Surgery for voice

D Garfield Davies

Preoperative assessment in a multidisciplinary voice clinic, using stroboscopy, is essential. In the treatment of benign vocal fold mucosal disorders precise phonosurgical techniques, using high magnification which respects the multilayered structure of the vocal fold, are mandatory. A paralysed vocal fold can be assessed by electromyography and medialization thyroplasty procedures offer excellent 'fine tuning' of the voice.

The term phonosurgery refers to any surgery designed primarily for the improvement or restoration of voice. During the first hundred years of laryngology, surgery was devoted largely to the removal of neoplasms, and any possible improvement in voice was really a byproduct of this process. For many years the reputation of a laryngologist was measured by the number of laryngectomies he performed, and the preservation of voice was of lesser importance. This phase has fortunately passed and today the maintenance and improvement of vocal function is the goal of every practising laryngologist.

WHAT MAKES A VOICE?

When the vocal cords or more correctly the vocal folds vibrate, they produce only a buzzing sound. However, this sound resonates throughout the supraglottic vocal tract, which includes the pharynx, the tongue, the palate, the oral cavity and the nose. This added resonance produces much of the perceived character and timbre, or vocal quality of all sounds in speech and song.

The power source for the voice is the infraglottic tract, i.e. the lungs, rib cage and abdominal, back and chest muscles that generate and direct a controlled air stream between the vocal folds. As the glottis closes, opens and alters shape, its air resistance changes almost continuously. The power source must therefore make rapid, complex adjustments to maintain a steady vocal quality. Actors and singers refer generally to the entire power complex as their 'support' or 'diaphragm'. Thus abnormalities in the supraglottic and infraglottic regions can involve an alteration in vocal resonance and surgery may be required in these regions to improve the quality of life. However, for the purposes of this review surgery for voice, or phonosurgery, will be confined to surgery of the vocal folds themselves.

A clear understanding by the surgeon of the microarchitecture of the vocal fold is essential in all phonomicrosurgical procedures. Hirano (1977) described the vocal fold muscle as the body of the fold, the epithelial and superficial layer of the lamina propria (Reinke's potential space) as the cover, and the intermediate layers of collagenous and elastic tissue (vocal ligament) as the transitional zone (*Figure 1*).

As a result of the different stiffness characteristics of these layers they are somewhat decoupled mechanically from each other during phonation. This allows the mucosa to oscillate with a degree of freedom from the ligament and muscle. Phonomicrosurgery is the convergence of theories that guide endoscopic vocal fold surgery with the principles that explains voice production (body — cover, mucosal — wave theory). The underlying premise of the surgical

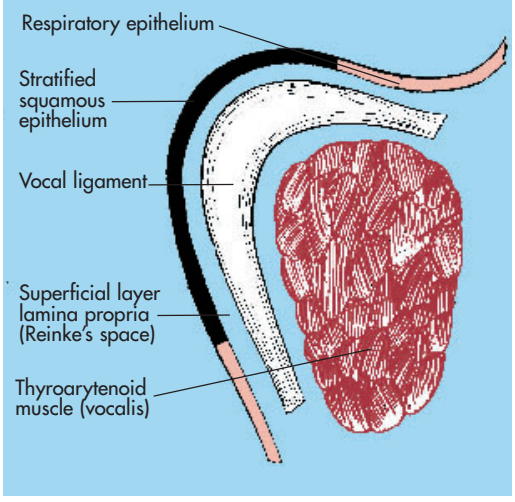

Figure 1. Cross section of vocal fold.

Mr D Garfield Davies is Consultant Emeritus Middlesex and University College Hospitals (UCL Hospitals), Honorary Consultant Otolaryngologist Royal National Nose, Throat and Ear Hospital, and Lecturer Institute of Laryngology and Otology, University College London

Correspondence to: Mr D Garfield Davies, 149 Harley Street, London W1N 2DE

approach is that optimal postoperative voice, which is observed as a pliable vocal fold cover, will be achieved if there is maximum preservation of the vocal folds' layered microstructure (lamina propria).

