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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

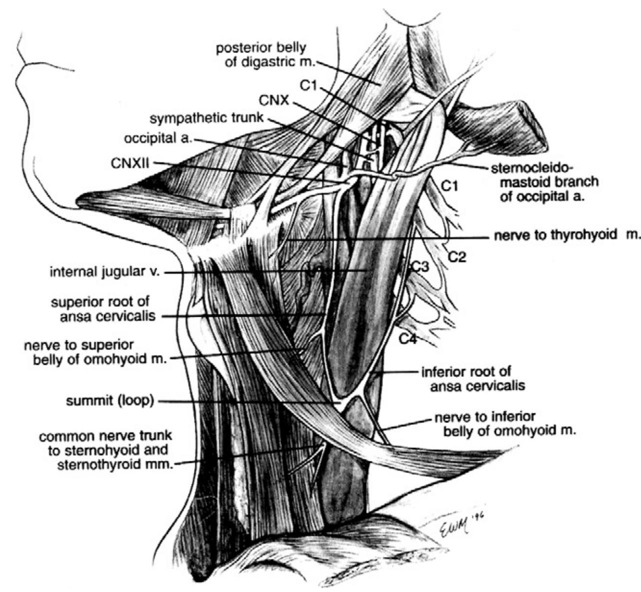

Figure 1 Topographic anatomy of the most common variation of the ansa cervicalis nerve.[9]

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

Figure 2 Illustrative case of recurrent laryngeal nerve (RLN) damage leading to unilateral vocal fold paralysis. (Image © Edward J. Damrose.) (Color version of figure is available online.)

native RLN is transected during reinnervation surgery, so it is understood that reinnervation should be undertaken after a determination is made that vocal fold paralysis is permanent. However, is it ever too late to perform reinnervation? It is generally felt that reinnervation becomes less effective with longer duration of nerve injury and the older age of the patient.[12] However, successful laryngeal reinnervation has been claimed as much as 50 years after onset of laryngeal paralysis.[13] State of residual innervation of the larynx likely plays a role in its potential for reinnervation. Other potential explanations include nerve sprouting that results in a low-grade but functionless innervation[14] or innervation from misdirected reinnervation from autonomic nerves.[15] In the larynx, the situation is complicated by the potential for cricoarytenoid joint fixation after prolonged period of paralysis, which can impair the functional results. However, the incidence of cricoarytenoid joint fixation may be less than was previously anticipated.[16]

Technique

The procedure is performed in the operating room under general anesthesia. Neuromuscular paralysis is avoided to allow proper identification of nerves. Because the RLN will be divided, it is important to ensure the correct surgery side. This can be achieved by careful review of the charts, preoperative videostroboscopic videos, and confirming the surgical site with the patient.

A horizontal cervical incision is made in a natural skin crease at the level of the cricoid cartilage. An approximately 4-cm incision is made starting from just off the midline on the contralateral side of the neck to the edge of the sternocleidomastoid muscle on the ipsilateral neck. Subplatysmal flaps are raised superiorly and inferiorly to fully expose the larynx. The ansa cervicalis nerve is first exposed by dissecting over the carotid triangle and exposing the lateral carotid sheath (Figure 1). The nerve is found on the carotid sheath, typically overlying the internal jugular vein. The superior root or an ansa branch is usually encountered and the nerve is then followed distally underneath the omohyoid muscle. Nerve stimulators can be used for proper identification of the nerve and its branches. A retractor is placed under the omohyoid, and blunt dissection will often expose the nerve branches distally. A suitable branch of the ansa cervicalis is identified, followed until adequate length is exposed to allow rotation of the nerve over to reach the RLN stump at the larynx, and then divided and transposed over in the region of the tracheoesophageal groove (Figure 3). The inferior (posterior) root of the ansa can be divided just proximal to formation of the ansa loop if there is inadequate length of the branches, and the nerve cannot be adequately transposed to reach the larynx without release of the posterior root.

