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Adduction arytenopexy for vocal fold paralysis: indications and technique

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Abstract

Adduction arytenopexy was designed as an innovation to arytenoid adduction, however the pragmatic issues regarding patient selection for these procedures has not been comprehensively assessed.

A prospective examination was performed on 100 consecutive patients who had undergone laryngoplastic phonosurgical reconstruction for paralytic dysphonia. Seventy-seven of 100 (77 per cent) were judged pre-operatively to gain potentially significant phonatory enhancement from an arytenoid procedure. Fifty-six of 77 (73 per cent) underwent adduction arytenopexy; 17 of 77 (22 per cent) were judged pre-operatively to have inadequate respiratory abduction of the contralateral arytenoid and two out of 77 (three per cent) had athletic aerodynamic requirements. In another two out of 77 (three per cent), there was a chance of favourable reinnervation and thus it was not the preferred method.

The majority of patients were judged pre-operatively to gain potentially substantial phonatory enhancement from an arytenoid procedure. However, in this series, approximately 25 per cent of the patients were considered to be unsuitable candidates for an arytenoid medializing procedure, primarily because it was deemed that the operation could result in an inadequate airway.

Key words: Vocal Cord Paralysis; Surgical Procedures, Operative

Introduction

Surgical procedures for treating unilateral vocal fold paralysis are primarily designed to medialize the denervated vocal fold, which allows the mobile one to close the glottis during phonation, deglutition, and tussis. However, when an abducted malpositioned arytenoid leads to glottal incompetence, corrective procedures that primarily modify the musculomembranous vocal fold do not restore an optimal adductory glottal configuration. In this scenario, effective vocal fold vibration (optimal voice) requires that the immobile arytenoid be medialized to allow for optimal compensatory closure by the mobile one.[1]

Previous reports[1–7] have demonstrated that substantial visual, aerodynamic, acoustic, and perceptual improvement can be achieved in selected patients by means of arytenoid repositioning procedures.

The classical arytenoid adduction simulates the contraction of the lateral cricoarytenoid muscle[2], however, the force vector for the suture repositioning is different. In this procedure, the origin of the suture tension is from the approximate level of the vocal fold (anterior thyroid lamina) rather than the natural caudal point of origin, the cricoid.[8] Furthermore, the suture tension on the muscular process typically leads to internal hyperrotation and the airway aperture reflects an abnormally contoured medial arytenoid surface.[1,4,9]

The adduction arytenopexy procedure was designed to provide a more normal physiological arytenoid closure pattern that would simulate agonist-antagonist contractile activities of the combined effects of interarytenoid, lateral cricoarytenoid, lateral thyroarytenoid, and posterior cricoarytenoid muscles.[1,7,10] In this technique, the paralyzed arytenoid (Figure 1) is affixed into an enhanced phonatory position (Figure 2) as compared with the classical arytenoid adduction. During adduction arytenopexy, the body of the arytenoid is positioned on the medial aspect of the cricoid facet, which simulates the natural gliding function and the inward rocking that occurs with normal adduction. Woodson *et al.*[11] also recognized the biomechanical limitations of the classical arytenoid adduction procedure and placed a second suture to enhance adductory positioning.

The aim of this investigation was to identify critical decision-making issues regarding selection for arytenoid repositioning and to elucidate key physiological principles underlying successful

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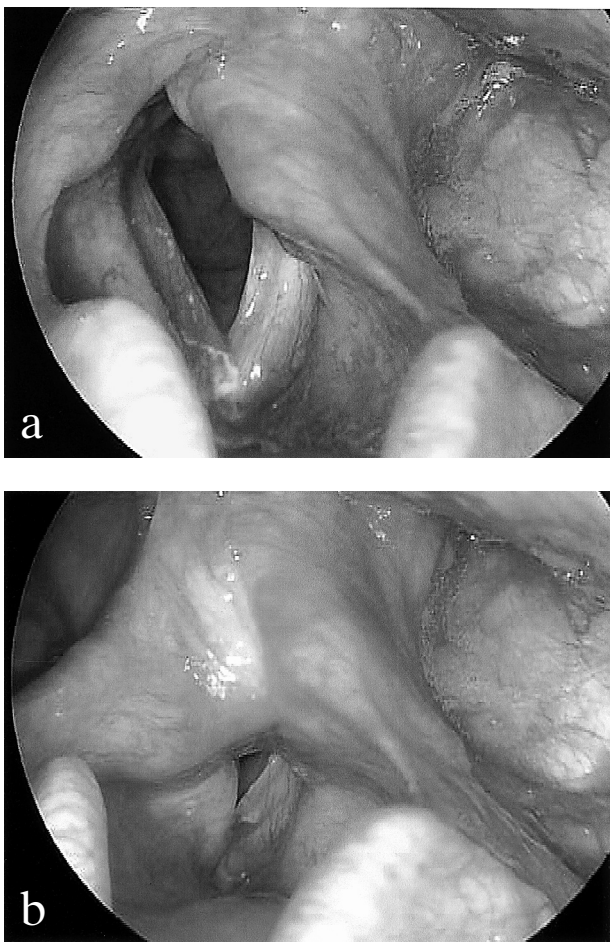

FIG. 1
Clinical examination during abduction of a patient who has a left vocal fold paralysis. Note the (a) antero-medial displacement of the corniculate cartilage, and the (b) infero-lateral position of the vocal process.

