The Laryngoscope

A Novel Endoscopic Arytenoid Medialization for Unilateral Vocal Fold Paralysis

László Rovó, MD, PhD; Andrea Ambrus, MD; Zoltán Tóbiás, MD; Christopher T. Wootten, MD, MMHC; Ádám Bach, MD, PhD

Objectives/Hypothesis: Arytenoid adduction (AA) has been indicated for unilateral vocal fold paralysis (UVFP) patients with vertical vocal fold height mismatch and/or large posterior glottic gaps that are unable to be adequately addressed by anterior medialization techniques. Although AA offers several advantages over other methods, it is technically challenging and involves significant laryngeal manipulation of the cricoarytenoid joint. A novel, minimally invasive endoscopic arytenoid medialization technique is presented for the closure of the posterior commissure.

Study Design: Prospective case series.

Methods: Seventeen consecutive patients were diagnosed and treated with unilateral endoscopic arytenoid medialization (EAM) combined with injection laryngoplasty because of unilateral vocal fold paralysis. Jitter, shimmer, harmonics-to-noise ratio (HNR), maximum phonation time (MPT), fundamental frequency (F_0), Voice Handicap Index (VHI), peak inspiratory flow (PIF), and quality of life (QoL) were evaluated preoperatively, 1 month, and 1 year after EAM.

Results: Jitter, shimmer, HNR, and MPT significantly improved and remained stable 1 year after the intervention. F_0 and PIF remained unchanged. Significant improvements in VHI and QoL demonstrated patient satisfaction with voicing and respiratory functions.

Conclusions: Endoscopic arytenoid medialization is a quick, minimally invasive solution for unilateral vocal fold paralysis. With simultaneous augmentation of the vocal fold, it provides a complete glottic closure along the entire vocal fold in UVFP patients.

Key Words: Arytenoid adduction, arytenoid medialization, injection laryngoplasty, unilateral vocal fold paralysis, vocal fold medialization.

Level of Evidence: 4

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INTRODUCTION

Patients with unilateral vocal fold paralysis (UVFP) typically present with voice changes, hoarseness, or aspiration. The symptoms of UVFP are frequently well tolerated; therefore, the true incidence of UVFP is certainly underestimated.[1–4] In the vast majority of cases, decreased quality of life (QoL) due to poor voice quality and increased vocal effort are the leading problems.[5–7] The spectrum of surgical interventions dealing with UVFP is less varied than the techniques used to manage bilateral vocal fold paresis. Furthermore, principles in medializing the paralyzed vocal fold have not changed substantially within the last decades.[1] In general, the widespread vocal fold medialization techniques for the treatment of persistent UVFP include injection laryngoplasty (ILP), laryngeal framework surgery (LFS), and arytenoid adduction (AA). However, none of these procedures has been shown to be superior over the others,[8,9] and each of these techniques has a different effect on the anterior and posterior commissure. ILP and LFS are optimal solutions for anterior closing insufficiency, whereas AA surgeries are particularly suitable for correcting pronounced posterior glottic chinks.[10–13] Not surprisingly, several reports have been published about the combination of these methods.[8,14–19] In addition, modifications of thyroplasty type I were also introduced to medialize the posterior portion of the glottis.[20–25]

The standard AA and the modified thyroplasty procedures require posterior dissection of the thyroid cartilage to gain access to the muscular process of the arytenoid cartilage. These procedures are often associated with a risk of perforating the piriform sinus, bleeding, and edema of the larynx.[17] Thus, a less invasive procedure for arytenoid medialization is desirable. Hereby, a new, minimally invasive, rapid endoscopic arytenoid medialization technique is reported with simultaneous augmentation of the vocal fold in UVFP patients.[26]

MATERIALS AND METHODS

Patients

Seventeen patients (11 females and 6 males, mean age = 55 years, range = 33–76 years) were treated with unilateral endoscopic arytenoid medialization (EAM) because of unilateral vocal fold paralysis. Etiologies of UVFP included thyroidectomy (13), cardiac surgery (one), lung surgery (one),

