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Laryngeal reinnervation for unilateral vocal fold paralysis using ansa cervicalis nerve to recurrent laryngeal nerve anastomosis

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In laryngeal paralysis, the stiffness of the denervated vocal fold is decreased. This leads to deviant vibratory patterns involving 2 asymmetric vocal folds and results in abnormal vocal quality. Follow-up studies of medialization thyroplasty patients have noted that decrement in vocal quality after medialization is often because of continuing vocal fold atrophy. Vocal cord atrophy from denervation injury can be countered by reinnervation. This article reviews the most commonly performed laryngeal reinnervation procedure for unilateral vocal fold paralysis: ansa cervicalis nerve to recurrent laryngeal nerve anastomosis.

Complete recovery from neurogenic vocal fold paralysis can only occur through the spontaneous and selective regeneration of the recurrent laryngeal nerve (RLN) axons to laryngeal adductor and abductor muscles. Current surgical interventions cannot reliably return physiological vocal fold movement or the rapid and fine adjustments required for continuous maintenance of vocal fold symmetry. Vocal fold medialization and augmentation procedures improve the phonatory glottal posture by closing the glottal gap but do not provide adequate muscle tone or stiffness during phonation. Reinnervation at the level of the RLN trunk can restore or improve laryngeal muscle tone and mass. The result is the potential for a near normal vocal ability.

The ansa cervicalis nerve to RLN anastomosis (ansa-RLN transfer) for laryngeal reinnervation was first reported by Frazier[1] in 1924 in an attempt to restore vocal fold movement. The most widely used technique was developed in 1986 by Crumley and Izdebski.[2] In this technique an end-to-end anastomosis of one of the ansa cervicalis branch to the distal stump of the RLN is performed close to the larynx. The procedure is indicated for unilateral paralysis because normal vocal fold adduction and abduction is not restored. Instead, muscle tone is restored to the entire hemilarynx, thus providing appropriate position, bulk, and tone to the vocal fold. In adults, the procedure is often commonly performed concurrently with a vocal fold medialization procedure (eg, injection laryngoplasty or arytenoid adduction) because of the 6- to 9-month lag time for reinnervation to occur and because ansa-RLN transfer alone is unlikely to adequately adduct the vocal fold for phonation.[2-4]

Relevant neuroanatomy

The RLN contains 1000 to 4000 axons, which include motor efferent axons and autonomic secretomotor fibers, depending on the level at which the count is made. The RLN also gives off branches to the cricopharyngeus muscle as well as a sensory branch that communicates with the superior laryngeal nerve before entering the larynx. In the motor branches of the RLN, 500 to 1000 fibers are present.[5] After entering the larynx, the RLN gives off 2 main branches: a posterior branch that innervates the posterior cricoarytenoid

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(PCA) and interarytenoid muscle and an anterior branch that innervates the lateral cricoarytenoid (LCA) and thyroarytenoid (TA) muscles. The branch to the PCA has characteristics of a slow-twitch motor nerve with axons containing 200 to 250 muscle fibers in each motor unit,[6] whereas the axons in the anterior branch are more characteristic of fast-twitch fibers with motor unit sizes of 2 to 20 muscles.[7] Before branching within the laryngeal framework, the motor fibers to the various muscles are intermixed throughout the RLN nerve trunk making selective reinnervation at this level impractical.[8]

The ansa cervicalis nerve has become the prime choice for laryngeal reinnervation because of its close proximity to the larynx, excellent size match to the RLN, and minimal morbidity from its division from the strap muscles.[4] Except for proprioceptive fibers carried within the nerve, the ansa cervicalis is a purely motor derivative of the ventral rami of the cervical plexus. Fibers from the first cervical rootlet (C1) join the hypoglossal nerve and descend in the neck until the hypoglossal assumes a horizontal course toward the tongue at the level of the occipital artery. At this point, most of the C1 fibers leave the hypoglossal nerve to form the superior (anterior) root of the ansa cervicalis. Some C1 fibers continue along the hypoglossal nerve to branch off as the nerve to the thyrohyoid closer to this muscle. The inferior (posterior) root of the ansa cervicalis is formed from the ventral rami of C2 and C3 cervical nerves. The superior root descends along the anterolateral side of the carotid sheath, where it may send a branch to the anterior belly of the omohyoid, and the inferior root descends along the posteromedial side of the carotid sheath until it joins the superior root to form a loop over the lateral side of the carotid sheath. The loop typically forms at the level where the omohyoid passes over the carotid sheath. One or 2 braches arise from the level of the loop and branch further to innervate the omohyoid, sternohyoid, and sternohyoid strap muscles. Topographic anatomy and morphologic variations of the ansa cervicalis have been previously reported, and the surgeon should review this anatomy thoroughly before undertaking the ansa-RLN transfer operation (Figure 1).[9]

