INTRODUCTION

Glottal gap is an incomplete glottal closure during phonation at comfortable intensity and pitch (Hertegard et al, 2002). It affects the ability of the larynx to serve as a vibrator during phonation and as a sphincter during swallowing (Hoffman et al, 2010). These patients with glottic insufficiency often suffer reduced quality of life because of voice and swallowing difficulties. Typical symptoms include a hoarse, breathy voice that is weak and difficult to sustain. Occasionally, there is difficulty of swallowing and aspiration, they can be a significant problem (Rosen and Thekdi, 2004).

One of the causes of glottal gap is vocal fold paralysis other less common causes are sulcus vocalis, vocal fold scar and vocal fold atrophy (Rosen, 2000). The diagnosis and treatment of glottic insufficiency is a challenging problem for the laryngologist (Damrose and Berke, 2003). Patient should be subjected to proper and careful evaluation before planning therapy. It relies primarily on laryngostroboscopic examination, voice assessment and swallowing evaluation (Peretti et al, 2006).

Unless there is severe swallowing impairment, treatment focuses on improving voice quality, thereby improving quality of life. Voice therapy may provide adequate improvement and should be considered as either sole or adjunctive therapy. If voice therapy is inadequate to correct voice quality, phonosurgery may be indicated (Rosen and Thekdi, 2004).

The general goal of surgery is to medialize the vocal fold and correct the closure defect to improve glottal vibrations, and to provide increased volume of the vocal fold in case of local defect or atrophy. This helps the unaffected healthy vocal fold to achieve the valving contact at midline of the glottis more easily (Hertegard et al, 2002). A wide variety of approaches have been employed including medialization laryngoplasty and endoscopic injection augmentation (Hsiung et al, 2003), arytenoid adduction (Isshiki, 1980) and reinnervation surgeries (Tucker, 1978; Lorenz et al, 2008).

Currently, medialization thyroplasty and vocal fold injections are the most popular and effective procedures of choice in the treatment of glottic insufficiency. (Damrose and Berke, 2003).

Advances in thyroplasty techniques over the last two decades have provided the laryngologist with a useful tool with which to address the problem of medialization. The need for simpler techniques with which to address glottic insufficiency spurred the development of materials that could be injected directly into the vocal fold. However, the problem of reabsorption has limited the utility of the injection in addressing the issue of glottic insufficiency. The technique has the advantages of ability to perform in an in-office, awake setting and may be easier to master than laryngeal framework surgery (Mallur and Rosen 2010).

This study is designed to investigate the early and long-term functional results of medialization thyroplasty with Gore-tex and injection augmentation using calcium hydroxylapatite (CaHA).

AIM OF THE WORK

Evaluation of laryngoplasty in the management of glottic insufficiency.

This thesis aims at comparing the injection and medialization laryngoplasty in treatment of large glottic gap regarding the postoperative gap closure and voice improvement.

OBJECTIVES

1. Review the anatomy, microanatomy of the larynx and physiology of voice production.
2. Review the presentation, evaluation and different causes of glottic incompetence.
3. Review various treatment options for glottic insufficiency.
4. Clinical study on patients.

APPLIED FUNCTIONAL ANATOMY

The larynx is a complex neuromuscular structure that sits at the crossroads of the respiratory and digestive systems (Merati and Rieder, 2003).

It consists of a framework of cartilages and fibro elastic membranes covered by a sheet of extrinsic muscles and lined with mucous membrane. It extends from an oblique entrance formed by the aryepiglottic folds, the tip of the epiglottis, and the posterior commissure to the lower border of the cricoid cartilage and bulges posteriorly into the laryngopharynx (Morris, 1988).

The thyroid cartilage is the largest cartilage of the larynx, composed of two rectangular alae fused in the midline and open posteriorly. In the male-, the alae fuse at about 90 degrees, making a laryngeal prominence or Adam's apple. In female, this prominence is absent owing to the more oblique fusion angle of 120 degrees. The fusion of the alae is deficient, accounting for the thyroid notch. Posteriorly, each ala has a superior and inferior horn or cornu. The inferior cornu articulates with a facet on the cricoid cartilage to form the cricothyroid joint. The superior cornu attaches to the greater cornu of the hyoid bone by the lateral thyrohyoid ligament (Hast, 1993).

