Correction of Dysphonia Using Laryngeal Framework Surgical Techniques

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Many dysphonias caused by incomplete glottis closure or inadequate vocal fold tension are eligible for phonosurgical correction. Most phonosurgeons presently advocate laryngeal framework surgery as the first treatment of choice.

For correction of incomplete glottis closure usually thyroplasty type 1 and arytenoid adduction techniques are used. For correction of vocal fold tension crico-thyroid approximation and thyroplasty type 3 can be used. Often combinations of different techniques are required to achieve the best result. It is therefore essential to perform these procedures under local anaesthesia, so that the voice can be monitored during the surgery and so that the surgery can be tailored to the patient's voice.

89 patients underwent laryngeal framework surgery, 85 of them for correction of incomplete glottis closure, which in 75 patients was due to unilateral vocal fold immobility. The results in this group were good also in long term follow-up. Complications were few and insignificant.

Key Words

Phonosurgery/laryngeal framework surgery/incomplete glottis closure/vocal fold tension/voice.

INTRODUCTION

Dysphonias resulting from incomplete glottis closure or inadequate vocal fold tension are eligible for phonosurgical correction. Many different phonosurgical techniques have been used for these indications.

The surgical treatment in dysphonia resulting from incomplete glottis closure is generally based

on attempts to medialize the affected vocal fold(s)¹.

A still frequently applied method to achieve medialization is the endolaryngeal injection of soluble substances, such as teflon, silicone, or collagen and more recently autologous fat. Such treatments with injectable substances are quick and apparently simple procedures, however they are associated with considerable disadvantages and risks :

- 1) The mass, volume, and stiffness of the injected vocal fold are influenced by the injected substances. Such changes in vocal fold mass, volume, and stiffness interfere with the vibratory properties of the vocal fold, which can result in a poor voice.
- 2) Distribution of the injected substances is difficult to control. The substance will spread according to the path of least resistance, rather than to the area requiring augmentation.
- 3) The treatment is irreversible. Overinjection is difficult to correct and generally requires partial resection of the vocal fold resulting in severe dysphonia.
- 4) If performed in general anaesthesia, as many endolaryngeal injection procedures are, voice monitoring during the procedure is not possible. Consequently it is difficult to estimate the proper amount of substance to be injected.
- 5) Some materials (collagen, fat) are subject to partial absorption so that initial overcorrection is required and repeated

injections may be necessary. Other materials (silicone, teflon) are known to have tendency towards migration, which may also require repeated injections².

- 6) Often vocal fold palsy is associated with a level difference of both vocal folds, although this is not always easily detected on laryngeal examination. Such a level difference usually can not be corrected by vocal fold injection.
- 7) Last but not least, a considerable number of complications and local tissue reactions attributable to the injected substances have been published³⁻⁶. The injection of autologous fat seems to present less complications².

Medialization of the vocal folds can however also be achieved by means of laryngeal framework surgery. Usually a thyroplasty type 1 or an arytenoid adduction is used⁷.

The advantages of the laryngeal framework medialization techniques are :

- 1) The affected vocal fold is not negatively influenced by mass, volume, or stiffness changes.
- 2) Direct control can be obtained over the degree, area and level of medialization also enabling correction for a vertical level difference of both vocal folds.
- 3) The procedure is reversible in the unlikely event of overcorrection.
- 4) The procedure is performed under local anaesthesia, so that fine tuning of the voice is possible during the operation and several combinations of techniques can be tested during the operation to achieve the best voice result.
- 5) The voice results have proved to remain stable with only very few exceptions, so that the need for repeated procedures is rare.
- 6) Very few complications have been reported following this type of laryngeal framework surgery and those that have been reported

were not serious or detrimental to ultimate voice improvement⁸.

The only disadvantages of laryngeal framework surgery are the elaborateness of the procedures and the fact that clinical observation of one day is advised in all but the most simple procedures.

Because of the above mentioned advantages laryngeal framework surgical techniques are rapidly gaining popularity as the treatment of first choice for dysphonias resulting from incomplete glottis closure. Although some types of laryngeal framework surgery had already been suggested decades ago ^{9,10}, the concept remained fragmentary until Isshiki¹¹⁻¹⁵ modified some of these procedures, introduced some others and integrated them all into the functionally oriented set of phonosurgical techniques which is available to us today.