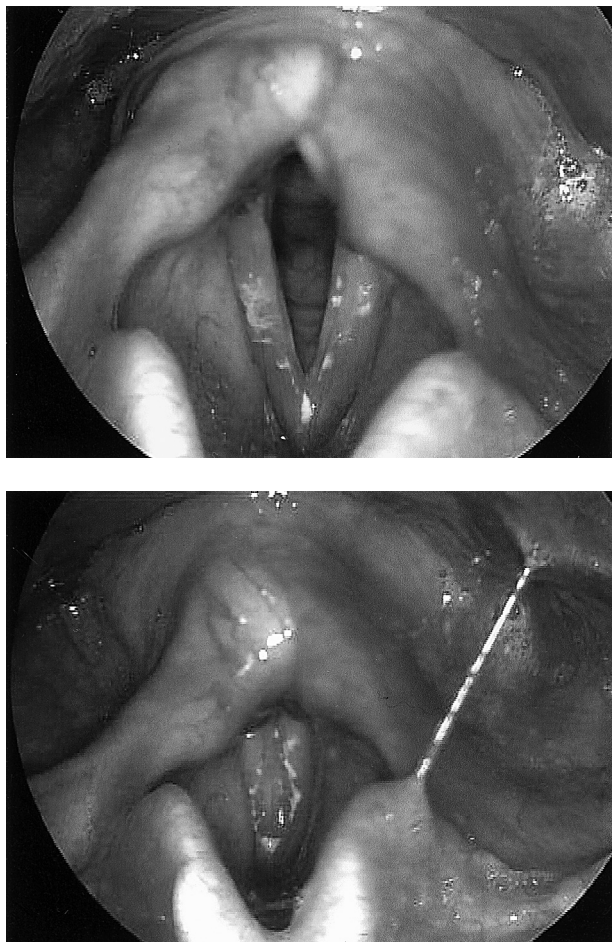

FIG. 2
Clinical examination of the same patient subsequent to adduction arytenopexy, Gore-Tex medialization laryngoplasty and crico-thyroid subluxation. Note the elongated and straight vocal fold in the midline position.

laryngoplastic phonosurgery. Objective acoustic and aerodynamic vocal outcome data were not included since almost all patients had at least two procedures and the majority had three procedures. Therefore, it is impractical to evaluate the differential contribution of the varying procedures towards phonatory efficacy. In addition, the phonatory outcome has been reported in a prior series.[1,12]

Materials and methods

A prospective examination was performed on 100 consecutive patients who had undergone laryngoplastic phonosurgical reconstruction for paralytic dysphonia. There were no patients excluded from this study. Surgery was comprised of a medialization laryngoplasty in all, a cricothyroid subluxation in most, and an adduction arytenopexy in the majority. Patients were evaluated pre-operatively for: (1) interarytenoid glottal-closure competency, (2) abductory function of the mobile arytenoid, (3) aerodynamic respiratory requirements, and (4) the possibility of favourable reinnervation. Based on these factors, each case was assessed to determine indications and contraindications for an adduction arytenopexy.

Pre-operative assessment

A careful cardiopulmonary history was obtained in each individual. Patients and their families were questioned regarding respiratory performance during sleep as well as awake states, and aerodynamic requirements during extreme-exercise conditions.

Dynamic glottal gestures were carried out during phonation and deep respiration. Airway tolerance was determined initially by a laryngoscopic inspection of the laryngeal aperture during passive respiration and subsequently during abductory tasks such as a 'sniff – ee'. These judgments, which remain subjective, can be difficult due to other interdependent factors (visual field, calibration of images, hyperfunction etc.)[13] and the fact that there are not standard criteria for normal and/or acceptable abductory excursion of arytenoids.

Phonatory sampling during stroboscopy was done at a variety of pitch frequencies and intensities (loudness) to simulate the vocal dynamics of conversational speech. The assessment was done to reveal glottal closure patterns and associated oscillation of the musculo-membranous region during a spectrum of gestures. At times, perturbation

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occurred only with rigorous tasks and was not evident in a limited examination.

Operative technique

The arytenopexy technique (Figures 3–11) has been described previously[10] and Gore-tex™[14] was used as an implant in all cases. Unless contraindicated, patients are given 0.2 mg/Kg of dexamethasone at least one hour prior the procedure. This helps to minimize intra-operative swelling, which can affect the judgment regarding implant size. The intravenous steroids are continued while the patient is hospitalized and the dosage is individualized based on the patients' baseline airway anatomy, procedural-induced oedema, and surgeon preference.

Post-operative management

All patients who undergo arytenoid repositioning are placed on oxygen saturation monitoring primarily to alert nursing staff to the potential of an airway problem. Their room is also selected in proximity to the nursing station based on the airway stability. There are no particular restrictions on voice use. Clear liquids are administered directly after the procedure and a per-oral anti-reflux diet is advanced as tolerated. Steroids in the form of a Solu-Medrol dose-pack are often administered at discharge for the initial post-operative period.

Results

Of the 100 patients who underwent medialization laryngoplasty for paralytic dysphonia, 77 (77 per cent) were judged to gain potentially substantial phonatory advantage from an arytenoid procedure; the remaining 23 (23 per cent) had a good adductory arytenoid position and associated interarytenoid closure. Fifty-six of 77 (73 per cent) underwent adduction arytenopexy, which was 56 per cent (56/100) of the original cohort. Twenty-one of 77 (27 per cent) were judged to have a contraindication for adduction arytenopexy. Seventeen of 77 (22 per cent) were judged pre-operatively to have inadequate respiratory abduction of the contralateral arytenoid to tolerate an arytenoid procedure. Two of 77 (three per cent), patients had athletic aerodynamic requirements, which would have been impaired by a midline-positioned arytenoid. In another two out of 77 (three per cent), adduction arytenopexy was avoided since there was a reasonable chance of favourable reinnervation.