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mediastinal lymph node biopsy (one), and idiopathic (one). All patients included in the present study had severe breathy dysphonia and a wide posterior glottal gap during phonation. EAM was performed at least 1 year after the onset of the paralysis, except for three patients in which, based on the patients' history and laryngeal electromyography, functional regeneration of the glottic movements was not expected.[27] Functional results were evaluated preoperatively, 1 month, and 1 year after surgery. Patients with former tracheostomy or other phonosurgeries/disorders that affect the larynx were not involved in the study. Ten of the 17 patients had speech therapy sessions before the operation, and five of them continued afterward. The study was approved by our institutional ethics committee (registration number 162/2019-SZTE). Statistical analysis was performed with MedCalc 19.1 statistical software (MedCalc Software, Ostend, Belgium).

Surgical Technique

All operations were performed under general anesthesia via total intravenous anesthesia with short-term myorelaxant

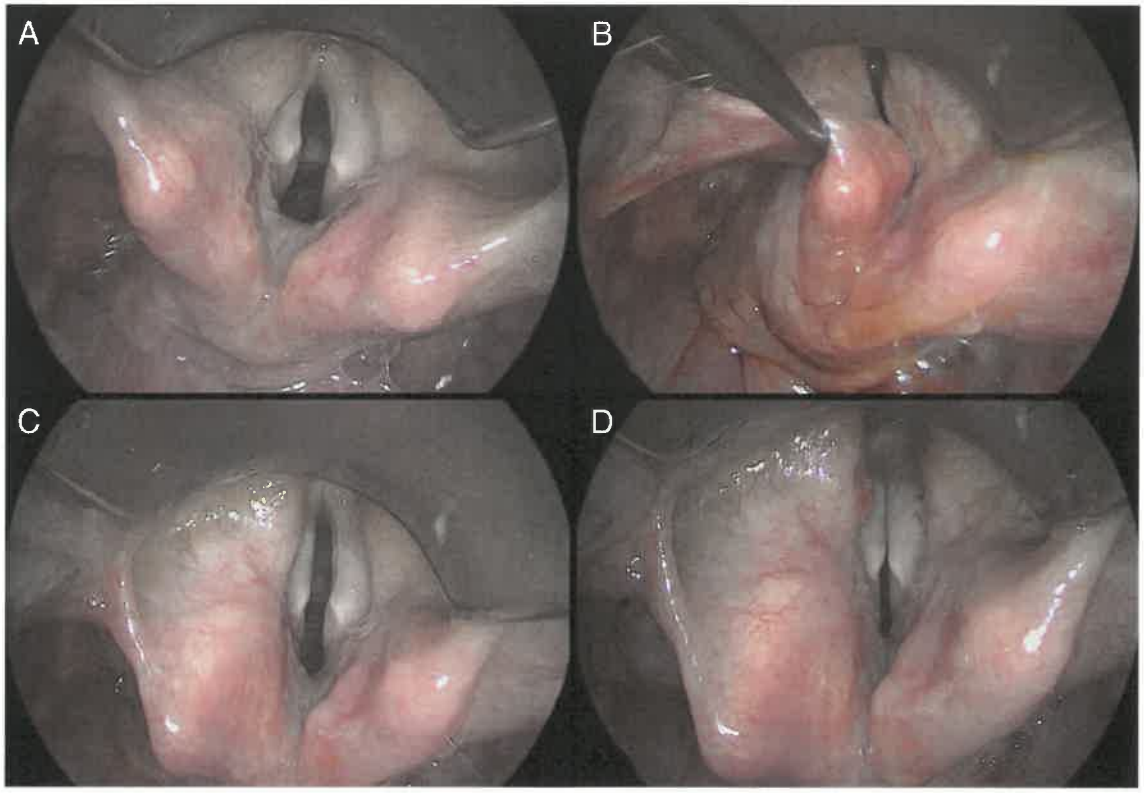

Fig. 1. Intraoperative endoscopic pictures of a 69-year-old female with idiopathic unilateral vocal fold paralysis on the left side. (A) The larynx is explored with a modified Weerda laryngoscope. (B) The left arytenoid cartilage is positioned into its physiological, maximally adducted position, and fat is injected to fix it in the same location. (C) The new glottic configuration with reduced glottic chink after endoscopic arytenoid medialization. (E) Final glottic configuration after augmentation of the left paraglottic space. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

