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**Chap. 6**

# INJECTION LARYNGOPLASTY UNDER FIBEROPTIC ENDOSCOPY

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## Abstract

Injection laryngoplasty can be performed easily under fiberoptic endoscopy. We use a flexible operative endoscope with a 2 mm working channel, into which a flexible needle is inserted. This needle is protected by a catheter and it is connected to a high-pressure gun, into which the injectable material is introduced. In our experience, this technique is usefull for the laryngeal injection of resorbable or partially resorbable materials such as hyaluronic acid, autologous fat and calcium hydroxilapatite. The main indications of this technique are vocal fold medialisation/augmentation in cases of glottic insufficiency caused by: unilateral vocal fold paralysis; atrophic vocal folds with or without vergeture (it is particularly indicated in presbyphonia); sequelae of cordectomies type III, IV, V; sequelae of partial laryngectomy. We can also obtain a decrease of the vocal fold volume (in Reinke's edema, hypertrophic vocalis muscle, androphonia) njecting Triamcinolon.
The procedure is performed under local anaesthesia, which makes it possible to monitor the effect of injection laryngoplasty on glottic closure and on patient's voice.

**Key words**: injection laryngoplasty, fiberendoscopic phonosurgery, office-based surgery, glottic insufficiency, fat injection.

Fiberendoscopic injection laryngoplasty involves a transnasal approach; it is one of the "office-based" phonosurgery techniques that can also be performed with a transoral and a transcutaneous approach (Rosen et Al., 2009).
Injection laryngoplasty is the main indication of fiberendoscopic phonosurgery (FEPS), a phonosurgery procedure that is performed under local anaesthesia using a flexible fiberendoscope, in a similar way to the other minimally-invasive procedures used in ENT endoscopy and in bronchoscopy. The FEPS technique was first proposed twenty years ago by the C.E.L.F. group of Santander (Spain) (Diaz et Al., 1999, Borragan et Al., 2002) and it was developed in Italy in Verona and Cesena (De Rossi et Al., 2008, 2009; Ricci Maccarini et Al., 2004, 2005, 2007, 2009, 2011). It is performed using a fiberoptic flexible endoscope, into which flexible instruments such as micro-forceps, micro-scissors and needles are introduced. Endoscopic needles can be used to inject into the larynx substances such as Cidofovir (for the treatment and the prevention of laryngeal papillomatosis), botulinum toxin (for the treatment of spasmodic dysphonia) and growth factors (plateletts-rich plasma, PRP) (Ricci Maccarini et Al, 2014), as well as materials that are commonly used for injection laryngoplasty. More specifically,for vocal fold augmentation/medialisation: autologous fat, long-term resorbtion hyaluronic acid (Restylane®), short-term resorbtion hyaluronic acid (Sinovial®), calcium hydroxylapatite (Radiesse Voice®) (Ricci Maccarini et Al., 2004, 2005, 2007, 2009, 2011) micronised human alloderm tissue (Cymetra®) (Trask et Al., 2005); in order to decrease the vocal fold volume the injection of a long-action steroid (Triamcinolon) is indicated (Isshiki et Al., 1974, Ricci Maccarini et Al., 2009).

## INDICATIONS

All the indications for fiberendoscopic injection laryngoplasty are:

1. **Vocal fold medialisation and augmentation in cases of vocal cord fixation due to unilateral vocal fold paralysis or blockage of the cricoarythenoid joint**

In cases such as these, phonosurgery is required when the fold is in an intermediate or in a lateral position or it is atrophic. When the vocal fold is in a paramedian position and has a straight profile, voice therapy is usually enough to obtain a complete glottic closure, improving glottic compensation by means of the normally mobile contralateral vocal fold. Two – three months after the onset of unilateral vocal fold paralysis, if voice therapy is unable to obtain a satisfactory glottic compensation and/or supraglottic compensation starts to establish (between the false vocal folds or between the mobile arythenoid and the foot of the epiglottis), there is an indication for injection laryngoplasty using resorbable material (autologous fat, slow-resorption hyaluronic acid, calcium hydroxylapatite) and the fiberendoscopic technique is the approach of election. By improving glottic closure we facilitate the speech therapist's work. When the vocal fold regains motility in the following months, the injected material will be rapidly resorbed and there will be no interference on vocal fold vibration.