There were three complications in the patients who underwent adduction arytenopexy. Two patients developed submucosal oedema requiring intubation. One required intubation several hours after completion of the procedure. It was discovered that he had not received the pre-operative steroids due to an unrecognized malfunctioning intravenous line. The patient was extubated the next morning without incident. Another individual had a post-operative bleed after a coughing episode, which caused mucosal oedema and required intra-operative cautery under general endotracheal anaesthesia. She was intubated electively during a normal induction in the operating room and extubated at the conclusion of the case. Remarkably, in both cases, the intubations and temporarily indwelling endotracheal tube did not clinically disrupt the arytenopexy or the vocal outcome. The third patient had a mild post-operative haemorrhage, with coughing, which was self limited and resolved without intervention. He did develop mild associated dyspnoea secondary to submucosal oedema. No patient sustained a tear of the pyriform sinus mucosa, fistula or post-operative wound infection.

Discussion

Arytenoid repositioning techniques were developed to treat phonatory aerodynamic incompetence that was due to a wide posterior glottal aperture associated with vocal fold paralysis.[1,2] However, most surgeons are reluctant to perform these procedures despite the proven efficacy. This philosophy arises primarily from three factors. Most importantly, adduction of the arytenoid under local-regional anaesthesia is a difficult operation. This is compounded by the fact that the voice can typically be improved by means of an implant medialization alone (albeit often not optimally), which is a much simpler operation. This compromise allows for avoidance of arytenoid procedures without neglecting the fact that voice enhancement is important. Finally, there is justifiable trepidation that optimizing vocal function by medializing the arytenoid could lead to airway restriction and/or obstruction.

Optimizing the voice at the potential risk of the airway heightens an appropriate concern that 'perfect (voice quality) is the enemy of good'. This disposition is evident even amongst surgeons who are comfortable with arytenoid medialization. The magnitude of intra-operative and post-operative oedema of the arytenoid region relates directly to the precision and extent of the cricoarytenoid joint dissection and length of time to perform it. Therefore, surgeons must carefully assess their individual skill-level along with the specific anatomical-physiological characteristics of each patient. Sound surgical judgment must be individualized with each case and cannot be translated into a formula.

Although commonplace, it is paradoxical decision-making to perform the anterior implant medialization as an initial corrective manoeuvre to determine if the voice is improved enough, with the hope of avoiding an arytenoid procedure.[1] This approach leads to an imperfect procedural algorithm. Ideally, repositioning the arytenoid should be done prior to implant placement since the posterior glottal configuration determines the size and shape of the ideal anterior implant. Once the arytenoid is appropriately positioned posteriorly near the midline, the anterior-positioned musculo-membranous region is inherently near the midline. Therefore, the implant serves primarily to support the flaccid denervated paraglottic musculature and

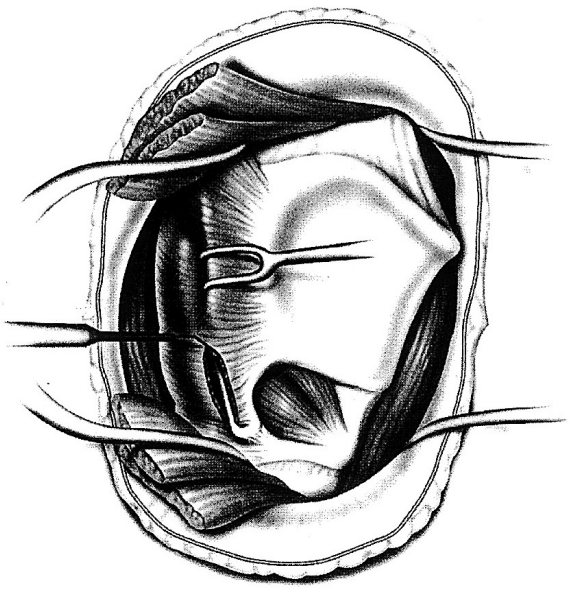

FIG. 3

A needle-tipped electrocautery knife is used to separate the inferior constrictor from the thyroid lamina. (Courtesy of WB Saunders)[10]

