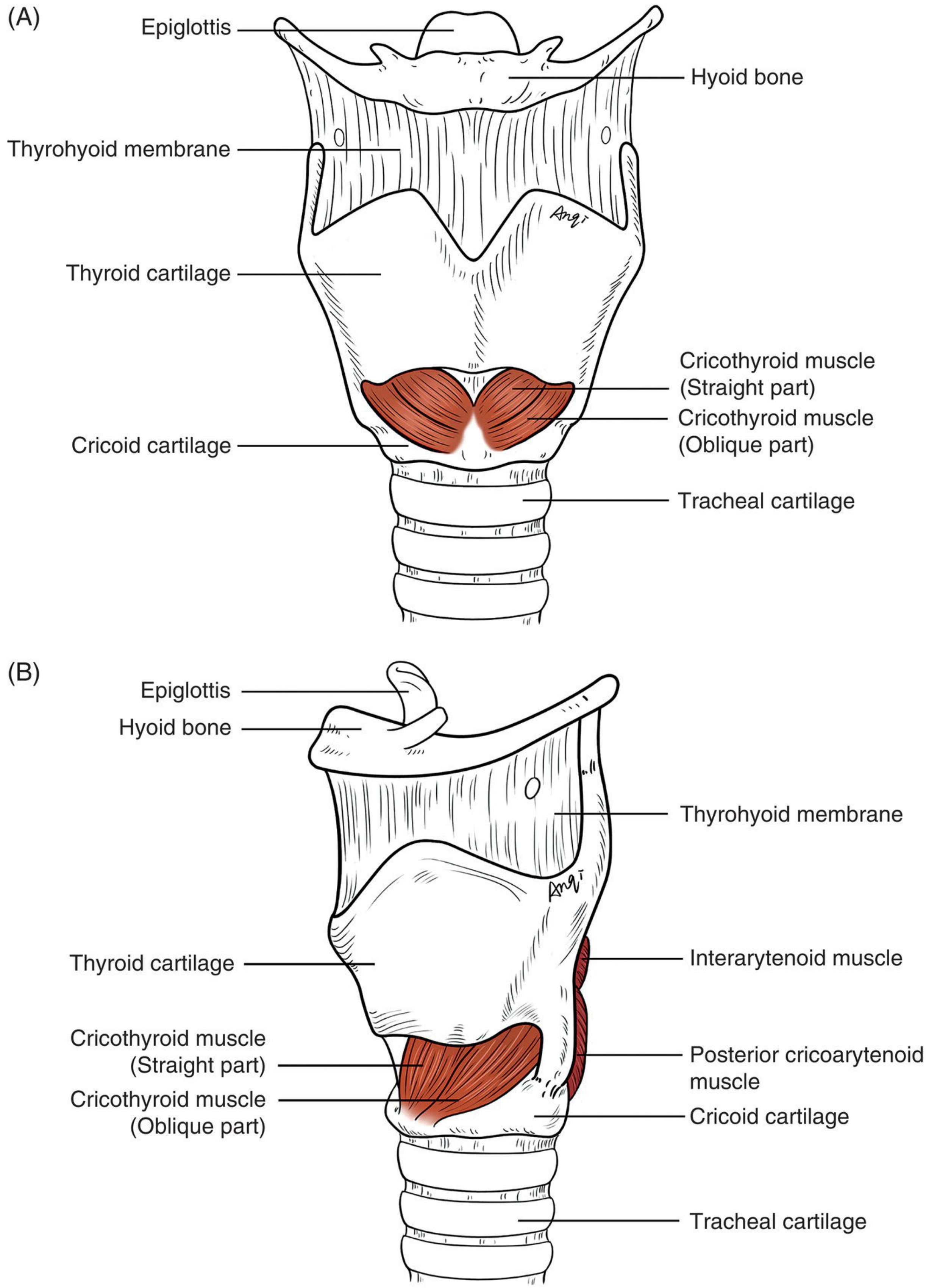
The intrinsic laryngeal muscles originate and terminate in the larynx and may be divided into four groups based on their main actions (Figure 1.1).

1.1.1 Glottic Dilator Muscles (Muscles That Abduct the Vocal Folds)

The posterior cricoarytenoid (PCA) muscles are the only abductor muscles of the larynx, located on the posterior surface of the cricoid lamina. The contraction of the PCA muscles pulls the muscular processes of the arytenoid cartilages inward and downward, causing the arytenoid cartilages to move, slide, and rotate outward, and then the vocal processes to rotate posteriorly, upward, and outward, assisting the abduction of vocal folds, enlargement of glottis, and tensing of vocal folds (Sataloff 2017).