Beside the category of laryngeal framework surgeries with the objective to correct incomplete glottis closure a second category can be distinguished, aimed at adjustment of vocal fold tension, unilaterally or bilaterally.

The most frequently applied techniques to adjust vocal fold tension are : Crico-thyroid approximation to increase vocal fold tension and thyroplasty type 3 to reduce vocal fold tension.

Sometimes a single modality laryngeal framework surgical technique sufficiently improves the voice, but often a better voice can be obtained by combining different techniques in one stage. This is not always predictable preoperatively, so that voice and functional fiberoptic endolaryngeal monitoring are essential during the procedure, not only to determine the required degree of medialization or change of vocal fold tension, but also to decide whether or not to continue with a combination of laryngeal framework surgical procedures. To enable this monitoring, the laryngeal framework surgical techniques are performed under local anaesthesia.

SURGICAL TECHNIQUES

The laryngeal framework surgical procedures are performed following an intramuscular

premedication of atropine sulfate (0.5 mg) and morphine (10 mg).

Local anaesthesia is obtained with infiltration of 1% lidocaine hydrochloride with 0.001% epinephrine.

The endolaryngeal situation is monitored by fiberoptic videolaryngoscopy during the surgery. The quality of the voice however is the most important assessment parameter during the surgery. Prophylactic antibiotic treatment is continued for 5 days postoperatively. Postoperative voice rest ranges from 2 to 4 days, depending upon the laryngoscopic findings. Occasionally steroid administration is added in case of exceptional postoperative endolaryngeal swelling or codeine medication in case of excessive coughing.

Correction of incomplete glottis closure

Thyroplasty type 1 (fig.1)

The skin incision is made horizontally on the anterior portion of the neck at the lower margin of the thyroid cartilage extending from 1 cm paramedially on the unaffected side to the posterior margin of the thyroid cartilage on the affected side.

Fig.1

Thyroplasty type I according to Isshiki for medialization of the vocal fold.

The cartilage of the thyroid ala is exposed on the affected side. At the level of the vocal fold a rectangular cartilage "window" is incised (approximately 5 x 10 mm in females, 6 x 12 mm in males) either with a knife or in case of cartilage calcification with a small cutting burr. Care is taken to preserve as much of the endolaryngeal perichondrium as possible, which is lightly elevated from the inner surface of the thyroid cartilage.

The rectangular cartilage window is depressed inward to various depths during phonation to decide the optimal degree of medialization. For fixation of the cartilage window in this position either a small silicone (or other material) wedge or plug, or sutures can be used, depending upon the required degree of medialization.

Overcorrection at the subglottic, glottic, or supraglottic level is recognised by a pressed and hyperkinetic, rough, voice quality and sometimes at laryngoscopy a protruding ventricular fold can then be seen.

Contrary to the recently advocated procedure of removing the cartilage window in order to more directly influence the shape and position of the vocal fold by using differently shaped silicon implants, I personally prefer to leave the cartilage window in situ, as a buttress against endolaryngeal extrusion of the silicon implant. Such extrusions have only been reported following removal of the cartilage window and incision of the inner perichondrium⁸.

Because thyroplasty type 1 does not interfere with vocal fold mobility, it can be used bilaterally if necessary in cases with incomplete glottis closure and mobile vocal folds. The medialization achieved by this procedure is more outspoken in the anterior part of the vocal fold.

Arytenoid adduction (fig. 2)

The skin incision is similar to the thyroplasty type I, but slightly longer, extending past the posterior margin of the thyroid cartilage. After exposure of the thyroid ala cartilage, the posterior margin is exposed over its entire length elevating and

Fig.2

Arytenoid adduction for medialization of the vocal fold, for correction of large glottal gaps especially posteriorly and for correction of a level difference between both vocal folds

sectioning the thyropharyngeal musculature. Elevation is continued around the posterior margin to the inner surface of the thyroid cartilage. For a good exposure of the arytenoid region the cricothyroid joint is dislocated and the superior horn of the thyroid cartilage may be sectioned (sometimes it is easier not to dislocate the cricothyroid joint and section the upper horn of the thyroid cartilage, but to resect a part of the posterior thyroid ala margin to achieve access to the arytenoid area). The muscular process of the arytenoid cartilage can then be palpated. It is approached following the cricoid cartilage surface upwards from the dislocated cricothyroid joint. Care should be taken at this stage not to enter the piriform sinus which can overlie the muscular process. The crico-arytenoid joint is opened and two or three Gore-tex sutures 5 are fixed at the muscular process and the surrounding musculature.