The distal portion of the RLN can be identified one of 2 locations—distally near the larynx and cricothyroid joint or more proximally in the tracheoesophageal groove. In the authors' practice, ansa-RLN transfer is typically performed in conjunction with an arytenoid adduction. To perform the adduction, the inferior constrictor muscle is divided at the posterior thyroid ala and the PCA muscle is identified. The

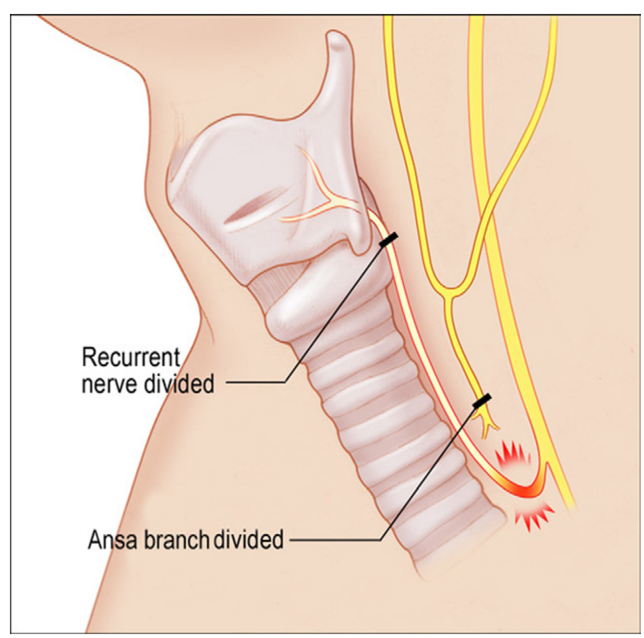

Figure 3 To prepare the nerves for laryngeal reinnervation an ansa cervicalis branch is divided distally, allowing adequate length to transpose this branch to the larynx. The RLN is divided at a suitable distance that allows tension-free anastomosis to the ansa cervicalis. (Image © Edward J. Damrose.) (Color version of figure is available online.)

PCA muscle inserts on the muscular process of the arytenoid. The RLN is found just lateral to the PCA muscle and just medial to the cricothyroid joint. The nerve can be further followed proximally, and the cricopharyngeus muscle can be divided to allow further dissection of the nerve and mobilization of adequate length for anastomosis. This approach is also very useful because in most instances, the RLN is intact here and not injured or trapped by surgical scar from previous neck surgery such as a thyroidectomy. Alternatively, the nerve can be found by dissecting in the tracheoesophageal groove if neck surgery has not been performed in this location previously. The superior thyroid neurovascular bundle can be rotated laterally and inferiorly, and by dissecting posteriorly and inferiorly, the nerve is identified because it comes up to enter the larynx at the inferior cornu of the thyroid cartilage just below the cricopharyngeus muscle. The nerve can also be located in the tracheoesophageal groove by rotating the thyroid lobe medially. The nerve is dissected out distally in the tracheoesophageal groove and divided at a suitable distance that allows for an unencumbered anastomosis (usually 7-10 mm) (Figure 3). A lateral tunnel is made deep to the sternohyoid and sternothyroid muscles and connects the 2 operative sites and facilitates the anastomosis.

After both nerves are identified and the distal RLN confirmed to be intact, the ansa and RLN are transected. Each nerve should be divided with enough length to allow a tension-free anastomosis (Figure 4). Microsurgical instruments and loupe or microscopic magnification are necessary to perform microsurgical neurorrhaphy of the ansa cervicalis branch and the RLN. Typically, 7-O or 8-O nylon suture is used to perform epineural anastomosis in 3 locations around the nerves. When reinnervation is combined with an arytenoid adduction, localization and preparation of nerves are performed first, followed by adduction, and finally nerve anastomosis (Figure 5). Magnification is used and can be with either a surgical microscope or loupes.