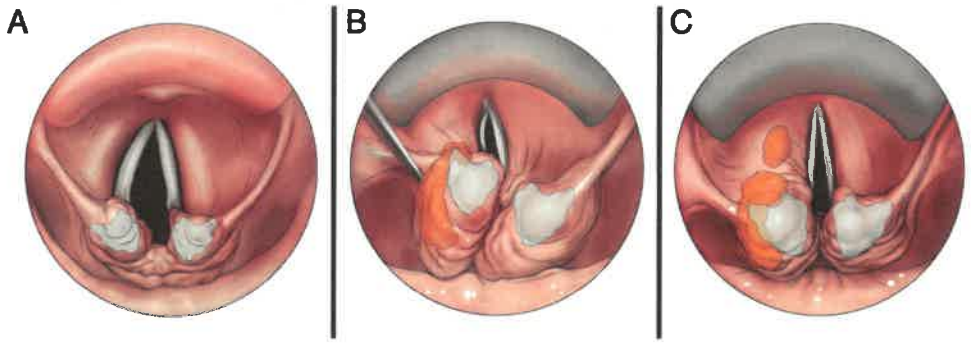

Fig. 2. The steps of endoscopic arytenoid medialization (schematic drawings, endoscopic view). (A) Left-sided vocal fold paralysis with pronounced posterior glottic chink. (B) The arytenoid cartilage is positioned into its physiological, maximally adducted position with the injecting needle, and fat is injected to stabilize it in that position. (C) New glottic configuration after further augmentation of the paraglottic space. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

(mivacurium) and supraglottic jet ventilation. Broad access to the arytenoid cartilages was allowed this way, and the laryngeal mucosa also remained preoperatively untouched. A curved periumbilical incision was made, and 2 to 3 cm^3 of fat were harvested. Fat lobules were separated from surrounding connective tissue, chopped, and homogenized by scissors.

After the direct visualization of the larynx with a modified Weerda laryngoscope, the mobility of the vocal fold and arytenoid cartilage was bluntly checked to exclude mechanical fixation of the cricoarytenoid joint (Figs. 1A, 2A).[28] At the same time, the pathway of arytenoid movements and the maximally adducted position of the arytenoid was also assessed by the passive moving of the arytenoid cartilage with a miniature grasping forceps. As the initial step of the EAM, the arytenoid mucosa was penetrated directly at the lateral surface of the arytenoid with a 16-gauge injecting needle. Next, the arytenoid cartilage was positioned with the same needle into its physiological, maximally adducted position, and approximately 1 cm^3

