Selective laryngeal reinnervation in the management of bilateral vocal fold paralysis

Selektywna reinerwacja krtani jako metoda leczenia obustronnego porażenia fałdów głosowych

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ABSTRACT:
Reinnervation of the larynx is a dynamic method of treatment of bilateral vocal cord paralysis, which has been gaining popularity over the past years. The traditional surgical treatment aimed to permanently modify the anatomical structures of the larynx in order to restore its respiratory function, thus unfortunately worsening phonatory dysfunction and compromising lower respiratory tract protection. So far, there has not been developed a unified management protocol in patients with bilateral recurrent laryngeal nerve injury agreed upon by head and neck surgeons. Considering that fact, we reviewed the current literature on laryngeal reinnervation techniques.

KEYWORDS: bilateral vocal cord paralysis, laryngeal reinnervation, recurrent laryngeal nerve, selective reinnervation

INTRODUCTION
Bilateral immobilization of vocal folds caused by paralysis occurring in the course of recurrent laryngeal nerve injuries is manifested mainly by the shortness of breath, albeit dysphagia or subtle phonatory changes may also occur. The inability to abduct one’s vocal folds upon inspiration results in significant narrowing of the airways at the glottic level, potentially leading to acute respiratory distress with stridor which is a life-threatening condition.

The most common cause of bilateral vocal fold paralysis consists in iatrogenic injury to recurrent laryngeal folds in the course of thyroid gland surgeries. This complication is diagnosed in 1 to 4.6% of patients subjected to thyroid surgery [1], either immediately following extubation or after a period of gradual development [2]. In most cases, initial treatment consists in protecting the airways by means of intubation or tracheostomy. Surgical methods are mainly aimed at widening the airways at the site of the narrowing, i.e. within the glottis. The treatment of bilateral vocal fold paralysis poses a significant challenge for laryngologists as it requires balancing between optimum volume of glottis and the quality of voice and the protection of lower airways. Adequate patency of the larynx must be achieved to ensure free breathing while maintaining normal phonatory function or impairing it only to a small degree [3].

While laryngeal reinnervation is a novel surgical approach, its concept was established as early as in the 19th century and the first surgery in a human subject was carried out in 1908 [4]. Over the years, numerous studies on laryngeal reinnervation have been conducted, initially in animal models and later in humans, ranging from experimental approaches to the increasingly widespread selective bilateral
reinnervation technique. In this paper, we provide an overview of the most recent literature on laryngeal reinnervation techniques used in the treatment of bilateral vocal fold paralysis so as to provide better understanding of the most common methods and reported outcomes.

**SELECTION AND PREPARATION OF PATIENTS FOR LARYNGEAL REINNERVATION**

The following criteria should be taken into consideration when qualifying a patient for laryngeal reinnervation: patient’s age, overall health status the use of general anesthesia, the extent of previous neck surgeries, and the absence of organic changes within the larynx. In addition, reinnervation should not be performed in cases of neuromuscular disorders [5].

The literature provides no clear guidelines on the age threshold for patients with bilateral vocal fold paralysis in whom laryngeal reinnervation would most likely be ineffective. However, numerous studies had been carried out in patients with unilateral laryngeal paralysis leading to Crumley’s recommendation to perform the procedures in patients below the age of 70 [6]; at the same time, better results were observed by Pannello et al. in the group of patients below 52 years of age [7].

According to Mau et al., the twelve-month period allowed for the spontaneous return of laryngeal nerve function is too long, with a six-month interval appearing to be completely sufficient and appropriate for surgical intervention [8]. On the other hand, Marina et al. reported that deferring the reinnervation procedures for periods longer than 6 months is not detrimental for patient’s condition as subclinical reinnervation prevents laryngeal denervation [3]. However, most authors suggest the waiting period of 6 months as optimal for laryngeal reinnervation.