Definitive procedures involving the intracordal injection of non-resorbable material such as polydimethylsiloxane (Vox Implans®) must only be performed when it is certain that the vocal fold paralysis is permanent, and it should be performed in microlaryngoscopy (Bergamini et Al., 1990, 2010, 2011), since the procedure must be very accurate.

2. **Vocal fold atrophy, with or without furrow due to a congenital lesion (vergeture) or to acquired iatrogenic scar**

In these cases, autologous fat or slow-resorption hyaluronic acid are injected into the vocalis muscle to increase its volume; fast-resorption (non-cross-linked) hyaluronic acid is injected into the superficial layer of the lamina propria (Reinke's space) to detach the adherence of the vocal fold epithelium to the vocal ligament.

3. **Vocal fold hypertrophy, Reinke's edema, androphonia**

In these cases injection laryngoplasty has the opposite aim to decrease the volume of the vocal fold, decreasing the vocal pitch. We inject Triamcinolon, a long-action steroid that causes an atrophy of the tissue into which it is injected. We use this effect in order to decrease the volume of the vocalis muscle in cases of hypertrophy caused by anabolic steroids in females or in transsexual patients male to female (Isshiki et Al., 1974, Ricci Maccarini et Al., 2009). The injection of the vocal folds has to be repeated after two-three months. We can obtain with this phonosurgery technique a decrease of 10-20 Hz of the vocal pitch. In Renke's edema we inject Triamcinolone into the superficial layer of the lamina propria in order to decrease the volume of the mixedema; recently we associate this procedure with the KTP laser application for a better result. All these procedure are performed under fiberoptic endoscopy..

4. **Glottic insufficiency secondary to cordectomy**

If the neocord is of a reduced size and glottic closure is very incomplete, two - three months after the laser cordectomy procedure, the fiberendoscopic injection of autologous fat and/or slow-resorption hyaluronic acid makes it possible to increase the neocord volume and elasticity. This procedure is indicated above all in type III (transmuscular) partial cordectomy (Remacle et Al., 2000), whereas in type IV (complete) or V (extended) cordectomy, autologous fat cannot be used because the scarred neocord does not guarantee adequate vascularisation for the implanted adipocytes. Hyaluronic acid injection is difficult because of the hard consistence of the neocord and consequently the slightest movement of the larynx results in the formation of a tear at the injection site through which the injected material extrudes. In these cases, the volume of the contralateral cord can be augmented, in order to improve glottic closure, or the microlaryngoscopic procedure under general anaesthesia can be performed, with the injection of slow-resorption hyaluronic acid, calcium hydroxylapatite or a non-resorbable material such as polydemethylsiloxane. The use of the two latter materials must be scheduled after a period that is long enough to prevent any foreign body reactions interfering with the oncological follow-up. The microlaryngoscopic technique under general anaesthesia guarantees larynx immobility, which allows a more controlled injection, in order to avoid tearing the neocord and causing leakage of the injected material.

The injection of autologous fat and/or hyaluronic acid in microlaryngoscopy can also be performed at the end of a transmuscular laser cordectomy (type 3), to obtain an increase in volume and better elasticity of the neocord, which improves glottic closure and vibration in the first few days after the cordectomy procedure (Bolzoni et Al., 2007, Ricci Maccarini et Al. 2009, Molteni et Al., 2010, Bergamini et Al., 2011).

At least two years (for oncological reasons) after a type IV or V cordectomy, it is possible to perform an external-approach neocord medialisation laryngoplasty (type I thyroplasty), which, in our experience, guarantees the best results in terms of glottic competence and of stability of the laryngeal implant over time (Magnani et Al., 2002).

**5. Combination with medialisation laryngoplasty through external approach (thyroplasty type I)**

During type I thyroplasty (Isshiki et Al., 1974) for the medialisation of a fixed cord in a lateral position or in sequelae of subperichondral total cordectomy (Magnani et Al., 2002), which for oncological reasons must be performed at least two years after the cordectomy, a diagnostic fiberendoscopy is performed. An operating fiberscope is used to remove secretions and carefully control the degree of vocal fold medialisation obtained. In the presence of significant glottic insufficiency due to cordectomy sequelae or unilateral vocal fold paralysis with bilateral vocal fold bowing, if it is not possible to obtain a satisfactory glottic closure after the thyroplasty type I, the volume of the contralateral cord can be augmented by an injection of autologous fat or slow-resorption hyaluronic acid. The material can also be injected into the vocal fold housing the thyroplasty implant, if it is unable to obtain a straight cord profile and the injection of the contralateral cord leaves an anteriorly or posteriorly incomplete glottic closure. In such cases, fiberendoscopic injection laryngoplasty can be performed either during the thyroplasty procedure or sometime later.