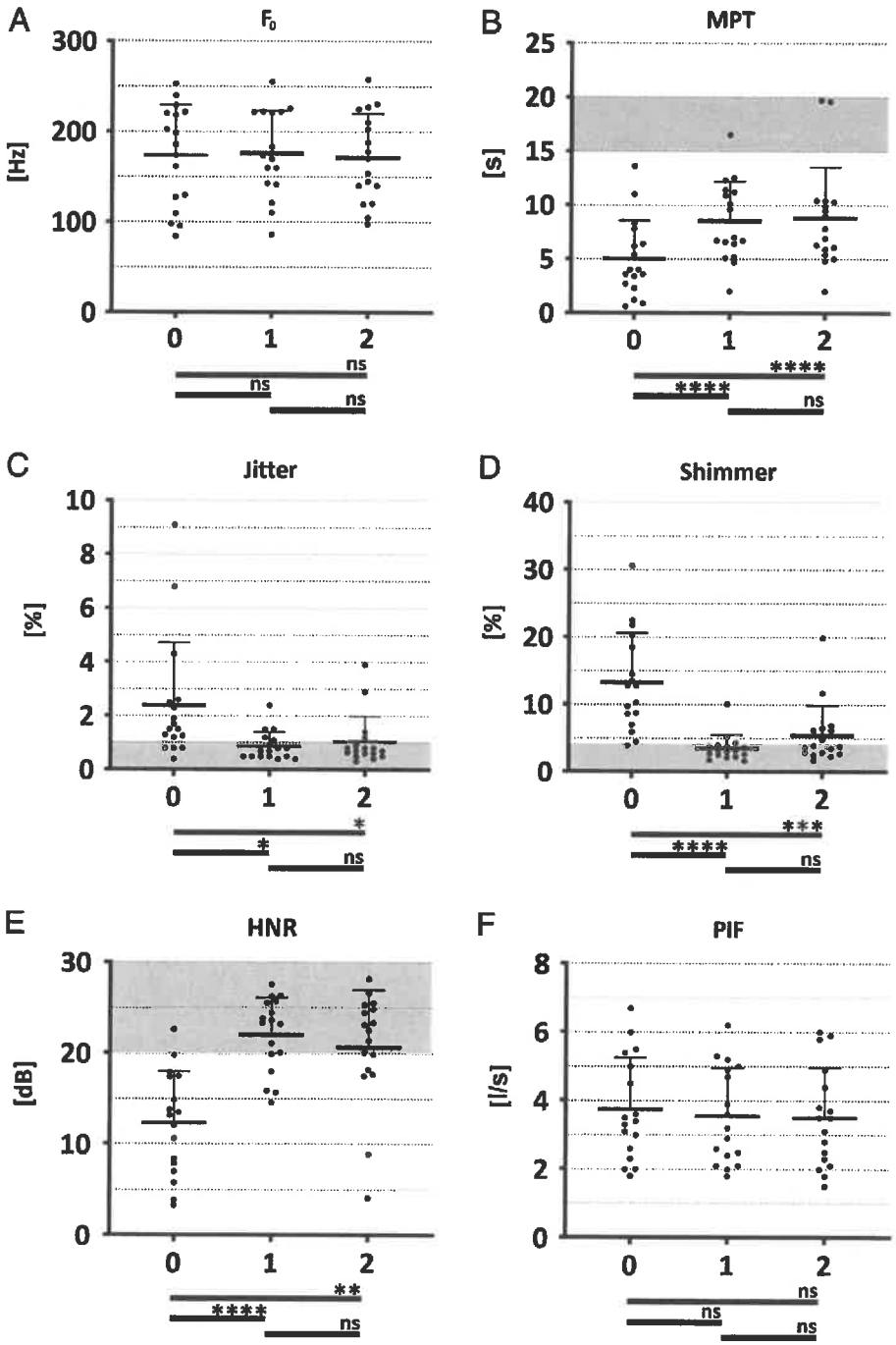

Fig. 3. Objective voice and respiratory results after endoscopic arytenoid medialization in unilateral vocal fold paralysis patients. The gray area represents the normal range of values. 0: preoperative measurement, 1: first postoperative month, 2: first postoperative year. (A) Fundamental frequency (F_0). (B) Maximum phonation time (MPT). (C) Jitter. (D) Shimmer. (E) Harmonics-to-noise ratio (HNR). (f) Peak inspiratory flow (PIF). *$P \leq .05$; **$P \leq .01$; ***$P \leq .001$; ****$P \leq .0001$. ns = not significant.

of fat was injected (with the bevel side facing medially) to the perichondrium of the cricoid cartilage to fix the arytenoid in the same location (Figs. 1B, 2B). To successfully mimic the physiological adduction, fat was injected anterior and posterior to the muscular process of the arytenoid. In optimal case, the injected fat surrounded the arytenoid cartilage laterally in a C shape. The posterior part of the fat was usually thinner because the loose retrocricoid mucosa allowed only a limited amount of fat to be injected without bulging of this particular area. Augmentation below the plane of the cricoarytenoid joint had to be avoided, due to the possible elevation of the vocal process. Additionally, repeated penetration of the periarytenoid mucosa had to be avoided to minimalize the outflow of the injected fat.

After the evaluation of the new glottic configuration (Fig. 1C) a second bolus of approximately 1 cm^3 of fat was injected into the paraglottic space of the paralyzed vocal fold to correct the contour of the vocal fold (Figs. 1D, 2C). Injection was lateral to the vocal process and into the lateral aspect of the thyroarytenoid/lateral cricoarytenoid muscle complex. Anticipating a degree of spontaneous fat absorption, the vocal fold was augmented beyond the midline in all cases for a slight overcorrection. This way the medialization of the arytenoid cartilage and the vocal fold was performed in an entirely endoscopic fashion, and no transcervical injection was required.