There is substantial body of evidence that reinnervated muscle takes on the characteristics of the donor nerve. This appears to be facilitated by the donor nerve imposing a pattern of activity on the muscle fibers it reinnervates. Thus, the selection of a donor nerve should ideally take into account the fiber type and contraction characteristics of the muscle to be reinnervated. The TA and LCA are fast-twitch muscles of the larynx with peak contraction times of 14 ms for TA and 19 ms for LCA. The composition of muscle fibers in these muscles reflects their faster response time. Only 19% to 36% of TA muscle fibers are type 1. The 2A and 2X muscle fibers are roughly equally divided among the remaining muscle fibers.[10] A similar percentage is found in the LCA muscle. The faster response characteristics of these muscles are appropriate for their phonatory and protective functions. By contrast, the peak contraction times of the thyrohyoid and sternothyroid are approximately 50 ms. The muscle fiber-type composition of the sternothyroid

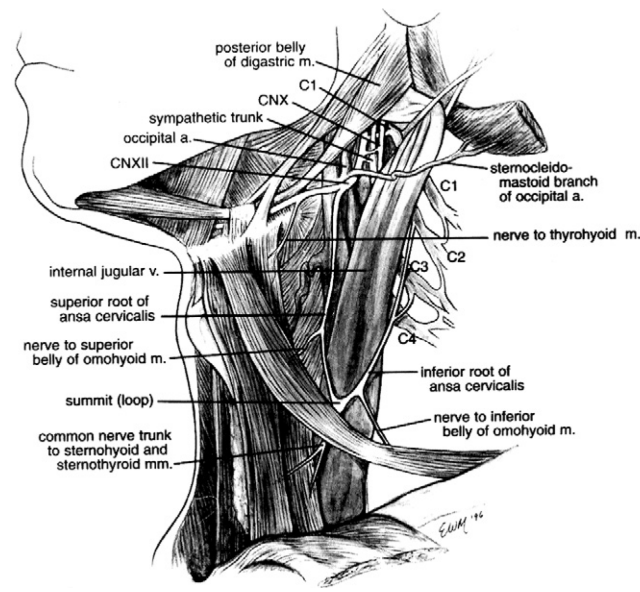

Figure 1 Topographic anatomy of the most common variation of the ansa cervicalis nerve.[9]

is roughly two-thirds type 1 fiber. After reinnervation for unilateral vocal fold paralysis with the ansa cervicalis, changes in the fiber type-composition of the laryngeal muscles would be expected. However, although the strap muscles, therefore, are less than perfect histochemical match to the recipient laryngeal muscles, for the aforementioned reasons of close proximity, size match, and minimal morbidity, the ansa cervicalis is still currently the best available nerve candidate for laryngeal reinnervation.

Indications for ansa-RLN transfer

Denervation eliminates both the trophic and nerve activity-related influences on the muscle. Without reinnervation, there is progressive atrophy and eventual fibrosis of the muscle despite an adequate blood supply and nutrients. The main indication for ansa-RLN transfer is neurogenic unilateral vocal fold paralysis where recovery of RLN function is not expected (Figure 2). Obviously, the distal stump of RLN and one intact ansa must be available for anastomosis. The operation is best performed under general anesthesia, although the operation can also be performed under intravenous sedation and local anesthesia. In addition, reinnervation takes places over a 6- to 9-month period, and the patient must accept and be able to tolerate this time delay for final voice results from reinnervation.

Contraindications for the surgery include glottic airway compromise, absent distal RLN stump, and absent ansa cervicalis bilaterally. Additionally, patients with poor prognosis who are not expected to survive long enough for reinnervation to occur or enjoy the long-term benefit of reinnervation should be offered other medialization procedures. If ansa is missing from one side, the contralateral ansa can be used.[11] Additionally, the most optimal timing for laryngeal reinnervation remains to be investigated. The