The sutures are pulled in the general direction of the lateral crico-arytenoid and thyroarytenoid muscles, which will result in rotation of the vocal process medially, thus medializing the vocal fold. The sutures are brought out in this direction through the thyroid ala (in cases of calcification it may be necessary to use a burr to pierce the

thyroid ala). Again under phonatory control in order to decide the optimal degree of traction, the sutures are tied on the outer surface of the thyroid ala. In most cases only one or two sutures are required to achieve a good result and the other sutures can then be removed.

Overcorrection is recognized by the pressed and hyperkinetic, sometimes breathy, voice quality and the endoscopic laryngeal image. Because arytenoid adduction restricts laryngeal mobility it can only be used unilaterally. The medialization achieved with this procedure is noticeable over the entire length of the vocal fold, but can be insufficient in the anterior part of the vocal fold, as is often the case in vocal fold atrophy. The arytenoid adduction technique furthermore enables correction of a level difference between both vocal folds, as often occurs in unilateral laryngeal palsy.

ADJUSTMENT OF VOCAL FOLD TENSION

Crico-thyroid approximation (fig.3)

Fig.3

Approximation of the cricoid and thyroid cartilages anteriorly results in stretching of the vocal folds, thus increasing the vocal fold tension and the vocal fold pitch. Left in resting position; Right in approximated position

Crico-thyroid approximation mimics the function of the crico-thyroid muscles, thus stretching the vocal folds and increasing the tension.

Four (or two for unilateral crico-thyroid approximation) thick (1-0 or 2-0) double armoured non-absorbable (Gore-tex) are used. One needle of each suture is inserted just behind the anterior part of lower margin of the cricoid cartilage and is advanced along its inner surface

and directed upwards. The needles are withdrawn at the upper margin of the cricoid cartilage and then reinserted just behind the lower edge of the thyroid cartilage.

They are directed along the inner surface of the thyroid cartilage and directed outward through the ala, slightly below the level of the vocal folds, 0.5 to 1.5 cm laterally from the midline. The needles at the other end of the sutures are passed anteriorly from the cricoid cartilage and are similarly directed upwards along the inner surface of the thyroid cartilage and taken out just a few

millimeters from the other end of the suture. This allows the sutures to be tied later as mattress-sutures on the outer surface of the thyroid ala.

Care should be taken not to enter the laryngeal lumen, which can be detected by the coughing reaction and by fiberoptic control. The mucosa is very close to the cartilage especially near the cricoid and in the lower anterior part of the thyroid.

In cases of extreme calcification of the thyroid cartilage it may be necessary to drill holes in order to bring the needles out through the ala.

Fig.4

Thyroplasty type 3 according to Isshiki. Resection of a vertical strip of cartilage from the thyroid ala results in reduction of vocal fold tension

The voice is tested while the sutures are being pulled tautly. Thus the cricoid and thyroid cartilages are approximated anteriorly and as a consequence the vocal folds are stretched. If the result is satisfactory and the sutures are tied it is advisable to use small silicone bolsters to disperse the pressure on the thyroid ala and the cricoid.

Thyroplasty type 3 (fig. 4)

Thyroplasty type 3 is based on the concept that a change in the anterior-posterior (A-P) dimension of the thyroid ala will result in a change of vocal fold tension. For this purpose a vertical strip of cartilage is resected from the thyroid ala 1/3 from the anterior midline. This will result in a reduction of the A-P dimension

of the thyroid ala and consequently in a reduction of the vocal fold length and tension. Both parts of the thyroid ala are sutured together when the required amount of vocal fold tension reduction has been achieved. This procedure can be performed unilaterally or bilaterally.

MATERIALS AND METHOD OF EVALUATION

Patients

119 patients who underwent laryngeal framework surgery in our department in the period 1987-1995 have been evaluated. In 30 patients, mostly transsexual, the primary aim of laryngeal framework surgery was the elevation of vocal pitch, which is beyond the scope of the present

Fig.5

Phonetogram of a 43 years old male patient before and after a combination of thyroplasty type I and arytenoid adduction.