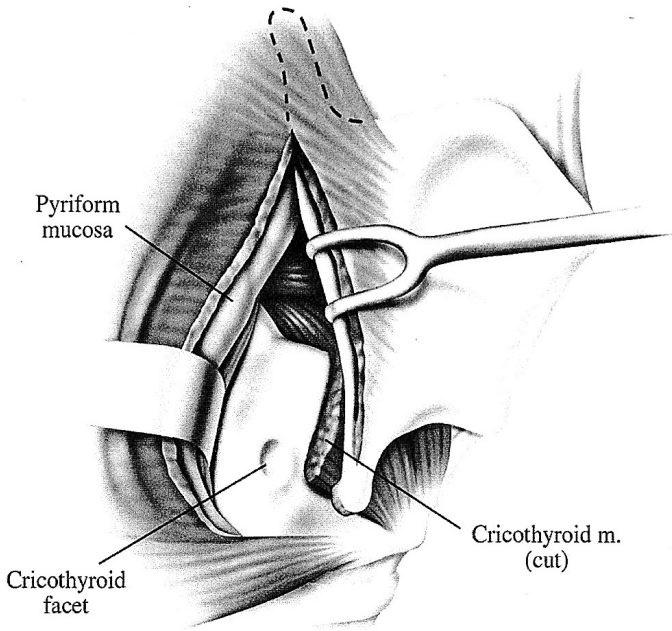

FIG. 4

Separating the cricothyroid joint and associating the inferior constrictor muscle from the thyroid cartilage allows for further antero-medial rotation of the thyroid lamina. Blunt dissection is performed in a cephalad and slightly anterior direction from the cricothyroid facet along the cricoid cartilage until the superior rim of the cricoid is encountered. The lateral aspect of the pyriform mucosa is bluntly dissected from the inner aspect of the thyroid lamina and the medial aspect of the pyriform mucosa is separated from the postero-lateral aspect of the cricoid. (Courtesy of WB Saunders)[10]

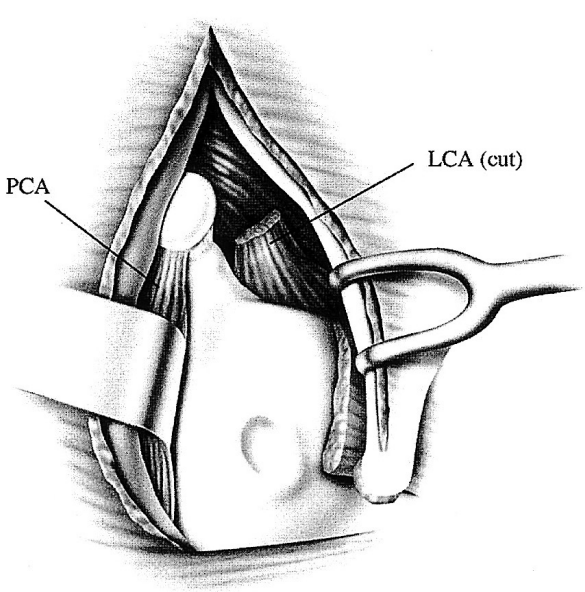

FIG. 5

Posterior superior dissection along the top of the cricoid results in separation of the lateral cricoarytenoid muscle from the muscular process and ensures that the cricoarytenoid joint will be identified easily. (Courtesy of WB Saunders)[10]

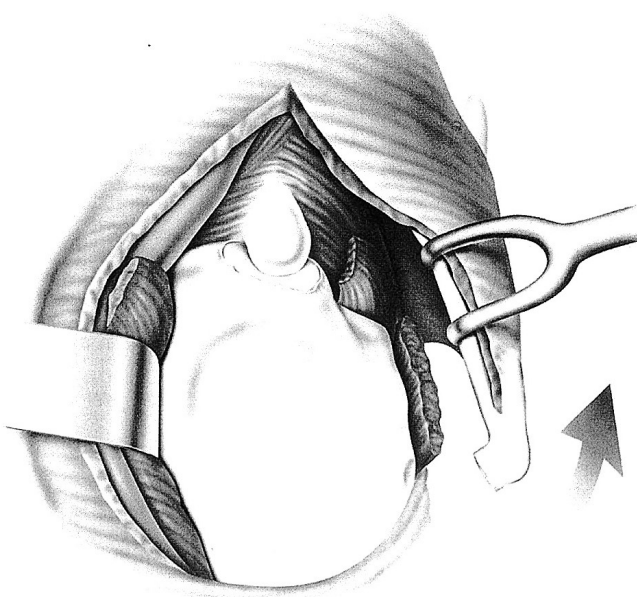

FIG. 6

The posterior cricoarytenoid muscle is separated from the posterior plate of the cricoid so that the posterior aspect of the cricoarytenoid joint is well seen and there is room to place a suture through this region. (Courtesy of WB Saunders)[10]

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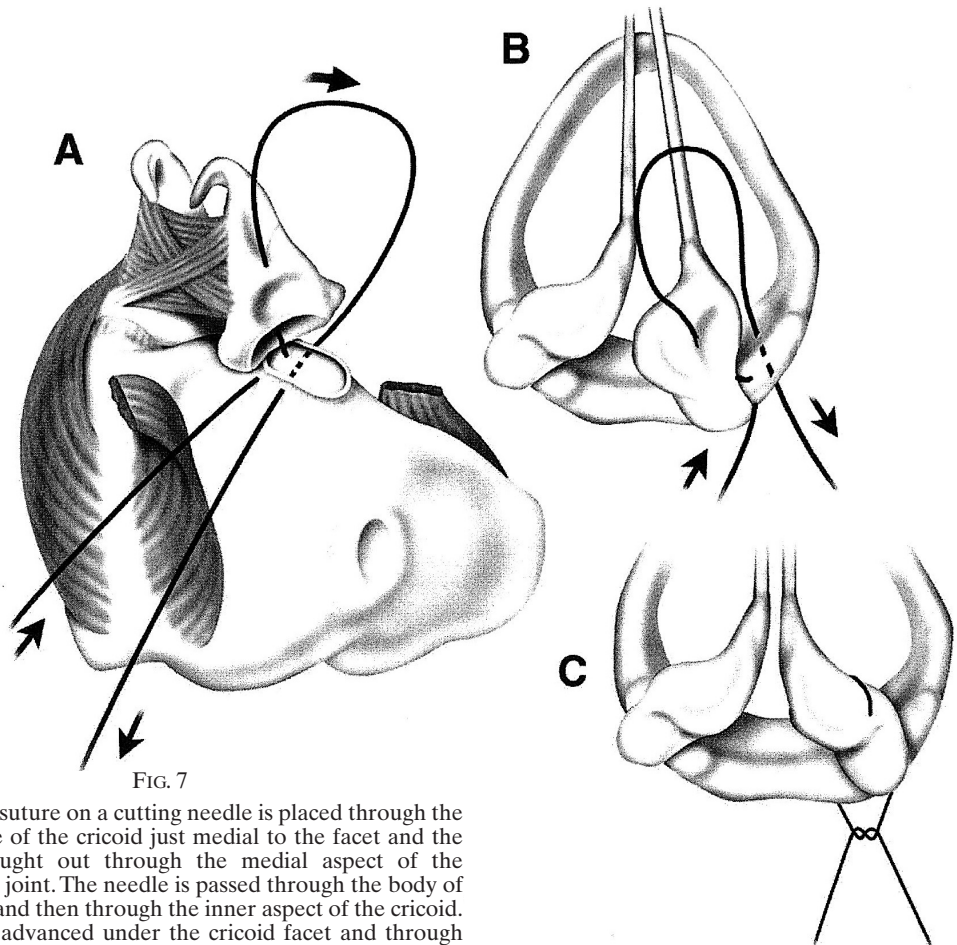