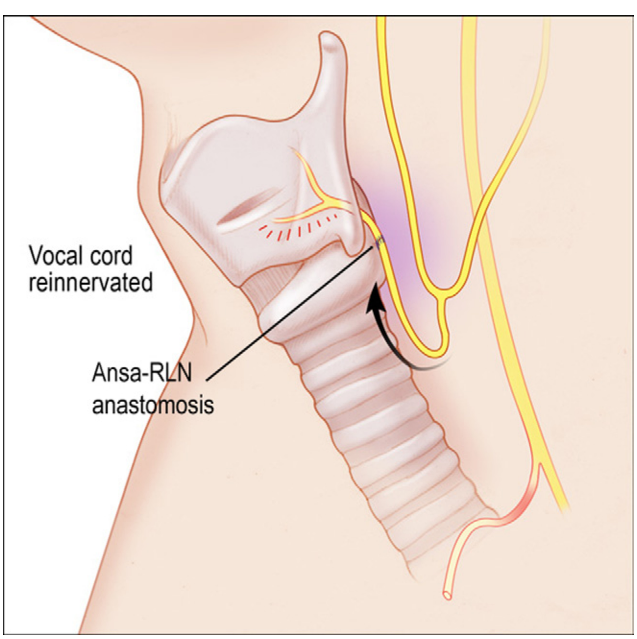

Figure 4 The ansa-cervicalis to RLN epineural anastomosis is performed close to the larynx using 7-0 or 8-0 nonabsorbable sutures. (Image © Edward J. Damrose.) (Color version of figure is available online.)

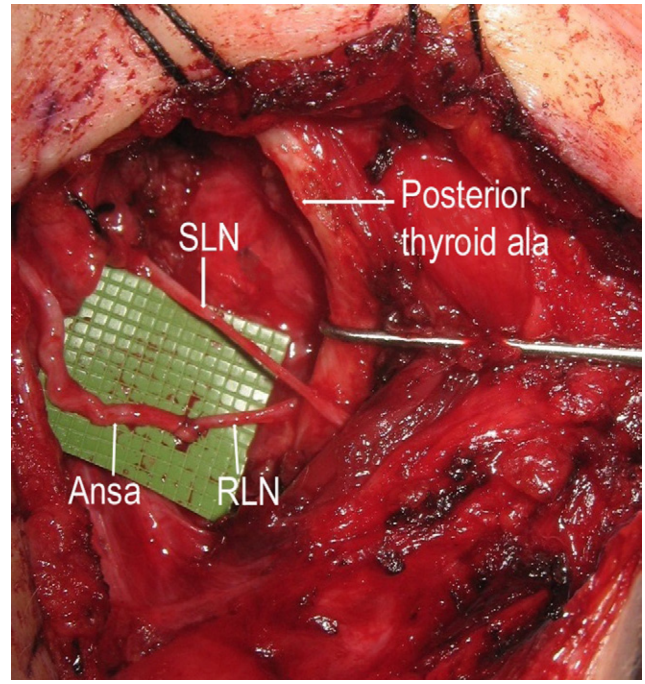

Figure 5 Illustrative case of ansa-RLN anastomosis performed concurrently with arytenoid adduction for right vocal fold paralysis. The posterior border of the thyroid ala is exposed by dividing the inferior constrictor muscles to facilitate the arytenoid adduction procedure. The superior laryngeal nerve is preserved. (Color version of figure is available online.)

Complications

Ansa to RLN transfer is a very safe and reproducible operation. Extra care should be given when separating the ansa cervicalis from the carotid sheath to prevent inadvertent injury to the internal jugular vein. In general, the nerve separates nicely from the vein and any extra bleeding is because of injury to minor vessels around the nerve or to small tributaries off the internal jugular vein. These can be easily controlled with bipolar electrocautery or suture ligation. Similarly, venae comitantes accompany the RLN, especially in the intralaryngeal portion, and careful cautery of these vessels may be needed during dissection, and inadvertent injury of the RLN should be avoided. If the nerve ends are excessively crushed during mobilization then the ends should be freshened before anastomosis.

Discussion

There are some disadvantages of ansa-RLN transfer operation compared with other procedures such as injection laryngoplasty or medialization thyroplasty. The procedure takes longer to perform than injection or thyroplasty, and surgical dissection in the setting of previous neck surgery can be challenging. At least one neurologically functional ansa cervicalis nerve as well as an intact distal stump of the RLN must be present. General anesthesia is typically used, and therefore, the patient should be healthy from a cardiovascular standpoint. The final benefit of reinnervation may only be obvious 6 to 9 months after the operation because reinnervation occurs over this period. Because the RLN is physically divided, the possibility of spontaneous recovery of vocal fold function is eliminated. Finally, care must be taken to perform correct side surgery and to avoid a major complication of bilateral vocal fold paralysis.