The two lateral thyrohyoid ligaments, along with the median thyrohyoid ligament, are condensations of the thyrohyoid membrane; these structures attach the hyoid bone to the thyroid cartilage. At the attachment of the superior cornu to the alae of the thyroid, a protuberance called the superior tubercle is found. About 1 cm anterior and superior to this tubercle, lie the superior laryngeal artery and the internal branch of the superior laryngeal nerve [Figure 1]. At this point, transcutaneous anesthesia of the internal branch can be performed (Sasaki et al, 1996; Rosen and Simpson, 2008).

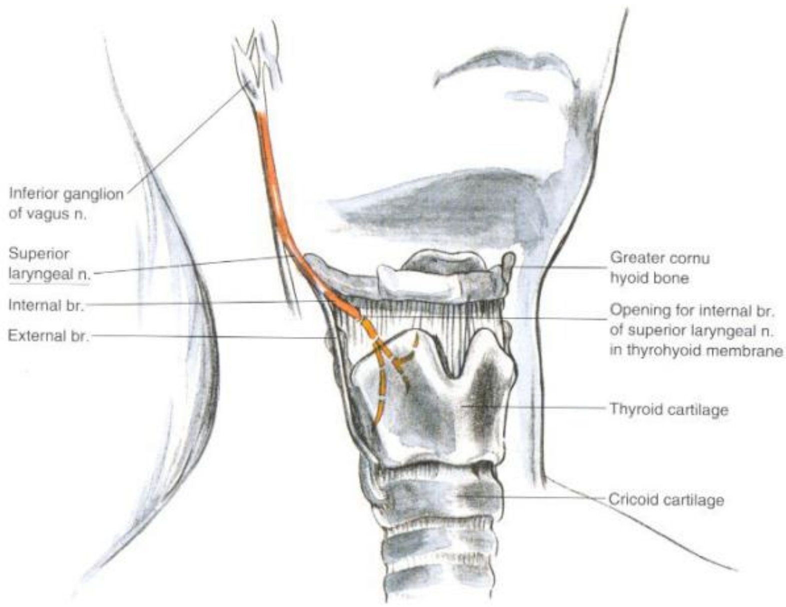

Fig. (1): Illustration for the course of the Superior laryngeal nerve. Quoted after Brown, 2010.

Understanding the relationship between the levels of the true cords in relation to the thyroid cartilage is crucial to performing thyroplasty. In this regard, the midline vertical distance from the thyroid notch to the inferior border of the thyroid cartilage ranges from 20 to 47 mm in men and 15.5 to 38 mm in women. The true cord is found at the midpoint between these landmarks (Maue and Dickinson, 1971; Rosen and Simpson, 2008). {Figure 2].

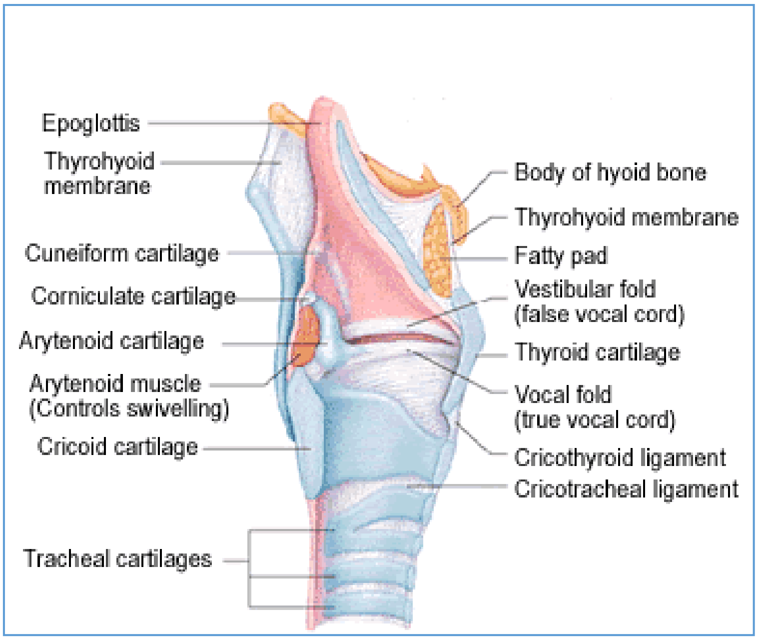

Fig. (2): Sagittal section of the larynx.
Quoted after Stojanović and Belić, 2013.