Although the first modern voice clinic in this country using sophisticated diagnostic equipment was set up at the Ferens Institute at the Middlesex Hospital in 1982 there are now more than forty multidisciplinary voice assessment clinics in the UK. The basic equipment needs of a voice clinic are:

- Light source — halogen and xenon lamps
- Flexible fibreoptic laryngoscope
- Rigid Hopkin's laryngoscope (telescope) 70° or 90°
- Video camera
- Stroboscope
- Audio microphone
- Video recorder
- Video monitor.

A more sophisticated clinic requires facilities for:

1. Frequency analysis
2. Spectral analysis
3. Waveform analysis
4. Aerodynamic studies.

Devices that analyse phonation aerodynamically and acoustically have little diagnostic value but are useful to quantify and document severity, and to help in biofeedback applications.

BENIGN VOCAL FOLD MUCOSAL DISORDERS

Vocal nodules

Vocal nodules are most commonly found in boys and women who are generally 'vocal overdoers'. If vibration of the anterior two-thirds (membranous portion of the vocal folds) is too forceful or prolonged it causes vocal localized vascular congestion with oedema in the mid-portion of this part of the vocal folds where the collisional and shearing forces are greatest. Long-term vocal abuse leads to hyalinization of Reinke's potential space and possibly some thickening of the overlying mucosa.

In over 90% of cases the localized swellings are usually reversible with good voice therapy and a compliant patient (Garfield Davies and Jahn, 1998). Vocal nodules occur bilaterally and although one swelling may be somewhat larger than the other, any one-sided localized swelling should be suspected of being a cyst. The distinction between cysts and nodules can usually be made by videostroboscopy and it is essential to define the lesion for the management of these conditions differ.

Surgical removal is necessary when nodules persist despite intensive voice therapy and the voice remains unacceptably impaired. The first principle of phonomicrosurgery is extreme technical precision so that the disturbance to the mucosa is kept to a minimum. Vocal nodules are removed by microdissection techniques followed by a period of relative vocal rest and further voice therapy.

Intracordal cysts

The patient with epidermoid or mucus cysts has similar symptoms to nodules such as inability to sing high notes, a breathy voice, vocal fatigue and a need for longer warm-ups. However, although voice therapy has no curative role, it is essential that the patient be assessed and given the rudiments of fundamental voice care.

Surgical removal is essential and care is taken to avoid injury to the mucosa other than that of an incision, for the surgeon dissects the cyst free of the surrounding mucosa and vocal ligament. Any excessive adhesions and scar formation between the vibratory layers will hold up the ensuing postoperative mucosal wave and result in vocal disability, especially in the higher register.

Bilateral diffuse polyposis

This usually occurs in somewhat extrovert middle-aged female smokers and presents with gradually increasing hoarseness. In the treatment of this problem it is essential that the patient stops smoking and hypothyroidism is ruled out. Until recently vocal fold stripping was performed in the management of this condition but although the vocal folds appear satisfactory on mirror examination after this procedure, when viewed by stroboscopy there was no vibrating wave and the adhesions and scarring of the edges resulted in a harsh voice which had a very poor pitch range.

In keeping with the modern theories of vocal fold vibration it is important to 'keep holy' the vocal fold vibrating edge. Thus a superficial cordotomy should be carried out in the lateral aspect of the superior surface of the fold and the gelatinous submucosal material, causing the oedematous swelling, can be gently aspirated. The edges are then approximated leaving the vibrating margin intact.

It is advisable to leave a gap of 4–6 weeks before carrying out surgery on the second vocal fold to avoid the risk of adhesions in the anterior commissure. Not infrequently, provided the patient stops smoking, the improvement after unilateral surgery is so great that operation on the second side is not warranted.

Vocal cord polyp

Vocal fold haemorrhage and unilateral haemorrhagic vocal fold polyps are more common in men, particularly those who work in noisy environments and engage in intermittent strenuous use of the voice. Sometimes these patients have a history of aspirin or other anticoagulant use and if the problem is recurrent then anticoagulant medication should be discontinued if at all possible. Should a bloodclot resulting from vocal abuse cause marked dysphonia which is persistent, then a tiny incision into any recent haemorrhage may be appropriate.

It is essential to locate any feeding capillaries that are likely to be the source of the haemorrhage, and if necessary coagulate these with a micro-coagulation tip. A sub-acute polyp of the early haemorrhagic variety should be trimmed away superficially at the time of coagulation with fine microsurgical instruments.