Ansa-RLN transfer is a technically reproducible and safe operation[17] that has the potential to restore the position, tone, tension, and bulk to the denervated vocal fold. The sacrifice of innervation to the strap muscles from division of the ansa cervicalis or its branches is clinically insignificant. There is also no limitation for subsequent framework procedures or injection laryngoplasty if outcome is not adequate. Reinnervation is a physiological procedure that can be performed in both pediatric and adult operation. Histologic and electromyographic evidence of reinnervation after ansa cervicalis to RLN anastomosis has been demonstrated previously.[18] Laryngeal reinnervation, especially when combined with laryngeal framework surgery such as arytenoid adduction, has the potential for restoring a near normal voice for the long-term.[4]

References

1. Frazier CH: Anastomosis of the recurrent laryngeal nerve with the descendens noni: in cases of recurrent laryngeal paralysis. J Am Med Assoc 83:1637-1641, 1924
2. Crumley RL, Izdebski K: Voice quality following laryngeal reinnervation by ansa hypoglossi transfer. Laryngoscope 96:611-616, 1986
3. Crumley RL, Izdebski K, McMicken B: Nerve transfer versus Teflon injection for vocal cord paralysis: a comparison. Laryngoscope 98: 1200-1204, 1988
4. Chhetri DK, Gerratt BR, Kreiman J, et al: Combined arytenoid adduction and laryngeal reinnervation in the treatment of vocal fold paralysis. Laryngoscope 109:1928-1936, 1999
5. Hayashi M, Isozaki E, Oda M, et al: Loss of large myelinated nerve fibres of the recurrent laryngeal nerve in patients with multiple system atrophy and vocal cord palsy. J Neurol Neurosurg Psychiatry 62:234-238, 1997
6. Hast MH: The primate larynx. A comparative physiological study of intrinsic muscles. Acta Otolaryngol 67:84-92, 1969
7. Hirose H, Ushijima T, Kobayashi T, et al: An experimental study of the contraction properties of the laryngeal muscles in the cat. Ann Otol Rhinol Laryngol 78:297-306, 1969
8. Gacek RR, Malmgren LT, Lyon MJ: Localization of adductor and abductor motor nerve fibers to the larynx. Ann Otol Rhinol Laryngol 86:771-776, 1977
9. Chhetri DK, Berke GS: Ansa cervicalis nerve: review of the topographic anatomy and morphology. Laryngoscope 107:1366-1372, 1997
10. Li ZB, Lehar M, Nakagawa H, et al: Differential expression of myosin heavy chain isoforms between abductor and adductor muscles in the human larynx. Otolaryngol Head Neck Surg 130:217-222, 2004
11. Wang W, Chen S, Chen D, et al: Contralateral Ansa cervicalis-to-recurrent laryngeal nerve anastomosis for unilateral vocal fold paralysis: a long-term outcome analysis of 56 cases. Laryngoscope 121: 1027-1034, 2011
12. Apel PJ, Alton T, Northam C, et al: How age impairs the response of the neuromuscular junction to nerve transection and repair: an experimental study in rats. J Orthop Res 27:385-393, 2009
13. Tucker HM: Human laryngeal reinnervation: long-term experience with the nerve-muscle pedicle technique. Laryngoscope 88:598-604, 1978
14. Crumley RL: Update: ansa cervicalis to recurrent laryngeal nerve anastomosis for unilateral laryngeal paralysis. Laryngoscope 101:384-387, 1991
15. Nomoto M, Yoshihara T, Kanda T, et al: Misdirected reinnervation in the feline intrinsic laryngeal muscles after long-term denervation. Acta Otolaryngol Suppl 506:71-74, 1993
16. Gacek M, Gacek RR: Cricoarytenoid joint mobility after chronic vocal cord paralysis. Laryngoscope 106:1528-1530, 1996
17. Blumin JH, Merati AL: Laryngeal reinnervation with nerve-nerve anastomosis versus laryngeal framework surgery alone: a comparison of safety. Otolaryngol Head Neck Surg 138:217-220, 2008
18. Green DC, Berke GS, Graves MC: A functional evaluation of Ansa cervicalis nerve transfer for unilateral vocal cord paralysis: future directions for laryngeal reinnervation. Otolaryngol Head Neck Surg 104:453-466, 1991