The cricoarytenoid joint is the primary moving structure of the intrinsic larynx. The arytenoids articulate with the cricoid cartilage forming multiaxial joints. The action of movement at the cricoarytenoid joints changes the distance between the vocal processes of the two arytenoids and between each vocal process and the anterior commissure. The combined action of the intrinsic laryngeal muscles on the arytenoid cartilages alters the position and shape of the vocal folds. Each cricoarytenoid joint sits at a surprisingly steep 45° angle with the horizontal plane on the cricoid cartilage and permits motion in a sliding, rocking, and twisting fashion (Armstrong and Netterville, 1995; Rosen and Simpson, 2008).

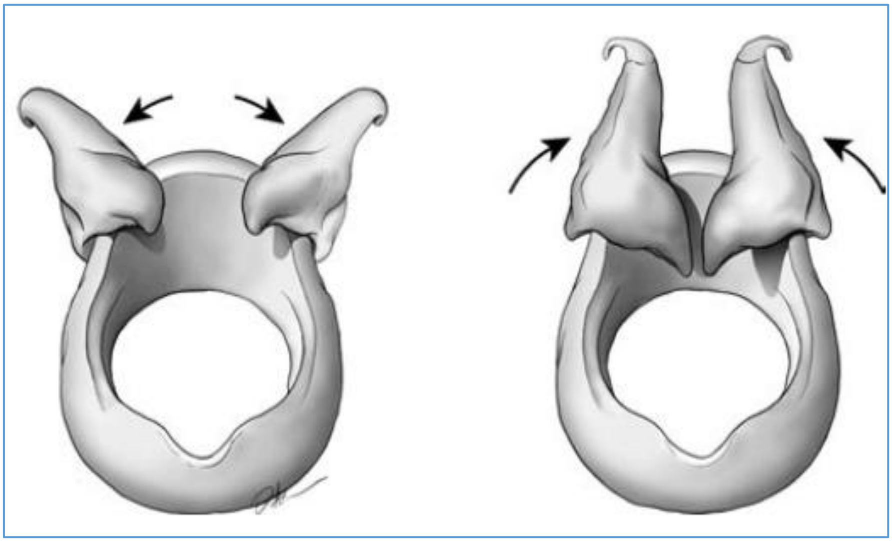

Fig. (3): Cricoarytenoid joint Action. Quoted after Rosen and Simpson, 2008.

The Intrinsic Muscles of the larynx are responsible for the movement, length and tension of the vocal folds. They also modify the size and shape of the glottis. They consist of multiple adductors (mainly lateral cricoarytenoid, thyroarytenoid and interarytenoid muscles), but only a single abductor (posterior cricoarytenoid muscle) and one tensor (cricothyroid) (Noordzij & Ossoff, 2006).

The lateral cricoarytenoid (LCA) muscle originates from the anterior part of the muscular process of the arytenoid and inserts to the superior border of the cricoid cartilage. Contraction of this muscle results in movement of the muscular process anterolaterally, while simultaneously forcing the vocal process downward and medially. The result is adduction and lengthening of the vocal folds (Rosen and Simpson, 2008).

The thyroarytenoid muscle arises from the inner thyroid cartilage and inserts on the vocal process of the arytenoid cartilage. The posterior cricoarytenoid muscle originates from the posterior surface of the cricoid cartilage and inserts onto the muscular process of the arytenoid (Noordzij and Ossoff, 2006).

The cricothyroid muscle is a laryngeal tensor that narrows the gap between the thyroid and cricoid cartilages, thereby stretching of the vocal folds. It is composed of two separate muscle bellies, located on the external surface of the laryngeal cartilages (Hillel, 2001).