Assessment of Functional Results

Voice assessment was performed according to our previously published protocol and was based on the guidelines published by the Committee on Phoniatrics of the European Laryngological Society.[29] Jitter %, shimmer %, fundamental frequency (F_0), harmonics-to-noise ratio (HNR), and maximum phonation times (MPT) were analyzed using Praat 5.3.37 software (www.praat.org). The Hungarian version of the Voice Handicap Index (VHI) was also used to assess the patients' voice-related QoL.[30–32]

For the objective assessment of the respiratory function, peak inspiratory flow (PIF) was measured.[33–35] From the subjective point of view, the functional outcomes of the surgery in terms of breathing, voice, swallowing, and overall satisfaction were evaluated by a QoL questionnaire.[36]

RESULTS

Voice Results

There were no major peri- or postoperative complications. The average F_0 of the 17 patients slightly increased in the early postoperative period, then decreased below the base line by the end of the first year (Fig. 3A). This fluctuation of pitch did not reach statistical significance. The average MPT improved significantly from 5.0 to 8.52 (change: 3.52 seconds, 170.47% of baseline; $P < .0001$) in the early postoperative period. MPT remained stable 1 year after the intervention (Fig. 3B). The value of jitter showed significant improvement ($P < .05$). This parameter decreased, and later stayed, within the physiological range (Fig. 3C). Shimmer improved significantly ($P < .0001$) and also reached its physiological range. In the late postoperative period, shimmer decreased ($P < .05$) but remained significantly better compared to the preoperative value (26.26% of baseline and 40.74% of baseline, respectively) (Fig. 3D).

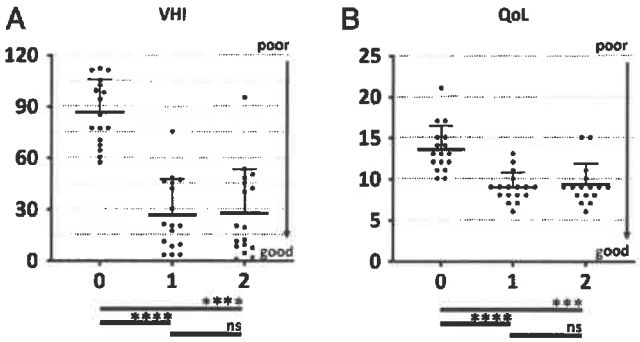

Fig. 4. Changes of the subjective parameters after endoscopic arytenoid medialization in unilateral vocal fold paralysis patients. The gray area represents the normal range of values. 0: preoperative measurement, 1: first postoperative month, 2: first postoperative year. (a) Voice Handicap Index (VHI). (b) Quality of life (QoL) score. *$P \leq .05$; **$P \leq .01$; ***$P \leq .001$; ****$P \leq .0001$. ns = not significant.

The value of HNR showed significant improvement ($P < .0001$; 178.82% of baseline) and increased to within the physiological range. At the end of the first year, it showed some nonsignificant decrease (167.65% of baseline) (Fig. 3E). The Hungarian VHI demonstrated that patients subjectively also found their voices improved. The average score decreased significantly, from 88.1 to 27.3, then changed to 28.4 in the late postoperative period ($P < .0001$; 31.01% of baseline and $P > .05$; 32.29% of baseline respectively) (Fig. 4A). At the end of the first year, one of the 17 patients (5.9%) required repeated EMA due to recurrence of increasing voice weakness.

Respiratory Results

PIF showed a slight decrease in the early and late postoperative period as well, but these did not reach statistical significance (Fig. 3F). Significant improvements in QoL demonstrated patient satisfaction with voicing and respiratory functions. The average score improved in the early postoperative period from 13.7 to 8.9, then further changed to 9.3 (Fig. 4B).