Contact granuloma

Contact granuloma ulceration is specially seen in male teachers, hard-hitting business executives, lawyers and ministers of religion. Chronic throat clearing and coughing and acid reflux from the stomach into the posterior larynx during sleep (posterior laryngitis) frequently cause this problem. An anti-reflux regimen should begin on an empirical basis even for patients with no symptoms of reflux, and the patient also should embark on a short course of voice therapy to abolish abusive vocal habits that have been acquired.

In the past granulomas were treated by cautery, cryosurgery and more recently laser surgery. However, they very frequently recurred and it was only in the last 10 years that it was appreciated that laryngo-pharyngeal reflux was the main aetiological factor. Very few granulomas fail to respond to proton pump inhibitors and voice therapy, but occasionally surgery should still be considered. This should be the last resort because postoperative recurrence of the ulcer or granuloma is predictable.

Laser

The laryngologist must select from a variety of instruments in order to produce the optimal surgical result. There is controversy about the merits of using carbon dioxide (CO_2) laser during microscopic surgery as a result of concerns about its potential harmful effects on the delicate vocal fold microstructure. The injudicious use of the laser has led to thermal trauma of the superficial lamina propria, resulting in vocal fold epithelium that is adherent to the vocal ligament. As a result, a stiff vocal system and disordered voice production ensues.

Cold instruments alone are better suited to resect superficial and smaller vocal cord lesions. As biopsies have to be obtained for histological examination with microsurgical instruments, it seems rational to complete the dissection of the lesion with the same equipment. The CO_2 laser, however, aids the use of cold instruments when dissecting larger more vascular lesions of the glottis, and has a definite place in treating papilloma of the airway and also, on occasions, very limited superficial and localized early cancer of the vocal fold.

Post-surgical dysphonia

Patients who have had bad surgical results usually have undergone the procedure of vocal fold stripping or laser vapourization of the mucosa. The pathology report not infrequently describes a fairly large specimen that may contain fibrous tissue or even muscle tissue, suggesting that the removal went too deeply into the vocal fold. If the vocal fold is stiff and scarred it means that a degree of freedom of the mucosa from the underlying vocal ligament has been lost as a result of scar tissue adhesion between the two layers.

Irregularities of the margin may occur as a result of a deep incision causing scarring between the layers and resulting in notching or pseudo bowing. Granulomas can also occur from surgical trauma that exposed the fold's deeper mesenchymal tissue. By and large postoperative dysphonia can be avoided by precise surgical techniques under high magnification and the graduated resumption of vocal activity after surgery under the supervision of an experienced voice therapist.

VOCAL FOLD MOTION IMPAIRMENT AND SOFT TISSUE DEFICITS

In a review of the changing aetiology of vocal fold immobility, Benninger et al (1998) found that surgical trauma, particularly as a result of cervical and skull base surgery, was an increasing cause of unilateral vocal fold immobility. Although thyroidectomy remains a relatively uncommon cause of unilateral vocal fold mobility, bilateral immobility secondary to thyroidectomy is still quite frequent but is decreasing in incidence.

As acute and chronic endotracheal intubation injuries accounted for a significant number of cases, differentiation between cricoarytenoid fixation and recurrent nerve injury is critical in these cases. Laryngeal electromyography plays

an important diagnostic role in the subsequent treatment of the vocal fold immobility.

The degree of glottal insufficiency may be determined by subjectively assessing the patient's symptoms of breathiness, aspiration or exertion intolerance. Objective measures of laryngeal function include simple phonatory tasks such as mean or maximum phonation time, measurement of phonatory air flow and acoustic parameters. However, these tests, although useful for assessing the outcome of therapy, are not always reliable in patient selection.

Videostroboscopy is the most useful objective test for pre- and postoperative assessment of patients with unilateral vocal fold impairment, for it provides visual assessment of glottic closure and the mucosal wave. The only test that is useful in the timing and choice of surgical procedures for the paralysed larynx is electromyography (EMG). However, despite normal voluntary electrical activity, vocal fold immobility may be present as a result of joint ankylosis, laryngeal synkinesis or cicatricial web formation. These conditions can only be distinguished by palpation of the vocal process during direct laryngoscopy.