Following examinations are recommended prior to selective reinnervation of the larynx: chest X-ray with diaphragmatic assessment, pulmonary function tests, phoniatric tests including acoustic voice analysis and subjective voice evaluation, laryngeal electromyography (LEMG), and palpation of the arytenoids and the posterior commissure region [9]. The protocol proposed by Song and Marie also includes microlaryngoscopy performed in conscious sedation with local anesthesia. Microlaryngoscopic or microdirectoscopic examinations should exclude potential ankylosis of the cricoarytenoid joint, scar within the posterior commissure, or stenosis within the subglottic and tracheal regions; at the same time, the main objective of these examinations involves the assessment of the motility of the vocal folds and the entire larynx during inspiration, expiration, and phonation. Paradoxical adduction of vocal folds upon inspiration is confirmative of bilateral laryngeal paralysis being the cause of impaired vocal folds motility and suggestive of synkinesia or the Bernouilli’s effect, constituting an ideal case for laryngeal reinnervation [10]. Listed in Tab. I. are the outcomes of bilateral selective laryngeal reinnervation as reported in referenced articles.

**SELECTIVE LARYNGEAL REINNERVATION**

**Neuromuscular island flap transplant**

In 1976, Tucker described a method of laryngeal reinnervation involving a neuromuscular island flap transplant. In 202 patients, parts of
the omohyoid or sternohyoid muscles innervated via the ansa cervicalis or, more precisely, via the omohyoid branch thereof, were grafted into the posterior cricothyroid muscle. Very promising long-term results were achieved, with overall efficacy within the study group amounting to 74%; however, the decannulation rate in patients with tracheostomy amounted only to 50% [11, 12]. Deterioration was observed in 17% of cases within 2–5 years after surgery (due to ankylosis of the cricoarytenoid joint). Other surgeons were unable to obtain similar results [5].

Phrenic nerve

The phrenic nerve is the main motor nerve involved in inspiration, and therefore appears to be a better physiological donor of neural impulses responsible for fold abduction than ansa cervicalis. Crumley et al. dissected the phrenic nerve for subsequent assembly with recurrent laryngeal nerve abductor branch. They also sectioned the main trunk of the recurrent laryngeal nerve in order to eliminate the remaining laryngeal innervation [13]. However, the results obtained in humans were not as satisfactory as those in animal models, leading only to a slight expansion of rima glottidis without active arytenoid abduction [14].

Although the technique of laryngeal reinnervation using the phrenic nerve was modified multiple times, significant progress was made only after bilateral reinnervation techniques had been introduced. Initially, bilateral Anastomosis with ipsilateral ansa cervicalis was performed using laryngeal adductor branches [15]; at present, however, the thyrohyoid branch of hypoglossal nerve is preferred [16]. The latter is a branch of the cervical ganglion which runs along the hypoglossal nerve to branch away from it in its further course. The branch conducts neural impulses during phonation and swallowing, but not during breathing [16, 17]. Innervation of both posterior cricoarytenoid muscles is delivered from the phrenic nerve (or, more precisely, at its upper C3 or C4 root) via an Y-shaped graft originating from the great auricular nerve whereas laryngeal adductor muscles receive their innervation from ipsilateral thyrohyoid branch of the hypoglossal nerve via a cable nerve graft (which frequently also originates from the great auricular nerve) [16]. Marie published the results of bilateral selective laryngeal reinnervation procedures performed in 35 patients [18]. Twenty-five out of 35 patients had been followed up for more than one year. Decannulation had been performed in 22 out of 25 patients and improvement in ventilation parameters was observed in the entire group, with only 3 patients requiring additional enlargement of the glottis. Unilateral and bilateral inspiratory arytenoid abduction was observed in 13 and 7 out of 25 patients, respectively. According to Dunya et al., more than 80 cases of bilateral selective laryngeal reinnervation have been included in long-term follow-up by the Marie group by December 2020 (JP Marie, unpublished results) [19]. Lee et al. employed the technique in 8 children with bilateral vocal fold paralysis [20]. Preoperative tracheostomy had been required in 6 out of 8 children; in all cases, the stomies were successfully closed within one year after the surgery. Inspiratory arytenoid abduction was observed in 7 patients, with ventilation improvement being observed in 1 patient despite the lack of vocal fold motility.