DISCUSSION

The length, elasticity, and mass of the vocal folds are crucial factors that determine outcomes during phonosurgery. In UVFP patients, these unbalanced vocal fold parameters cause chaotic vibration patterns and hoarseness. Besides these, incomplete vocal fold closure is mainly responsible for the typical breathy voice of this population.[37] Modern phonosurgical procedures must deal with these multiple problems simultaneously. The current treatment for UVFP includes ILP, laryngeal framework surgery, arytenoid adduction, laryngeal reinnervation, and cricothyroid subluxation.[38] The basic principles of the mainstream methods (i.e., ILP, LFS, AA) have not changed significantly in the last decades, and only a few new techniques were introduced in this particular field of interest.[39]

Laryngeal reinnervation procedure might be the ideal solution for vocal fold medialization via rehabilitation of the tone of the adductor muscles without any foreign body implantation. This surgical method still has not achieved general acceptance, although younger patients with higher neuroregenerative potential could benefit from this approach.[40–45]

The closure of the anterior commissure can be relatively easily restored by a variety of injected materials or implants.[9] However, considering the complex movement of the arytenoid cartilage,[46–49] restoring optimal closure of the respiratory glottis in patients with UVFP is a more complicated issue. The exact anatomy and kinesiology of the cricoarytenoid joint is still a matter of debate today.[46,50–53] Our earlier study supports the opinion that during adduction, the medial sliding motion of the vocal process is accompanied by a downward and occasionally slightly anterior movement, with the arytenoid cartilage turning medially and downward on the cricoid cartilage facet.[50,54] Thus, the arytenoid cartilage with the vocal process moves in three dimensions, not in a singular plane, as the classic rotation mechanism suggests.[55] Although abduction serves only to expand the airway, precise adjustment of vocal fold movements is required for glottic closure during phonation.[50]

First described by Isshiki et al. in 1978, arytenoid adduction involves medialization of the posterior vocal fold by placement of a suture in the muscular process of the arytenoid, thereby simulating contraction of the lateral cricoarytenoid muscle.[13] AA has been indicated for patients with vertical height mismatch as well as those with large posterior glottic gaps that are unable to be adequately addressed by anterior medialization techniques. Theoretically, surgical adduction of the arytenoid cartilage imitates best the physiological phonatory position of the arytenoid cartilage and vocal fold. Although arytenoid adduction offers several advantages over other procedures, it is a technically challenging procedure that involves significant laryngeal manipulation of the cricoarytenoid joint.[17] Several modified versions and combination of Isshiki's procedure have been reported for the purpose of improving its specificity and direct clinical applicability.[15,56–59] In parallel, a large number of altered thyroplasty type I procedures were published to medialize the paralyzed arytenoid cartilage directly, not by rotation.[60]

The delicate adductive movements are determined by the resultant force of active (muscles) and passive (cricoarytenoid joint, ligaments) structures.[53] Similarly, surgical arytenoid adduction introduces passive structures into the larynx to position the arytenoid. This is key to an effective medialization procedure, because lower resistance against the passive muscular and fixating sutures arises if the joint is moved in its natural way. Likewise, to maintain a maximally adducted position, the injected material in EAM must be filled along the pathway of the physiological arytenoid movement. A simple suture or augmentation cannot replace the sophisticated neuromuscular regulation of the adductive movement. Nonetheless, a physiological-like medialized arytenoid position can be achieved with the presented augmentation technique. Considering the mechanics of the cricoarytenoid joint, the anterolateral part of the injected fat is mainly responsible for medialization of the arytenoid but might also have some rotational effect on it. Likewise, the posterolateral fat might give rise to the forward and rotational movement of the cartilage as well (Fig. 5). A systematic radiological examination is needed for further clarification of the postoperative position of the arytenoid.

EAM is an entirely endoscopic, minimally invasive solution for arytenoid medialization. The gentle manipulation of the arytenoid cartilage makes the intraoperative assessment of the cricoarytenoid joint possible. It is crucial because the actual movements of the joint often show