FIG. 7

A 4-0 Prolene suture on a cutting needle is placed through the posterior plate of the cricoid just medial to the facet and the needle is brought out through the medial aspect of the cricoarytenoid joint. The needle is passed through the body of the arytenoid and then through the inner aspect of the cricoid. The needle is advanced under the cricoid facet and through the posterior plate of the cricoid, where a slip knot is placed. (Courtesy of WB Saunders)[10]

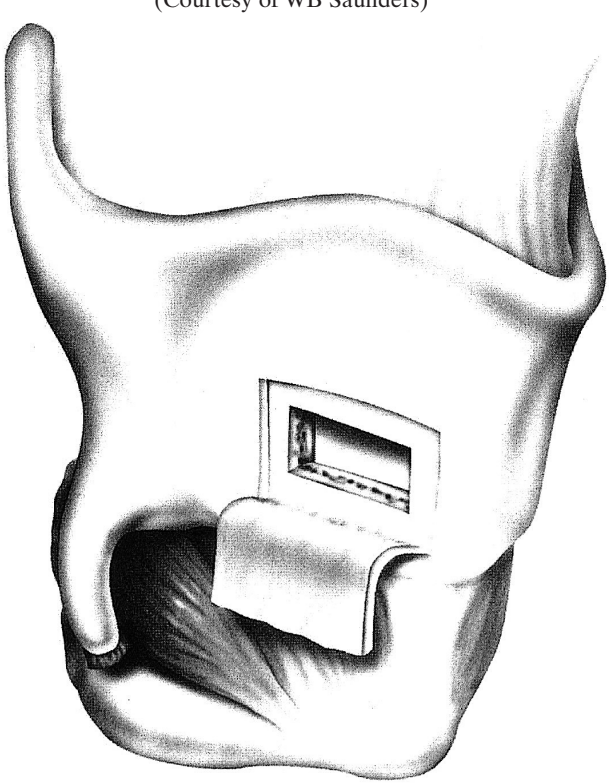

FIG. 8

After raising an inferiorly-based perichondrial flap, a cartilage window is created lateral to the paraglottic musculature. (Courtesy of WB Saunders)[10]

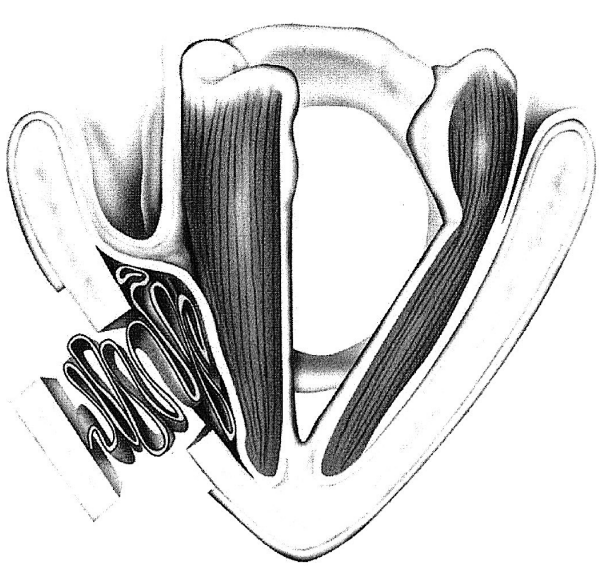

FIG. 9

Then a thin sheet of Gore-Tex is gradually layered in to support the denervated flaccid musculature. (Courtesy of WB Saunders)[10]