The postoperative phonetogram can be considered normal for a male

The mean habitual pitch of the voice was 175 Hz pre-operatively and 131 Hz postoperatively

paper and will not be further discussed here. For 85 patients the primary aim was to correct a dysphonia due to incomplete glottis closure. In 4 patients the indication for the surgery was primarily adjustment of vocal fold tension.

The 85 patients who have been treated with the intention of improving the glottis closure have undergone a single modality laryngeal framework technique (40 x thyroplasty type 1; 3 x arytenoid adductions) or a combination of these techniques (28 x thyroplasty type 1 in combination with arytenoid adduction ; 6 combinations of thyroplasty type 1, arytenoid adduction and

crico-thyroid approximation; 8 other combinations). Nine of these patients had bilateral mobile vocal folds, 75 had a unilateral immobile vocal fold, 1 patient had bilateral immobile vocal folds.

Of the 4 patients who have been treated with the primary intention of adjustment of vocal fold tension 2 underwent surgery to increase the tension (both underwent cricothyroid approximation), because of superior laryngeal nerve palsy.

Two patients underwent surgery to reduce vocal fold tension (once bilateral thyroplasty type 3,

Fig.6

a) The maximal dynamic range as can be obtained from the phonetogram. b) The dynamic range at the level of the habitual speaking voice pitch level. In this example at 196 Hz or the musical tone g. c) The maximal vocal intensity as measured in the phonetogram. d) The melodic range as can be obtained from the phonetogram

Laryngeal Framework Surgery Overall Results (medialization)

Fig.7

Results obtained with medialization laryngeal framework surgery

once unilateral thyroplasty type 3 and thyroplasty type 1), both patients had previously undergone extensive microlaryngeal surgery according to Bouchayer for bilateral vocal fold "vergeture".

All patients, excluding 10 who had malignant mediastinal disease, had undergone extensive voice training without satisfactory result.

Voice assessment

Voice evaluation was performed by means of a phonetogram (fig. 5) registered according to the guidelines of the Union Europeen de Phoniatrie¹⁶ with a microphone to mouth distance of 30 centrimeters preoperatively, between 1 and 4 months postoperatively (short term results) and more than one year postoperatively (long term results). In addition the maximal phonation time of the sustained vowel/a/was recorded in the patients undergoing medialization laryngeal framework surgery. Furthermore the mean pitch

of the voice during normal speech was determined by means of a Glottal Frequency Analyser (Teltec type GFA 06, Sweden) in both patient categories.

This resulted in the following objective voice parameters :

- 1) Maximal phonation time (Phone Time) in seconds of a sustained vowel /a/ (best of three efforts)
- 2) Maximal dynamic intensity range (Dyn Range) in deciBels obtained from the phonetogram (fig. 6a)
- 3) Dynamic intensity range at the mean habitual pitch of the speaking voice (Dyn Range MVP) in deciBels obtained from the phonetogram (fig. 6b)
- 4) Maximal vocal intensity (Max Int) in deciBels obtained from the phonetogram (fig. 6c)
- 5) Melodic range (Mel. Range) in semitones

obtained from the phonetrogram (fig. 6d)

- 6) Mean habitual pitch of the voice during speech (MVP).

RESULTS

Voice assessment

Of 85 patients who had undergone medialization laryngeal framework surgery, none showed a deterioration of the voice. Three patients considered their voice to be unchanged or only marginally improved following the procedure. All three had undergone extensive previous phonosurgical procedures, two of them including teflon injections. All patients with a dysphonia based on vagus or recurrent nerve paralysis who had not previously undergone any phonosurgical procedure obtained a markedly improved voice and were highly satisfied with the result. About one third of all patients considered their postoperative voice to be absolutely normal, even in demanding circumstances. More than half of the remaining patients considered their voice to be "functionally adequate".

Objective postoperative voice evaluation was obtained in 60 patients following medialization laryngeal framework surgery (fig. 7). Twenty-five patients were excluded from voice evaluation; seven patients because they were from abroad and the voice assessment performed in the respective referring centres was not consistent; ten patients because they had terminal disease (malignant involvement of mediastinum); eight patients because they were unable to produce a reliable phonetrogram mostly because of hearing loss. A considerable voice improvement was found postoperatively in all voice parameters:

The mean maximal phonation time (Phon. Time) increased from 6.8 seconds to 13.7 seconds ;

The mean dynamic range (Dyn. Range) increased from 14.9 deciBels to 24.1 deciBels;

The mean dynamic range at the mean vocal path pitch level (Dyn. Range MVP) rose from 10.3 deciBels to 16.8 deciBels;

The mean maximal vocal intensity (Max. Int.) increased from 79.9 deciBels to 85.9 deciBels;

The mean melodic range (Mel. Range) showed a slight improvement from 19.9 semitones to 22.3 semitones.