The pars recta, the more vertical component, arises laterally from the superior rim of the cricoid cartilage and inserts on the inferior rim of the thyroid cartilage, while the pars obliqua, runs obliquely from the superior arch of the cricoid to insert on the inferior cornu. Contraction of the cricothyroid muscle bellies affects motion at the cricothyroid joint. During contraction, the cricothyroid space is narrowed anteriorly, while the posterior cricoid lamina and cricoarytenoid joints are forced caudally, resulting in lengthening, tightening and thinning of the vocal folds as well as increasing their resonant frequency. This action also results in vocal fold adduction. Professional singers rely particularly on proper cricothyroid muscle control to reach higher pitches while singing (Bryant et al, 1996; Hillel, 2001).

The interarytenoid muscle (IA) consists of both transverse fibers and oblique fibers. The transverse fibers insert on the posterior face of each arytenoid and run horizontally, while the oblique fibers attach to each arytenoid apex and run obliquely to attach to the posterior face on the opposite side. Contraction of this muscle leads to arytenoid adduction, closure of the posterior glottis, and narrowing of the laryngeal inlet. Some oblique fibers extend to travel along the quadrangular membrane and are referred to as the aryepiglottic muscle (Rosen and Simpson, 2008).

Compartmentalization of the intrinsic laryngeal muscles allows for ultrafine control of the vocal fold position. The posterior cricoarytenoid, cricothyroid, and thyroarytenoid muscles all have subdivisions, each with separate nerve branches. The division of the thyroarytenoid muscle into superior and inferior subcompartments, which appear to contract independently, allows the human larynx to produce sounds with a variety of intensities and qualities that would not otherwise be possible (Sanders et al, 1998).

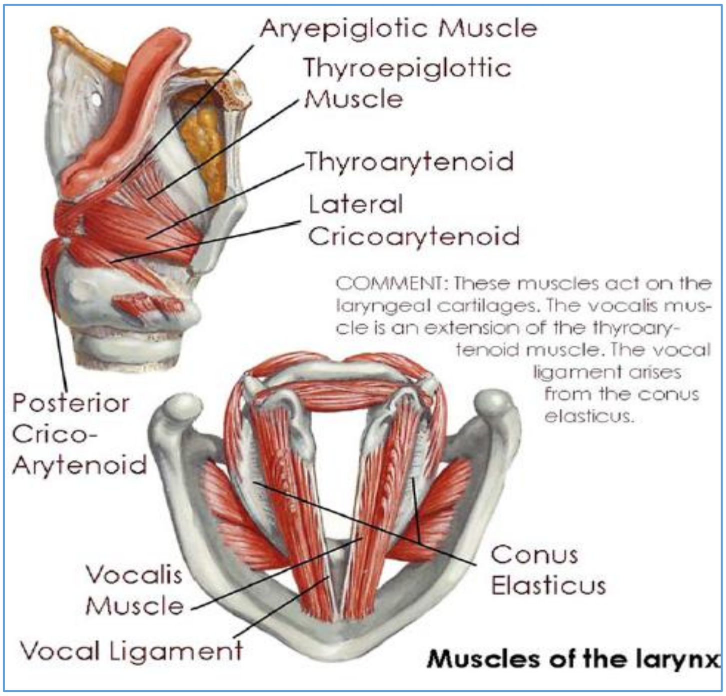

Fig. (4): Muscles of the larynx. Quoted after Noordzij and Ossoff, 2006.

The vagus nerve provides motor and sensory innervation to the larynx through two branches, the superior and recurrent laryngeal nerves (Noordzij & Ossoff, 2006). [Figure 5].

The superior laryngeal nerve (SLN) arises from the vagus at its sensory ganglion (nodose ganglion). It splits into a smaller motor external division and a larger internal division (mainly sensory) (Stockwell et al, 1995; Rassekh et al, 1998; Olthoff et al, 2007).

The external branch of the superior laryngeal nerve (SLNeb) follows the course of the superior thyroid artery descending along the lateral surface of the inferior constrictor muscle (to which it sometimes sends a branch to share in its supply with the RLN) and then innervates the cricothyroid muscle (Rassekh et al, 1998; Monfared et al, 2002).