1.1.2 Muscles That Adduct the Vocal Folds

The laryngeal muscles that adduct the vocal folds consist of the lateral cricoarytenoid (LCA) and interarytenoid (IA) muscles.


(A)
Epiglottis
Hyoid bone
Thyrohyoid membrane
Thyroid cartilage
Cricothyroid muscle
(Straight part)
Cricothyroid muscle
(Oblique part)
Cricoid cartilage
Tracheal cartilage
(B)
Epiglottis
Hyoid bone
Thyrohyoid membrane
Thyroid cartilage
Interarytenoid muscle
Cricothyroid muscle
(Straight part)
Posterior cricoarytenoid
muscle
Cricothyroid muscle
(Oblique part)
Cricoid cartilage
Tracheal cartilage

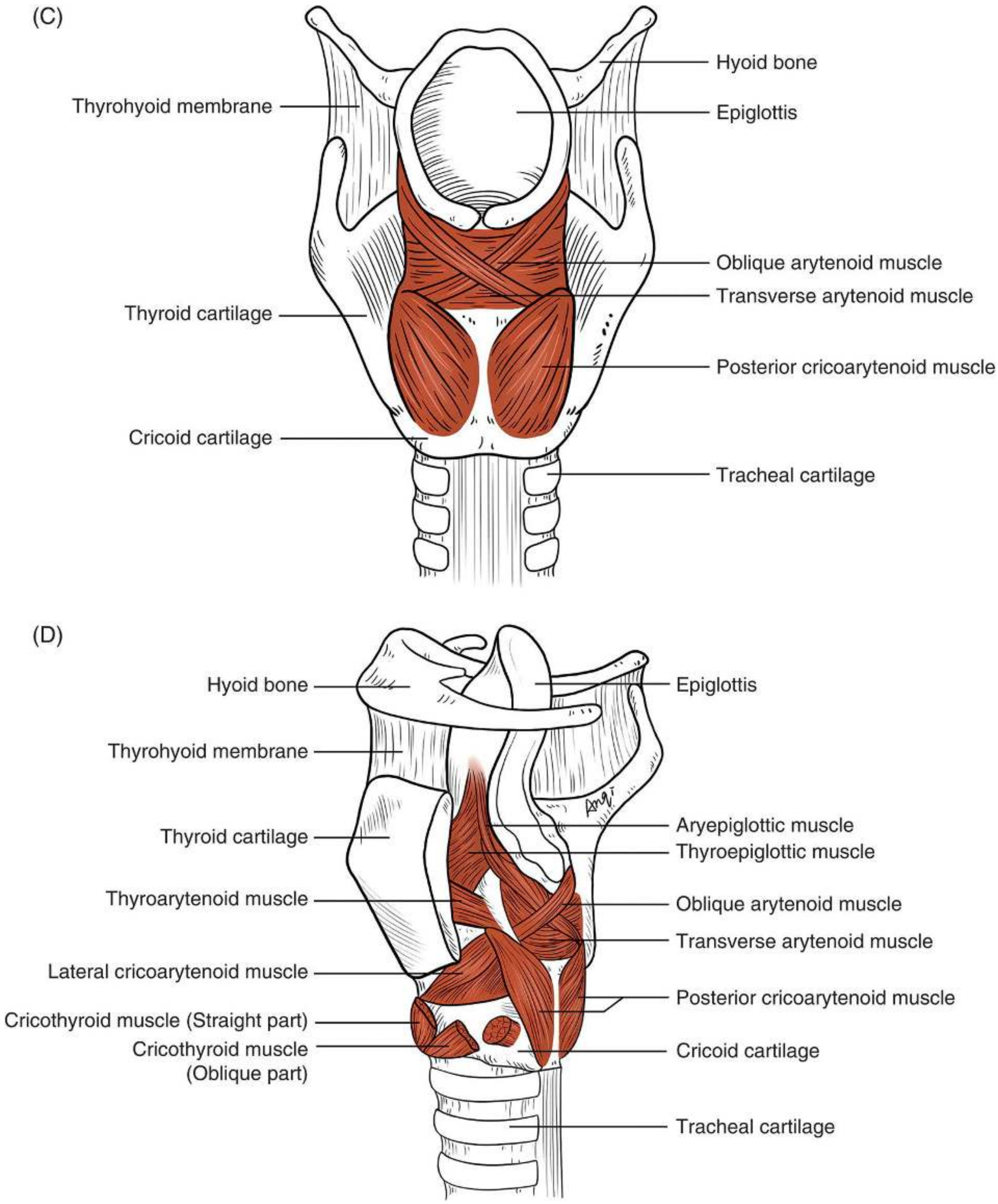


FIGURE 1.1 Diagram of the laryngeal muscles. (A) Anterior view. (B) Left lateral view. (C) Posterior view. (D) Sectional view

Lateral Cricoarytenoid Muscle

When the LCA muscles contract, they rotate the arytenoid cartilages and thus medially swing the vocal process onto which the vocal ligaments are attached. This brings the tips of the vocal processes together, resulting in adduction of the vocal folds, closure of the ligamentous part of the rima glottidis, and opening of the posterior intercartilaginous part in a triangular shape.