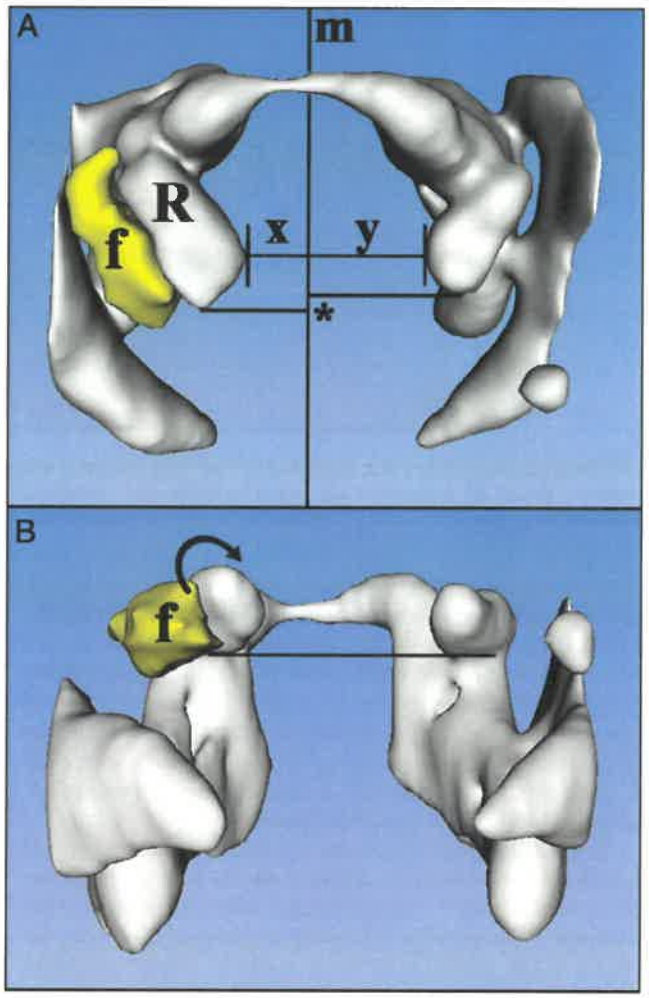

Fig. 5. Three-dimensional computed tomography reconstruction of the larynx after right-sided endoscopic arytenoid medialization procedure in a 34-year-old female unilateral vocal fold paralysis patient. (The patient is not involved in the study, 25th postoperative month, software: Slicer 4.10.1, BSD-style open source license). (A) Superior view: The right-sided arytenoid cartilage (R) is medialized ($x < y$), and a slight anterior movement is also visible (*). (B) Anterior view: The arytenoid cartilages are on the same vertical level. A slight rotation of the right-sided arytenoid is also visible (curved arrow). m = midline, f = injected fat tissue. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