When there is evidence of denervation by EMG, medialization thyroplasty can be carried out early in the presence of aspiration or severe dysphonia. As the operation is reversible, unlike the Teflon injection technique, return of vocal fold mobility simply means taking out the prosthesis. Patients who are not too disabled by their dysphonia, and have no aspiration problems, should undergo a course of voice therapy in the first instance to determine what progress can be made by conservative means.

Medialization thyroplasty

Although there are many variations of Isshiki et al's (1974) description of this operation, the basic principles remain. Medialization is performed through a window in the thyroid lamina at the level of the vocal fold (*Figure 2*). The inner perichondrium should remain intact (*Figure 3*). Factors that determine the outcome include the shape and size of the implant, position of the implant, maintenance of the proper position of the implant and limited duration of the surgical procedure.

Silastic implants can be fashioned at the time of the procedure. Alternatively the preformed dense, hydroxylapatite implant of Flint and Cummings (1993) or the softer silastic implant of Montgomery et al (1993) with matched size templates which allow rapid determination of the correct implant size and position can be used. During the operation, which should ideally be carried out under local anaesthesia, the larynx is assessed by a fibreoptic naso-laryngoscope and 'fine tuning' of the voice is determined by asking the patient to phonate at the same time as the template is moved through all four quadrants of the window to determine the optimum position (*Figure 4*).

Smaller or larger templates may be selected as needed. Generally the largest prosthesis possible is used while maintaining good quality of voice (*Figure 5*). Complications associated with the medialization thyroplasty have included mucosal perforation, infection, displacement of implants and extrusion, and also airway compromise. As airway obstruction is a potential problem patients should be observed in hospital for at

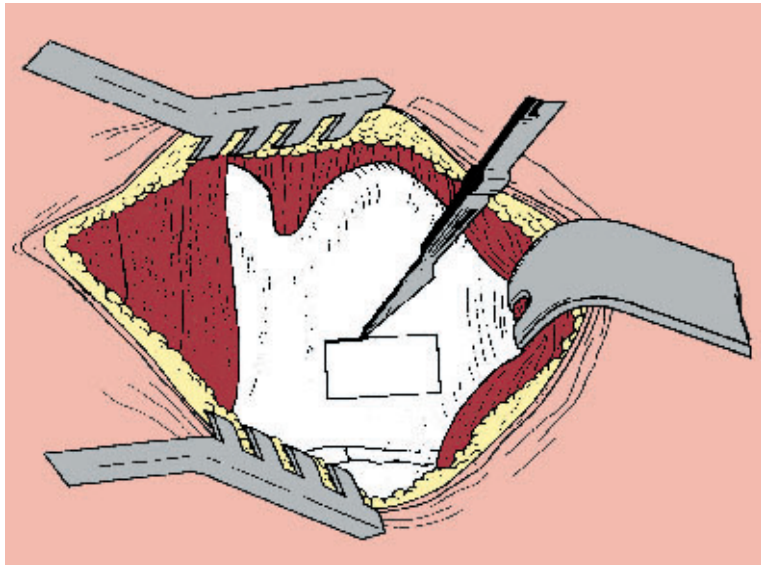

Figure 2. Incision of outer perichondrium and eventual removal of cartilaginous window.

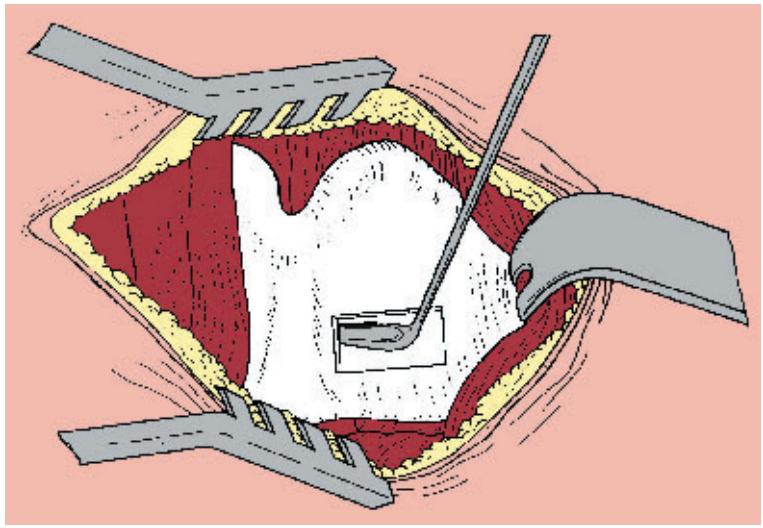

Figure 3. Elevation of inner perichondrium.