Interarytenoid Muscle

The arytenoid muscles, also known as the interarytenoid (IA) muscle, include the transverse arytenoid muscle and the oblique arytenoid muscle. Contraction of the IA muscle brings bilateral arytenoid cartilages together to close the posterior of the rima glottidis.

1.1.3 Vocal Fold Tension/Relaxation Muscles

The muscles that tense or relax the vocal folds consist of the cricothyroid (CT) and thyroarytenoid (TA) muscles.

Cricothyroid Muscle

The CT muscle is divided into two parts – straight and oblique parts. The former lies in front, while the latter lies to the outside of it. When the CT muscle contracts, the thyroid cartilage and the arch of the cricoid cartilage approach each other. The distance between the arytenoid cartilage and thyroid cartilage increases, which tightens the TA muscles, increases the tension of the vocal folds, raises the pitch, and then causes slight adduction of the vocal folds. It has also been suggested that during phonation, the cricopharyngeal muscle contracts so that the cricoid cartilage is fixed in front of the spine, while the lower edge of the thyroid cartilage approaches the arch of the cricoid cartilage. During swallowing, the arch of cricoid cartilage approaches the lower edge of the thyroid cartilage.

Thyroarytenoid Muscle

The main role of the TA muscle is to regulate the tension of the vocal folds. Contraction of the TA muscles causes the arytenoid cartilages to rotate inward to shorten and relax the vocal folds and narrow the rima glottidis. Some researchers believe that the vocal fold muscle fibers are divided into longitudinal, transverse, and oblique fibers, which can regulate muscle tension in segments, allowing the vocal folds to vibrate as a whole or partially.

1.1.4 Epiglottis Movement Muscles

The muscle group that activates the epiglottis mainly consists of the aryepiglottic and thyroepiglottic muscles.

The role of the internal laryngeal muscles varies, but it is a coordinated and unified entity in the physiological activities of the larynx. For example, the PCA muscle is mainly related to respiration. It contracts during inspiration to abduct the vocal folds. In recent years, it has been found that the PCA muscle is also involved in phonatory activities. During phonation, the slight contraction of the PCA muscle can stabilize the arytenoid cartilages and maintain the vocal folds in the phonatory position, resulting in stable and strong adduction of the vocal folds, which is conducive to sustained phonation. The PCA muscle also plays a role in increasing the tension in the vocal folds and regulating the pitch and intensity of the voice.

1.1.5 Classification of Laryngeal Muscle Fibers

Human muscle fibers are divided into two types according to their histochemical reaction: type I and type II fibers. Type I fibers (also known as slow muscle fibers) are more reactive to oxidative enzymes and less reactive to both phosphatases and ATPases. Type II fibers (also known as fast muscle fibers), on the other hand, can be divided into three subcategories based on their response to ATPase-IIA, IIB, and IIC. IIC fibers are primarily fetal progenitor cells and are rarely seen in adults. Slow fibers with high oxidative activity tolerate fatigue, whereas fast fibers with high glycolytic activity and low oxidative enzymes tend to be fatigued. The number of mitochondria in the muscle represents the level of aerobic metabolism in the cell. Berendes found that the order of mitochondria in the intrinsic laryngeal muscles was as follows: IA > PCA > TA > CT > LCA.

Among the intrinsic laryngeal muscles innervated by the unilateral recurrent laryngeal nerve (RLN), the TA muscle contains the most type II fibers associated with rapid contraction (up to 65%) and fewer fatigue-resistant type I fibers (35%), making the TA muscle more capable of rapid contraction. The PCA muscle has the most type I fibers (up to 67%) and the least type II fibers (33%). The PCA muscle contains more mitochondria, as well as a high capillary blood flow. Therefore, the PCA muscle has a strong ability to contract slowly and continuously. The structure of the IA muscle is different from other intrinsic laryngeal muscles and has a typical muscle spindle structure, in which the type of extrafusal muscle fibers is similar to that of normal trunk muscles. Due to the specificity of function, the IA muscle can contract rapidly during activities such as breathing, coughing, and phonation. In a resting state, some muscle fibers also keep tension to maintain the position of the larynx and the tension in the vocal folds. Since the IA muscle is innervated by the bilateral RLNs and is not easily injured, it plays an important compensatory role in unilateral laryngeal nerve paralysis, laryngeal joint