The internal branch of the superior laryngeal nerve (IBSLN; or internal laryngeal nerve) passes deep to the superior thyroid vessels to penetrate the thyrohyoid membrane with the superior laryngeal artery lying inferior to the nerve (in some cases, the superior laryngeal artery may be superior or anterior to the IBSLN). The nerve then divides into three branches (superior, middle and posterior descending) supplying supraglottis, glottis and laryngopharynx (Furlan et al, 2002; Monfared et al, 2002).

There are some recent anatomic studies that suggest that the superior aspect of the TA muscle (the ventricularis muscle in the false vocal fold) may have SLN innervation, which could explain the presence of false vocal fold muscular contraction in cases of RLN transection (Rosen and Simpson, 2008).

The recurrent laryngeal nerve (RLN) arises from the vagus nerve in the upper chest and loops under the aortic arch (left) or subclavian artery (right), and ascends back into the neck, traveling in the tracheoesophageal groove. The nerve enters the larynx posteriorly, adjacent to the cricothyroid joint. The RLN innervates the ipsilateral posterior cricoarytenoid (PCA), the interarytenoid (IA) (an unpaired muscle), and the lateral cricoarytenoid (LCA), and terminates in the thyroarytenoid (TA). Thus, the RLN supplies all of the intrinsic laryngeal muscles with the exception of the cricothyroid muscle. The RLN also supplies the glottic and subglottic mucosa (Garrett et al, 1991; Sanders et al, 1993; Olthoff et al, 2007).

Both left and right recurrent laryngeal nerves may be non-recurrent, meaning the nerve does not travel into the thorax but rather directly from the skull base through the neck into the larynx. This occurs on the right side in approximately 0.5% of cases and much less commonly on the left side (Henry et al, 1988).

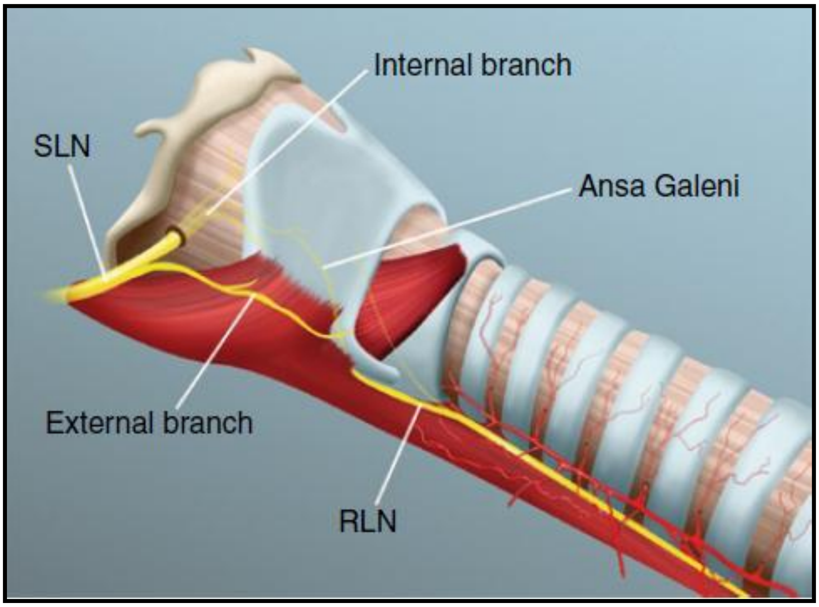

Fig. (5): Innervations of the larynx Quoted after Monnier, 2011.

MICROANATOMY OF THE VOCAL FOLD

The complex microanatomy of the free edge of the vocal fold is especially adapted for its phonatory function. This vocal fold epithelium is squamous rather than respiratory and contains no mucous glands. The arrangement of connective tissue within the vocal fold allows the loose and pliable superficial mucosal layers to vibrate freely with minimal restriction from the underlying vocalis muscle (Noordzij & Ossoff, 2006; Nassar & Bridger, 1971).