least 24 hours. Medialization procedures have been carried out in elderly people who are unable to project their voices effectively because of marked severe bowing of the vocal folds (presbyphonia), and this operation has also been used in improving the weak, breathy voice frequently seen in patients with Parkinson's disease (Koufman, 1989).

Arytenoid adduction

The success of vocal fold medialization using the above thyroplasty technique may be limited in the presence of a large posterior glottic chink or if there is any difference in the level of the two vocal folds. This condition occurs commonly with high vagal nerve injuries when denervation of the ipsilateral cricothyroid muscle and recurrent laryngeal nerve injury coexist. The arytenoid adduction procedure results in rotation of the arytenoid with downward displacement of the vocal process and closure of the posterior gap. This is achieved by inserting a suture in the muscular process and medializing and rotating the vocal process, thus reducing the posterior chink. This operation may be performed in combination with a thyroplasty or as a separate procedure.

Reinnervation procedures

A variety of procedures have been carried out by Tucker (1977) and Crumley (1983) using a phrenic nerve graft or the ansa hypoglossi. The initial reports appeared to be encouraging but universal success has not been achieved. A significant amount of basic work has to be done on reinnervation techniques in this area before this procedure can be recommended as the treatment of choice.

Vocal fold medialization by injection

If it has been established that one vocal fold has been permanently paralysed then injection techniques may be used to increase the bulk of the paralysed vocal fold and thus close the glottic gap. Alloplastics (Teflon) or biological implants such as fat and collagen are used and can be injected under local or general anaesthesia. Teflon should be placed in the most lateral and most posterior aspect of the thyroarytenoid muscle, and to avoid troublesome granulomas it is essential to place the needle deep to the thyroarytenoid muscles and also to avoid injecting the anterior third of the vocal fold.

Autogenous fat can be obtained via liposuction from a small abdominal incision and can be placed into a Bruenings syringe and injected superficially into Reinke's space. This technique is only good for gaps of 1.5 mm or less, and over-injection is necessary because approximately 60% of fat is eventually absorbed. Collagen (Ford and Bless, 1986) has been used for the paralysed vocal fold and is injected superficially into the vocal ligament itself. However, hypersensitivy reactions can occur and it is usually necessary to perform skin tests on patients preoperatively.

Injection techniques *vs* thyroplasty

Medialization by injection technique should be considered in patients with short life expectancy and aspiration or severe dysphonia. Teflon aug-

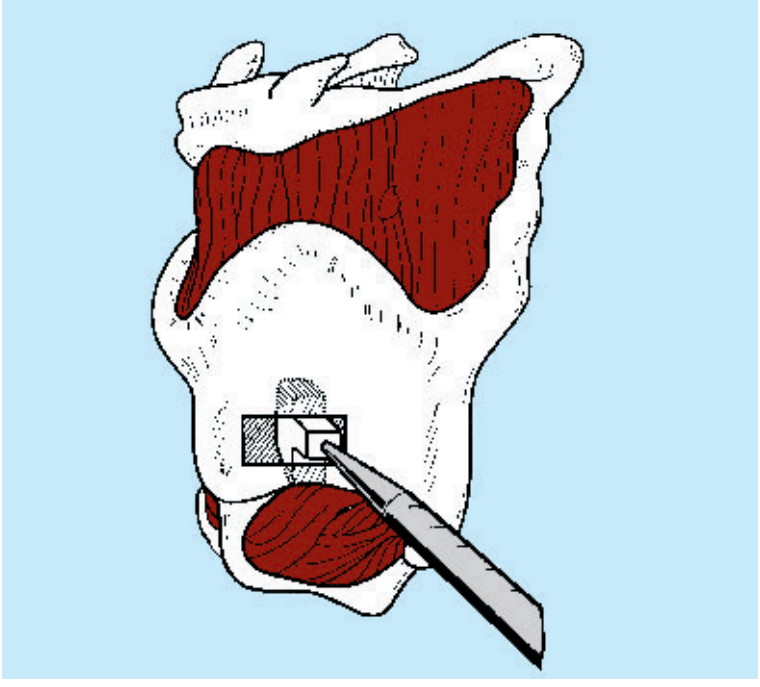

Figure 4. Insertion of template which is adjusted to the optimum position.