In two patients a crico-thyroid approximation was performed a correct a superior laryngeal nerve paralysis (one unilaterally, one bilaterally). Both demonstrated a slightly higher pitch (2 and 4 semitones respectively) and a stronger voice postoperatively.

The indication for lowering the vocal fold tension is very rare and has been performed only twice; once a bilateral thyroplasty type 3 have been performed in a patient with weak and high-pitched voice due to a congenital vocal fold hypoplasia and bilateral vergeture; once using a unilateral thyroplasty type 3 with shortening of the anterior-posterior dimension of the thyroid ala in combination with slight anterior medialization on the same side and a thyroplasty type 1 on the other side in a case of severe dysphonia with a strained, weak, high-pitched voice, due to congenital hypoplasia of the vocal folds and bilateral vergeture, with incomplete glottis closure. In both cases the mean pitch dropped a few semitones (3 and 6 semitones respectively) and the glottis closure improved, resulting in an improved maximal phonation time (an improvement of 2 and 5 seconds respectively) and in a slightly stronger and less strained voice.

Generally the best results were obtained in patients with dysphonia and or aspiration caused by recurrent or vagus nerve paralysis. Worst results were obtained in patients who had previously undergone intracordal teflon injections, patients with laryngeal fibrosis following laryngeal trauma, or patients who had undergone radiotherapy of the neck and larynx.

COMPLICATIONS

Complications observed were minor (2 local infections, successfully treated with antibiotics;

1 transient stridor because of edema, successfully treated with steroid medication; 1 fracture of the posterior thyroid ala without consequences; 1 slight dyspnea on exertion because of overcorrection, which was corrected secondarily by reducing the degree of medialization of the cartilage window 4 months later, with preservation of the achieved voice improvement). One patient required a second thyroplasty type 1 when her initially satisfactory postoperative voice deteriorated following an intubation for a gynaecological procedure 2 years following the first thyroplasty. The second thyroplasty again resulted in a good postoperative voice.

DISCUSSION

Laryngeal framework surgery is rapidly gaining popularity as a technique to treat dysphonia caused by incomplete glottis closure. Especially thyroplasty type 1 has become the first treatment of choice for many phonosurgeons. The reasons for this popularity have already been outlined and are supported by the results presented above. We should however always keep in mind that we are dealing with surgery aimed at improvement of phonatory function and that sometimes minor changes of the laryngeal framework can result in major changes of the voice. Therefore the most important factor determining success of these procedures is the monitoring of the phonatory function during the surgery. That is why these procedures should only be undertaken in local anaesthesia. Furthermore the surgeon who is performing this type of surgery should be able to manage the different techniques

described above, so that the surgery can be tailored to the individual patient's situation, which will often require a combination of techniques to obtain the best result. In this respect the importance of adjustment of vocal fold tension in addition to vocal fold medialization is often underestimated. Personally I always test the effect of a cricothyroid approximation at the end of a medialization laryngeal framework surgery, to find out if this leads to a further voice improvement.

Tucker¹⁷ has suggested a reinnervation procedure (nerve-muscle pedicle) in addition to medialization laryngeal framework surgery to restore vocal fold tension. Preoperative laryngeal EMG-studies have however taught us that most of the "unilateral laryngeal palsy" patients do not have a lack of innervation of the laryngeal musculature, but they have an inappropriate reinnervation leading to synkinesia, tension dysbalance and sometimes even a tendency towards paradoxal laryngeal mobility. Since hyperinnervation of an, albeit subclinical, innervated muscle is physiologically impossible, the effectiveness of these additional reinnervation procedures is questionable.

In conclusion laryngeal framework surgery offers a safe and usually effective method to improve incomplete glottis closure and adjust vocal fold tension. Local anaesthesia enables fine-tuning of the voice during the procedure. The possibility to combine different laryngeal framework surgeries according to the dysphonic patient's needs illustrates the tailored approach to surgical voice improvement.

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