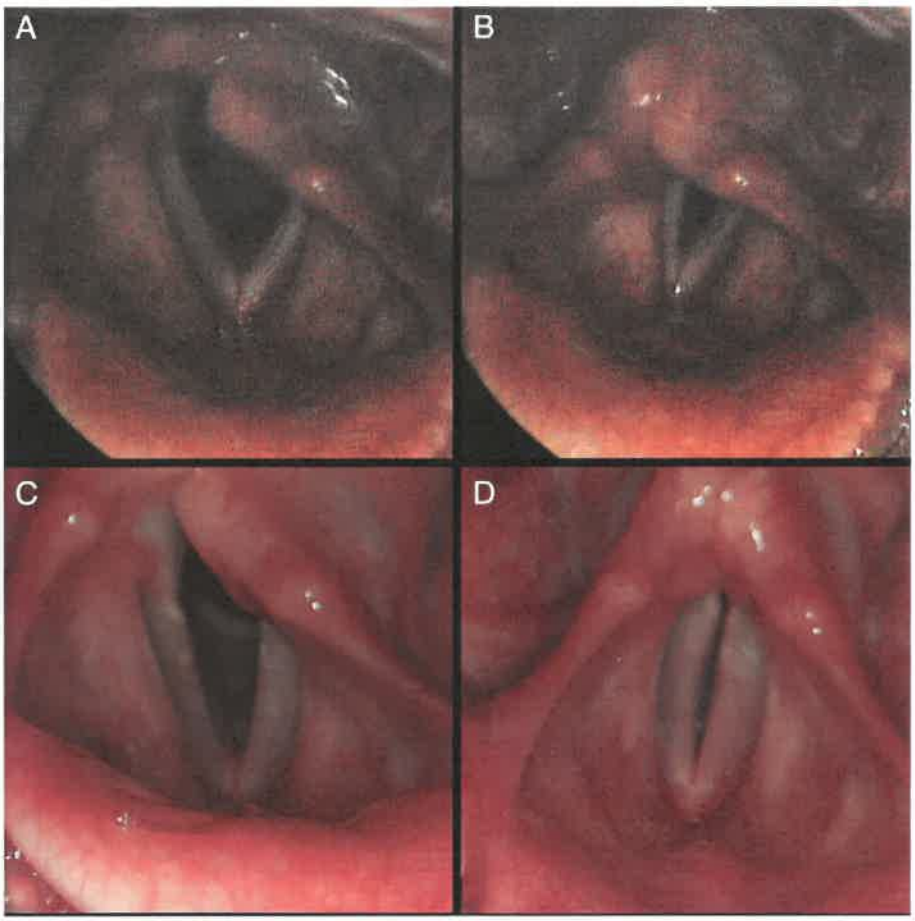

Fig. 6. Endoscopic pictures of a 43-year-old male with unilateral vocal fold paralysis on the left side after mediastinal lymph node biopsy. Preoperative picture of inspiration (A) and phonation (B). Inspiration (C) and phonation (D) 1 year after left-sided endoscopic arytenoid medialization. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

slight individual variations. Arytenoid adduction is rarely performed in isolation.[14] For the best possible results, we also combined the procedure with injection laryngoplasty (lipoaugmentation) of the vocal fold.[26] The combination of these two techniques is almost obligate, because in our experience, injection laryngoplasty itself may increase the posterior glottic gap via a slight passive posterolateral movement of the arytenoid cartilage.

Due to the good long-term experience of our surgical team, autologous fat was applied as an injectable material in this study.[26] Theoretically, any other injectable materials with similar physical characteristics can be used for EAM. Autologous fat is a cheap, easily available material with favorable viscosity and vibratory properties, without reactive granuloma formation, rejection, or migration.[10,11,26,61] According to our results, it can permanently stabilize the arytenoid cartilage as well, if injected into the correct location (Fig. 6). However, the rate and time of its absorption is unpredictable; thus, approximately 20% overcorrection was applied. Excessive overfilling may even lead to compromised airway and a relatively higher percentage of absorption because revascularization of the central area would take more time. The harvested fat was not centrifuged, but only chopped by scissors. It might ensure better survival of the adipocytes and prevents possible migration and interarytenoid bulging.

The positioning of the arytenoid cartilage into its maximally adducted position is crucial (Fig. 1) and requires a completely steady larynx; thus, general anesthesia is recommended for the procedure.[62,63] The immediate feedback gained by intraoperative monitoring of the voice is lost under general anesthesia, but the protective laryngeal reflex can be provoked by the mechanical irritation of the glottis (e.g., with a suction tube) due to the short-term myorelaxant in the late phase of the surgery. Therefore, the expected closure of the glottis can be estimated and can be corrected during the intervention. The endoscopic laryngeal manipulation also reduces the occurrence of complications and makes the external neck incision unnecessary, which has a high priority in the treatment of a mostly iatrogenic disease.[17] However, one potential limitation of EAM should be acknowledged. This technique may not be the optimal choice for vocal fold medialization for patients with longstanding paralysis, because the arytenoid can be restricted by contracture of the cricoarytenoid joint capsule and laryngeal muscles.[64]

The objective voice analysis demonstrated significant improvements in voicing across every tested parameter. Furthermore, the results remained almost completely stable in the follow-up period, as was demonstrated by the improved voice parameters at the end of the first year. This increase of voice quality was well reflected by the change of the VHI. Despite the medialization of the paralyzed vocal fold, the airway was not significantly affected. In total, our functional tests clearly demonstrate the advantages of endoscopic arytenoid medialization procedure. The voice improvement, together with the adequate airway and aspiration-free swallowing, clearly explains the significantly improved QoL.

CONCLUSION

EAM is a minimally invasive alternative to the classic arytenoid adduction procedure with good functional results. With simultaneous lipoaugmentation of the vocal fold, endoscopic arytenoid medialization provides a complete glottic closure along the entire vocal fold in UVFP patients.

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