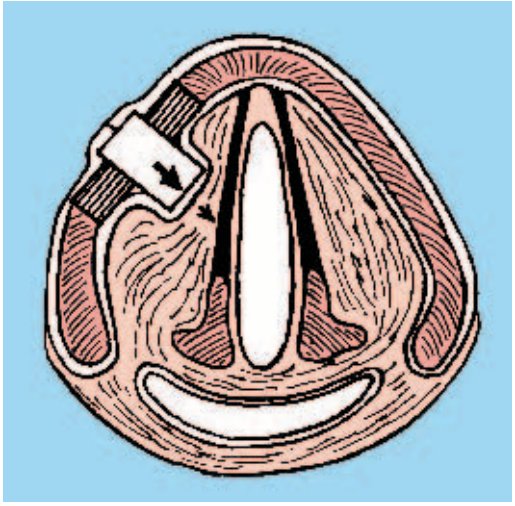

Figure 5. Horizontal view of implant in relation to the plane of the true vocal fold.

mentation should not be considered a reversible procedure and is contraindicated in patients where recovery of vocal function is likely. Complications have included migration of Teflon, granuloma formation and airway compromise. However, thyroplasty is reversible, as noted earlier, and is not absolutely contraindicated if recovery is anticipated.

Bilateral vocal fold impairment

The majority of procedures that enlarge the laryngeal airway, thus eliminating the need for a tracheotomy, also result in a voice of rather poorer quality and increase the possibility of aspiration.

Arytenoidectomy may be performed via the laryngoscope but is far from an easy procedure. However, over the last few years laser cordotomy has been introduced which results in a wedge-shaped widening of the posterior glottis caused by retraction of the divided thyroarytenoid muscle. Removal of the ipsilateral false vocal fold (vestibulectomy) may also improve exposure and facilitate the operation of cordotomy. However, the most reliable way of ensuring a satisfactory airway, albeit at the expense of a good voice, is the direct midline thyrotomy approach with subperichondral dissection or transmucosal incision. The lateral external approach described by Woodman (1953) avoids disruption of the commissure and has been well proven over the years. Both the midline and lateral methods involve placing a suture to fix the vocal process in a lateralized position at least until scarred tissue produces a more permanent fixation.

CONCLUSIONS

Voice disorders should be assessed in a multidisciplinary voice clinic with facilities for carrying out videostroboscopy and EMG studies. A clear understanding by the surgeon of the microarchitecture of the vocal fold is essential in all phonosurgical procedures. High magnification must be used in dealing with vocal fold mucosal disorders and microsurgical dissection, with technical precision, aims at maximum preservation of the vocal fold layered microstructure (lamina propria) to obtain an optimum postoperative voice which is observed as a viable fold cover.

Voice therapy has an essential part to play in the postoperative management. In the treatment of vocal fold motion impairment disorders, medialization thyroplasty (which is a reversible procedure) has an essential part to play in the management of the paralysed vocal fold when there is evidence of denervation, aspiration or severe dysphonia. Further work on reinervation techniques in this area is being carried out, but grafting cannot yet be recommended as the first choice for the paralysed vocal fold. **HM**

Figures 2–5 *are reproduced from Cummings (1993) by kind permission of Mosby Year Book, St Louis.*

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KEY POINTS

- A clear understanding by the surgeon of the microarchitecture of the vocal fold is essential in all phonosurgical procedures.
- A pliable vocal fold cover will be achieved if there is maximum preservation of the vocal folds' layered microstructure.
- Assessment of voice disorders should be carried out in a multidisciplinary voice clinic where videostroboscopy is available.
- In the management of the paralysed vocal fold Teflon augmentation should only be considered in patients with short life expectancy with severe aspiration and dysphonia.
- Medialization thryoplasty is reversible and not contraindicated if recovery is anticipated.