**6. Neoglottic insufficiency secondary to partial laryngectomy**

Following a partial laryngectomy procedure and, in particular, after reconstructive subtotal laryngectomy with cricohyoidopexy or tracheohyoidopexy, neoglottic incompetence can be accentuated during phonation and swallowing; neoglottic incompetence is almost always the consequence of unfavourable surgical sequelae (fixed or insufficiently motile residual arythenoid cartilage, reduced arythenoid volume, narrowed or scarred piriform sinuses, anteriorisation of the tongue base due to an excessively forward position of the hyoid bone in the pexy with the cricoid cartilage, pexy detachment). When even lengthy speech therapy rehabilitation does not allow adequate basic sphincter competence for safe swallowing and good voice quality, there is an indication for surgical rehabilitation: in addition to procedures with an external approach, neoglottic competence can be improved with fiberendoscopic injection laryngoplasty or microlaryngoscopy procedures (Ricci Maccarini et Al., 2007, 2011; Bergamini et Al. 2009, 2011). The latter consists in an augmentation in the residual arythenoid cartilage/s and/or of the mucosa covering the cricoid or first ring of the trachea and/or of the tongue base.

With the fiberendoscopic procedure, also in these cases we inject slow-resorption materials and, in particular, long-term resorption hyaluronic acid in the mucosa responsible for phonatory vibration (arythenoid cartilage/s), calcium hydroxylapatite in the cricoid and first tracheal ring and autologous fat in the tongue base (the only part of the neoglottis able to guarantee good vascularisation for the survival of the implanted adipocytes). Until four years ago, the material of election in these cases for the use of fiberendoscopy was heterologous or homologous collagen (Ricci Maccarini et Al., 2007), which guaranteed excellent results in that they are very similar to the tissue of the implant host site (submucosal connective tissue). Unfortunately collagen is no longer produced since dermatologists and plastic surgeons (the main users of fillers for subcutaneous and submucosal infiltration) have replaced it with hyaluronic acid.

SURGICAL AND ANAESTHESIOLOGICAL TECHNIQUE

Fiberendoscopic injection laryngoplasty is performed under local anaesthesia or assisted local anaesthesia, on day service, day surgery or ordinary in-patients, depending on their internal situation and origin. The first night after the procedure, patients who are not hospitalised must stay close to the hospital, in case complications arise involving obstruction of the glottis and breathing problems. Even when the procedure is performed under local anaesthesia with sedation administered by the surgeon, it is in any case necessary for an anaesthetist to be readily available in case problems arise during the procedure.

The procedure is performed by two practitioners, either two surgeons or a surgeon and an expert instrument nurse, who plays an active part in the intracordal injection.

The patient must be premedicated (unless contraindications exist) with intramuscular atropine half an hour before the procedure in order to reduce laryngeal secretions and the potential for vagal reflexes (bradycardia, lipothymia) as the fiberscope is introduced through the nose.

The patient is made to lie on the operating bed with his/her upper body raised 45° and administered an intravenous 1 mg infusion of Midazolam, a hypnotic sedative (unless contraindications exist), in order to reduce emotive tension and improve patient cooperation. If the injection laryngoplasty is to be performed using autologous fat, the patient is initially placed in a supine decubitus position and the infiltration of the local anaesthetic and vasoconstrictor solution administered, by means of a 20 cc syringe and a 25 gauge needle (fig.1), followed 20 minutes later by the liposuction phase. To harvest the autologous fat, we use the procedure proposed by Coleman (1997), with one difference: instead of the blunt-tip cannula with sharp side opening that is introduced into the subcutaneous tissue through a small incision in the abdominal skin, we use a 14 gauge needle (fig.1) that is inserted into the subcutaneous tissue through the lower edge of the navel.