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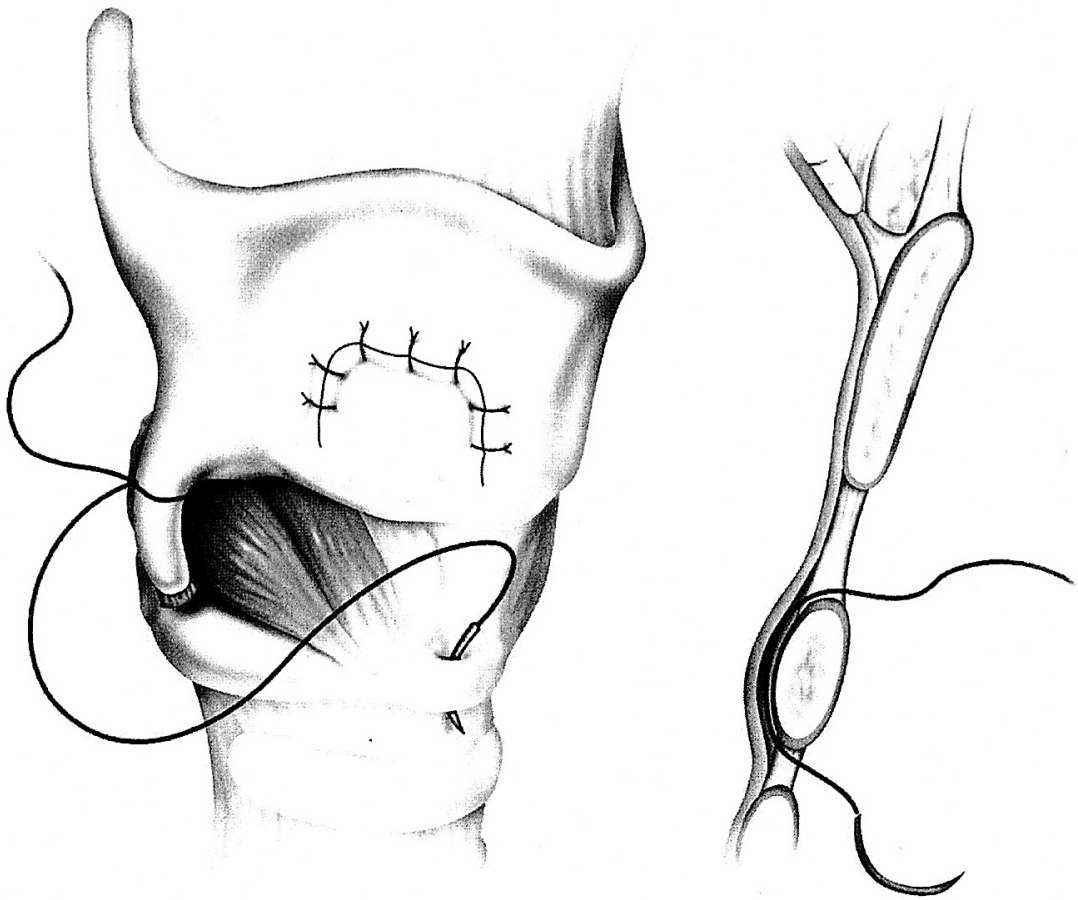

FIG. 10

The newly described C-T sub is accomplished, by placing a 2-0 Prolene suture around the inferior cornu of the thyroid lamina. It is then passed in a submucosal fashion underneath the cricoid anteriorly. (Courtesy of WB Saunders)[10]