The true vocal fold can be divided into three major layers: the mucosa, the vocal ligament, and the underlying muscle. [Figure 6]. The mucosa of the vocal fold is highly specialized for its vibratory function. It is formed of squamous epithelium which is very thin and helps to hold the shape of the vocal fold. [Figure 7]. Deep to the epithelium are three layers of lamina propria, each of increasing rigidity. The most superficial layer (superficial layer of the lamina propria (SLP) is mostly acellular and composed of extracellular matrix proteins, water, and loosely arranged fibers of collagen and elastin. The SLP is gelatinous in nature and it offers the least resistance to vibration. The potential space between the SLP and the intermediate layer of lamina propria is Reinke's space. The intermediate and deep layers of the lamina propria (ILP and DLP) are composed mostly of elastin and collagen. The deepest (DLP) is the most dense layer composed of tightly arranged collagen fibers.

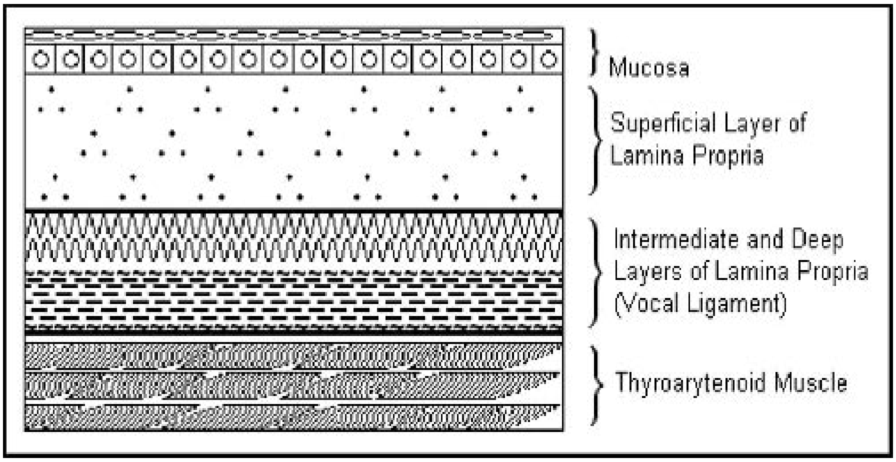

Fig. (6): Layers of the vocal folds.
Quoted after Damrose and Berke, 2003.

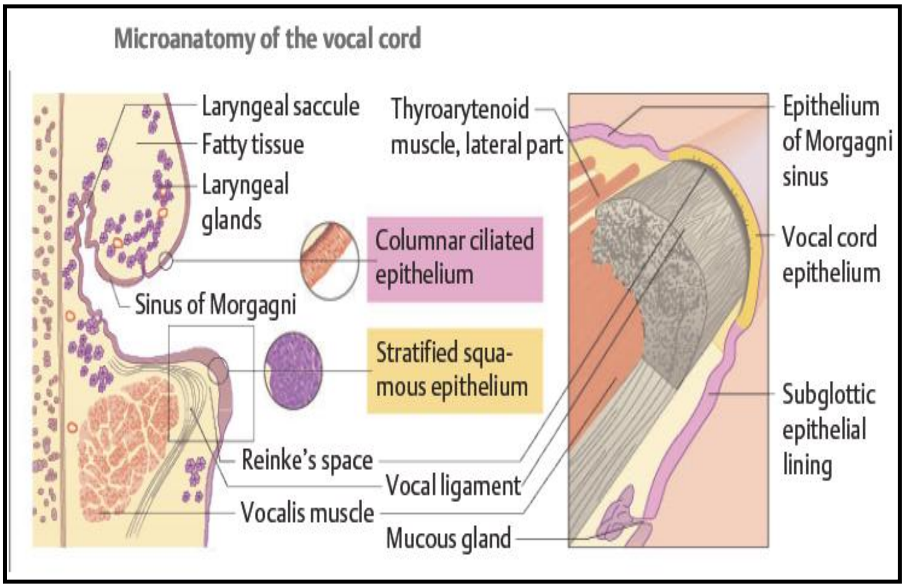

Fig. (7): Ultrastructure of the vocal cord.
Quoted after Sternburg, 1989.

The ILP and DLP together form the vocal ligament. The vocal ligament is the uppermost free edge of the conus elasticus. The vocal fold mucosa and vocal ligament cover the vocalis muscle and extend from the anterior commissure to the vocal processes of