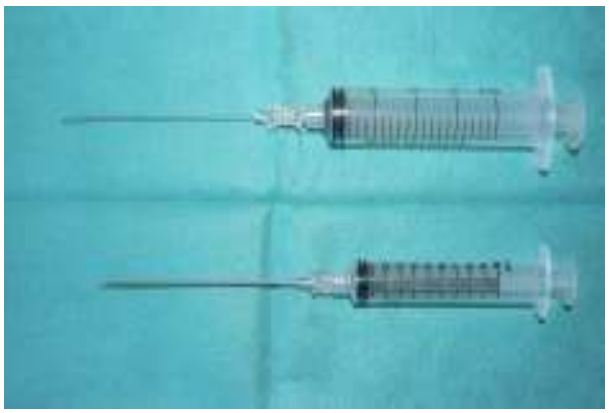

*Fig.1 Above: 25 gauge needle, 9 cm long, connected luer-lock to a 20 cc syringe, for the infiltration of anaesthetic and vasoconstrictor solution (20 cc of lidocaine 2%, 0,5 cc of adrenaline 1/1000, 3 cc of one molar watery baking soda, 70 cc of saline solution).*
*Below: 14 gauge Chiba needle, 7 cm long, connected luer-lock to a 10 cc syringe, for the lipoaspiration.*

In addition to the absence of incisions in the skin, this makes it possible to obtain a more fluid adipose tissue that slides more easily inside the long flexible needle.

The centrifugation of the lipoaspirate for 3 minutes at 3000 rpm (according to Coleman's technique) permits adipocyte concentration, separating it from the serum and the anaesthetic and vasoconstrictor solution, which are eliminated. It also concentrates the stromal stem cells present in the adipose tissue that guarantee the regeneration of the infiltrated laryngeal tissue as well as increasing its volume (Mazzola et Al., 2007). In connection with this, we recently also started using PRP (platelets-rich plasma), injected together with the autologous fat into the vocal muscle and/or

alone into the superficial layer of the lamina propria of hypotrophic and/or scarred vocal folds, a technique that is giving promising results (Woo et Al., 2014, Ricci Maccarini et Al., 2014).
At the end of the autologous fat harvesting (or from the start when using other materials such as hyaluronic acid or calcium hydroxylapatite), the patient is put in a semi-seated position, with his/her head tilted slightly backwards, to facilitate the sight of the glottis. The video column is placed by the patient's head and the two operators position themselves to the right of the patient (first surgeon) and to the left of the patient (second surgeon or instrument nurse).

**Preparing the instrument trolley**

In addition to the syringes containing the material to inject, the following are positioned on the trolley:
- a flexible operating fiberendoscope, which must be short (to facilitate manoeuvrability), with a working channel of about 2 mm (to allow the introduction of flexible endoscopic needles) and a maximum external diameter of 5 mm (to allow it to pass through the nasal cavity) (fig.2). The fiberscope must be able to be turned through 180°, without altering the position of the camera, in order to have the working channel always on the side of the vocal cord to be injected. If using a flexible digital endoscope, it must be possible to rotate the image provided by the distal chip camera.

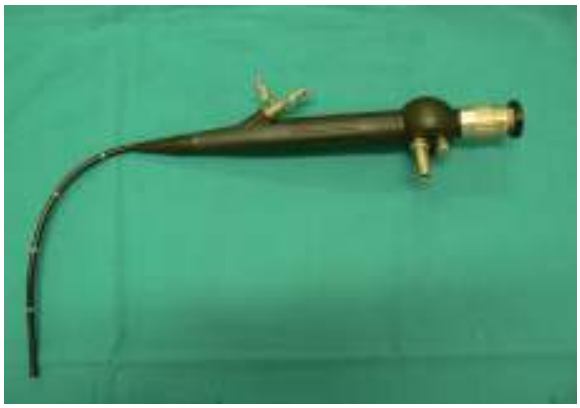

*Fig.2 Storz 11001UD1 flexible operative fiberendoscope, operating length 23 cm., external diameter 5 mm., working channel 2.3 mm.*