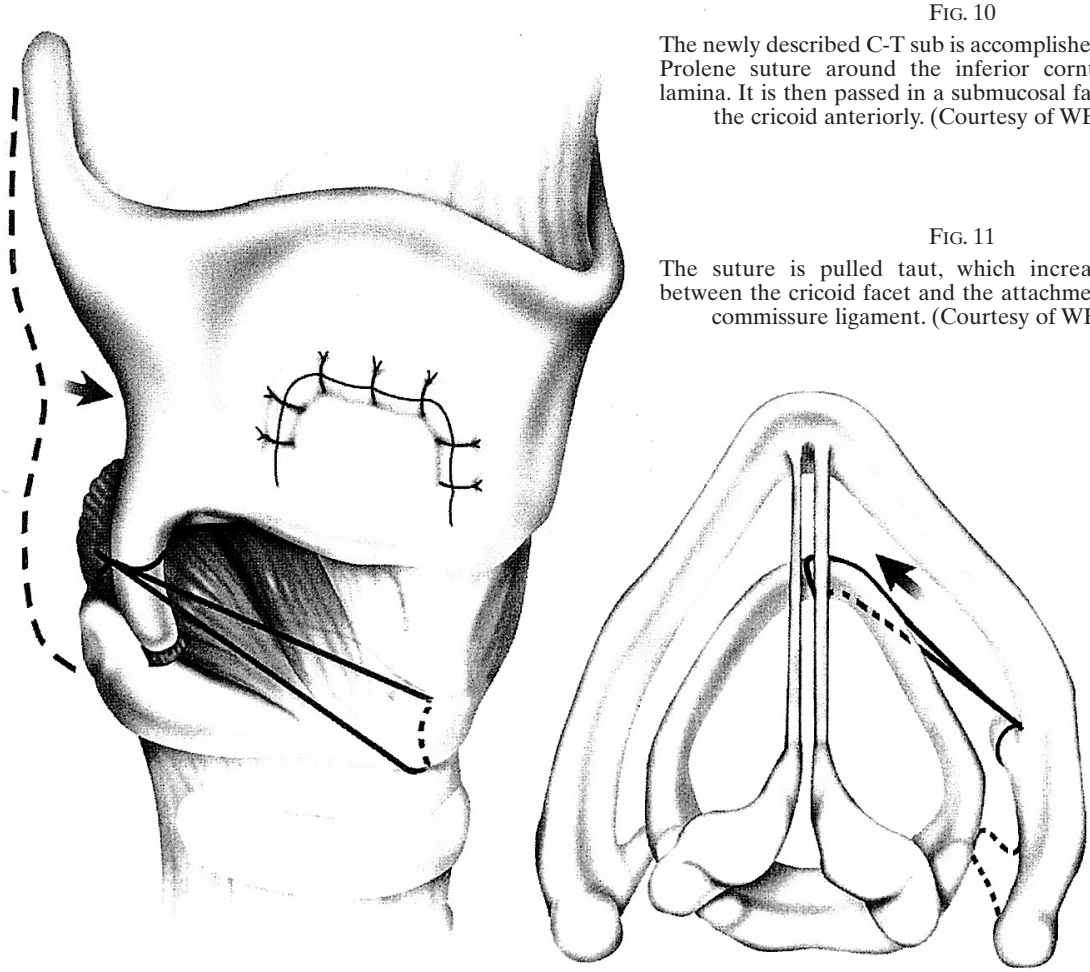

FIG. 11

The suture is pulled taut, which increases the distance between the cricoid facet and the attachment of the anterior commissure ligament. (Courtesy of WB Saunders)[10]

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TABLE I

RELATIVE INDICATIONS AND CONTRAINDICATIONS FOR ARYTENOID REPOSITIONING

Relative indications	Relative contraindications
Poor arytenoid closure (widely abducted arytenoid)	Reduced abduction of innervated arytenoid
Poor arytenoid closure (Height discrepancy)	Athletic aerodynamic needs
	Possible favourable re-innervation

secondarily to medialize the slightly-excavated atrophic vocalis-muscle and its overlying mucosa.

The primary candidates for an arytenoid medialization are those individuals who have moderate to severe aerodynamic incompetence and poor sustained entrainment of the vocal folds. This is typically associated with a wide inter-arytenoid chink and/or height discrepancy of the vocal folds. (Table I) Brief periods of glottal closure are often seen in those patients with a laterally-positioned arytenoid due to compensatory medial subluxation of the mobile arytenoid. This self-limited hyperfunctional compensation strategy should not be confused with optimal sustainable phonatory biomechanics.

Based on the aforementioned decision-making paradigm, 77/100 (77 per cent) were judged to potentially benefit from an arytenoid medialization procedure. However, 21/77 (27 per cent) were not considered appropriate candidates for other reasons. The most common contraindication to an arytenoid medialization was concern about the post-procedural airway 19/21 (90 per cent). In the overwhelming majority, it was deemed that peri-operative and/or final post-operative airway patency was not compatible with the patient's routine activity.

These clinical judgements can be difficult because there are not standard methods or criteria for quantifying a normal airway aperture or abductory excursion of arytenoid(s). Age-related changes of cricoarytenoid joint mobility are as yet uninvestigated and have a critical bearing on this issue. Also, there is great variation in the glottal aperture due to swelling of the overlying mucosal cover, which is primarily due to chronic laryngo-pharyngeal reflux. Finally, the interpretation of the laryngoscopic image provided by a rigid telescope or a flexible fibrescope is subjective and quantification of the airway aperture is not readily accessible with current technology.[13] These anatomical factors must be integrated with decisions to reposition the paralyzed side. Furthermore, the airway aperture must be individualized to accommodate the cardiopulmonary stability of the patient in various states of activity and sleep. In summary, integrating the spectrum of subtle interdependent factors requires sound complex surgical-judgment and can not be replaced by simple formulae or algorithms.

In this study, there were two patients who were very active in sports and elected not to undergo an adduction arytenopexy. These individuals accepted a non-optimal vocal outcome to reduce the chances of airway restriction during extreme athletic exercise. This may be a transitory contraindication since their preference could change and they could undergo an adduction arytenopexy in the future. Also, it is advisable to avoid irreversible arytenoid repositioning procedures in individuals who have sustained a recent vocal fold paralysis, in whom there is reasonable chance of favourable re-innervation.

Complications related to cricoarytenoid joint dissection can be life-threatening and those encountered herein are consistent with prior reports.[5,15,16] In this series, two out of 56 (3.56 per cent) of patients who underwent an adduction arytenopexy required a temporary endotracheal intubation. This is commensurate with Weinman *et al*.[16] who reported 3.5 per cent incidence of tracheotomy in patients undergoing an arytenoid procedure. Neither patient in this series sustained discernable deficit as a result of the intubation. The patient who did not adequately receive the steroids in the pre-operative holding unit, due to an unrecognized non-functional intravenous line, developed acute airway oedema and obstruction three hours subsequent to the procedure, and was intubated by the surgeon. He was extubated without difficulty the following morning without further intervention and was discharged 24 hours later without consequence.

Although the majority of patients can be discharged within 36 hours, elderly patients are often monitored for an extra night. They may have diminished airway reserve and /or cardiopulmonary vigour and may be slower to resume an adequate diet. It is prudent to examine the larynx prior to discharge and to administer an out-patient Solu-Medrol dose-pack if there is concern about airway stability.

The authors believe that the method for cricoarytenoid joint exposure depicted herein and detailed elsewhere provides discreet reliable cartilage and muscular landmarks,[1,10] which allow for a rapid precise arytenoid procedure. This is unlike the arytenoid adduction procedure,[2,3] which requires a subepithelial dissection in a microvascular plane in which landmarks are often obscured.[3] In turn, the adduction arytenopexy dissection technique minimizes airway risk since the authors' observations reveal that oedema/obstruction is dependent on the procedural time and collateral trauma to surrounding subepithelial soft tissues.