Song et al. carried out a study to compare the method involving the use of the left phrenic nerve with laser arytenoidectomy [21]. The group of patients subjected to laser arytenoidectomy consisted of 65 individuals while the group of patients subjected to selective bilateral
reinnervation consisted of 52 individuals. Arytenoid abduction was observed following reinnervation in 89% of cases, with the decannulation rate also being higher in the reinnervation group (88%). With respect to vocal function, patients undergoing reinnervation presented with better parameters whereas a worsening in vocal function was observed in the arytenoidectomy group.

A modification of Marie’s technique for bilateral selective laryngeal reinnervation was proposed by Li et al. [22]. Following the dissection of damaged recurrent laryngeal nerves, distal stumps were connected to the superior root of the right phrenic nerve using a Y-shaped cable graft. Hypoglossal nerve branch was connected to the ipsilateral laryngeal adductor branch. Intralaryngeal interarytenoid laryngeal adductor branch was sectioned in order to prevent synkinesis and the proximal stunt was grafted into the belly of the posterior cricoarytenoid muscle. A total of 7 patients were included in the study, with improved aerodynamics and pulmonary function test results being improved in all subjects. Bilateral vocal fold function was restored in 6 cases, with minimum motility of one vocal fold being observed in the remaining case.

**Superior laryngeal nerve**

The activity of the superior laryngeal nerve is minor upon steady spontaneous inspiration and increased upon deeper voluntary inspiration [5]. Orestes et al., pioneered the use of superior laryngeal nerve in selective laryngeal reinnervation in human subjects [23]. The procedure consisted in the external branch of the superior laryngeal nerve being assembled with the recurrent laryngeal nerve adductor branches and the adductor branches being assembled to ansa cervicalis to provide tension. To date, the method has been used in 2 patients, and the results appear promising. However, further research is necessary to evaluate this technique.

Despite numerous techniques for laryngeal reinnervation having been introduced, an animal model study of nerve reconstruction revealed that neither free nerve nor neuromuscular flap grafting had histological and physiological efficiency comparable to the direct end-to-end anastomosis [24]. Therefore, early revision performed due to bilateral vocal fold paralysis following a thyroid surgery is important for identification of the type of recurrent laryngeal nerve injury (sectioning, ligation, compression by a hematoma or entrapment within a scar), elimination of causes and restoration of nerve continuity or potential reinnervation. The routine developed at the Department of Otolaryngology, Head and Neck Surgery of the Medical University of Warsaw for the management of patients with bilateral vocal fold paralysis occurring in the course of iatrogenic laryngeal nerve damage is as follows:

- **up to 7 days from injury** – urgent revision of post-operative wound (nerve decompression, end-to-end anastomosis);
- **within 3 to 6 months after damage** – wound revision scar removal and possibly end-to-end anastomosis of recurrent laryngeal nerves;
- **within 6 to 12 months after damage** – selective bilateral laryngeal reinnervation;
- **above 12 months** – laser posterior cordectomy with or without arytenoidectomy (Fig. 1.)

**CONCLUSIONS**

The surgical treatment of bilateral vocal fold paralysis should provide patients with breathing comfort and adequate vocal function without the risk of foreign body aspiration. Bilateral selective laryngeal reinnervation appears to fulfill the above criteria while being an innovative method which opens up new horizons while not precluding the option of traditional static surgeries being carried out to expand the rima glottidis in cases of previous treatment failure. Proper selection of patients including detailed diagnostic tests is important for the success of the treatment. Selective reinnervation of posterior cricoarytenoid muscles facilitates the abduction of vocal folds upon breathing. Reconstruction of the separate innervation of laryngeal muscles prevents the addition of vocal folds upon inspiration while simultaneously preventing their atrophy and ensuring proper tension. Pulmonary function improvement is observed with good voice quality being maintained and no synkinesis being observed. However, selective laryngeal reinnervation requires high precision and experience in the formation of microsurgical nerve anastomoses. Temporary tracheostomy is also required in patients. Transient aspiration may occur following the procedure and should be prevented.

As seen from the cited studies, long-term follow-up results are favorable and bilateral selective laryngeal reinnervation should be included in the protocols for the management of patients with bilateral vocal fold paralysis.

**REFERENCES**