Phonatory considerations

In the present study, patient selection for arytenoid repositioning was based on pre-operative laryngoscopic and stroboscopic examinations. Seventy-seven per cent of the patients were judged to gain potentially worthwhile phonatory advantage from an arytenoid procedure. This decision-making process is guided by assessment criteria during visualization of static and dynamic glottal tasks (deep respiration and phonation).

The static assessment was done during quiet passive respiration. Typically, patients who were judged to gain significant voice improvement from

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an arytenoid procedure demonstrated a foreshortened vocal fold with and infero-laterally displaced vocal process that was visually obscured by an antero-medially positioned corniculate region, (Figure 1) The body of the arytenoid is infero-laterally displaced down the sloping facet of cricoid.[17] These vocal folds typically have minimal residual innervation and/or unfavourable synkinesis.

- **Adduction arytenopexy is a reliable reconstructive method (with acceptable risks) for severe dysphonia associated with paralytic dysphonia**
- **Despite the fact that 77 per cent of patients who presented with vocal fold paralysis were judged to potentially derive benefit from an arytenoid medialization, only 73 per cent of that group were deemed to be suitable surgical candidates**
- **The primary contraindication for performing an adduction arytenopexy was diminished mechanical abduction of the normally innervated cricoarytenoid joint**
- **Optimal management requires careful pre-operative assessment, peri-operative steroids, and meticulous intra-operative dissection**

Dynamic glottal gestures are comprised of phonation and deep respiration. Phonatory sampling should be performed at a variety of pitch frequencies and intensities (loudness) to simulate the spectrum of vocal dynamics during varied conversational speech patterns. The stroboscopic assessment should display glottal closure patterns and associated oscillation of the musculo-membranous region during a range of phonatory manoeuvres. Perturbation may occur only with rigorous tasks and may not be evident in a limited examination. This is classically observed when an individual with a denervated vocal fold attempts loud phonation and a harsh diplophonia develops. In this scenario, inherent differential viscoelasticity between the vocal folds results in different resonant vibration characteristics, and the flaccid vocal fold is overdriven by the subglottal air-pressure associated with a loud voice.

When a paralyzed vocal fold has been optimally reconstructed, stroboscopic findings will reflect the dramatic improvement in the efficient translation of aerodynamic force into an acoustic signal. The entrained mucosal-wave oscillation that is seen on stroboscopy may show normal phase symmetry despite the presence of vocal folds with radically different viscoelastic properties. The presence of the implant reduces the amplitude of excursion on the paralyzed side. However, these flaccid soft tissues are favourably predisposed to the closing forces of Bernoulli's effect, which counterbalance the loss of normal elastic recoil from the denervation.

In the normal state, symmetric viscoelastic tension between the vocal folds results in an optimal glottal sound source since the resonant frequency for vocal fold vibration is similar. With uncorrected unilateral paralysis, patients intuitively adjust (albeit inadequately) for the closure incompetence and symmetry in viscoelastic tension with varying degrees of hyperfunctional muscular behaviour. However, these glottal configurations limit phonatory capabilities. Although static reconstruction (arytenoid repositioning and implant medialization) realigns the full length of the vocal fold to re-establish aerodynamic competence, there is unavoidable and substantial asymmetry in the viscoelastic properties of each vocal fold. Surgical manoeuvres that reduce this discrepancy enhance vocal function. A discussion of surgically-induced adjustment of viscoelastic tension with relation to the variety of interdependent framework-procedural options is valuable since it is seldom elaborated.

The Isshiki arytenoid-adduction procedure slightly elongates the musculo-membranous region by means of rotation.[4] In a cadaver study,[1] the adduction arytenopexy was demonstrated to elongate the vocal fold better because the arytenoid is sutured posteriorly away from the anterior commissure tendon unlike the anterior direction of the classic arytenoid adduction suture. This positioning advantage was also confirmed in a clinical trial.[1] Cricothyroid subluxation[7,12] stretches the vocal fold even more substantially by increasing the distance between the cricoid facet and the insertion of the vocal fold into the thyroid lamina, thereby simulating cricothyroid muscle function, (Figures 1,2) The value of this procedure is best illustrated when the surgeon observes intra-operatively that subsequent to an adequate medialization of the musculo-membranous vocal fold and/or arytenoid, a patient's voice improvement is not acoustically commensurate with the observed midline position of the paralyzed vocal fold. The authors believe that the perturbated vocal quality, which does not reflect glottal closure incompetence, is the result of differential viscoelasticity between the vocal folds. This scenario can lead to futile and disappointing attempts at altering the shape and size of an implant.

Sustainable stable vocal-fold vibration requires alignment of the arytenoid vocal processes. Since the denervated vocal fold is foreshortened, lengthening it by means of adduction arytenopexy and cricothyroid subluxation reduces compensatory hyperfunctional foreshortening of the mobile fold, which is done reflexively to achieve alignment. Although perfect viscoelastic symmetry is never realized if one vocal fold has been denervated, greater symmetry is achieved by means of the cricothyroid subluxation procedure, regardless of the chosen static medialization procedure(s).[7,10,12] In turn, the reduction in hyperfunctional behaviour of the mobile fold results in greater vocal flexibility demonstrated by maximal-range tasks (pitch and loudness). This was demonstrated with a variety of objective acoustic and aerodynamic measures. Most notably, nearly all patients achieved two octaves of dynamic frequency range.[12]

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