- a flexible endoscopic needle. We use disposable needles obtained from oesophageal varices sclerosis needles manufactured by BTC Medical Europe to our design; they are constituted by a plastic catheter whose distal extremity is fitted with a metal needle with 3 different calibres: 19 Gauge, 23 Gauge and 25 Gauge. The endoscopy needle is housed in a second plastic catheter inside which it slides; consequently, the needle can be locked with the tip protected when the flexible needle is introduced into the operating fiberscope and then locked in an extruded position to perform the laryngeal injection. It is also possible to use an Olympus endoscopic needle, which can have a 19 or 21 Gauge calibre and is contained inside a protective metal catheter. It is important to make sure the needle is retracted into the protective catheter when it is extracted through the fiberscope's working channel, to avoid damaging it. The flexible endoscopic needle can have three lengths: 60 cm, 80 cm and 100 cm (fig. 3); the Olympus needles are 105 cm long.; it is important to choose the shortest flexible needle compatible with the length of the fiberscope, to avoid wasting the material to be injected (which remains inside the needle at the end of the injection) which, in addition to being precious, can also be expensive.
Laryngeal anaesthesia is obtained with Lidocaine 2% followed by 10% (to reduce the irritating impact on the pharyngeal-laryngeal mucosa), either instilled or administered using the same flexible endoscopic needle (with the needle retracted inside the protective catheter) or with a 1,6 mm diameter resterilisable flexible catheter (BTC) .

*Fig.3 23 Gauge flexible endoscopic needle (De Rossi, Ricci-Maccarini, Borragan, by BTC Medical Europe), left: with the tip retracted into the protective catheter; right: with the tip protruding from the catheter.*

- a high-pressure injection pistol. This is a fundamental tool for fiberendoscopic injection laryngoplasty; after experiments for many years with the various commercial or newly built models, we finally succeeded in devising a pistol that obtains gradual material progression, even in the case of high densities, without the material flowing back into the syringe and that can be adapted to the position of the needle (which is particularly useful when performing microlaryngoscopic injections) (Ricci Maccarini et Al., 2009). The capacity of the syringe (3 cc) makes it particularly well-suited to intercordal injections of centrifuged autologous fat, given both the quantity and the gradual progression of the material. In this case, we modified the Uroplasty pistol usually used to inject polydimethylsiloxane (Vox Implants®), by replacing the pistol tip with a steel adaptor shaped like the tip of the piston on a 3 cc syringe. Instead of a syringe containing 1 ml of polydimethylsiloxane, we introduce a 3 cc polycarbonate disposable syringe whose plastic piston has been removed, keeping the rubber cap, which is applied to the new metal tip of the pistol piston (fig.4).

*Fig.4 Uroplasty pistol for high-pressure laryngeal injection as modified by Ricci Maccarini and De Rossi, with adapter for 3 cc polycarbonate syringe. (Ricci Maccarini et Al., 2009)*

The material to be injected is poured into the syringe contained in the pistol through a disposable plastic 3-way Luer-lock connector (fig. 5); this prevents the adipose tissue from coming into contact with the air, causing it to oxidise, which promotes a higher absorption of the material injected, therefore making it less stable over time.

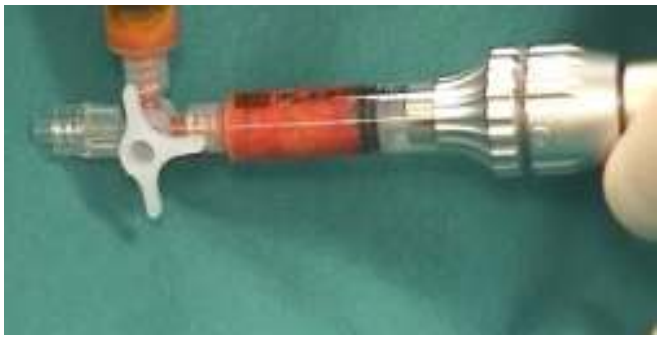

*Fig. 5 Transfer of centrifuged autologous fat into the syringe inside the high-pressure injection pistol (Ricci Maccarini and De Rossi), through a three-way luer lock connector.*

Once the instrument trolley has been prepared, 10% lidocaine is sprayed into the nasal cavities and oropharynx. The application of nose plugs soaked in anaesthetic and vasoconstrictor solution and kept in place for a few minutes before starting the surgical procedure, improves anaesthetic efficacy and nasal cavity patency, to reduce the risk of nasal mucosal tears with consequent bleeding.
The fiberscope is introduced into one nasal cavity (the most patent), aspirating the secretions through the operating canal connected to an aspirator. By means of a resterilisable catheter or protected endoscopic needle, lidocaine is applied to the base of the tongue, in the piriform sinuses, in the laryngeal vestibule and on the glottic plane; initially Lidocaine 2% or 4% is used, followed by Lidocaine 10%, in order to reduce the irritating effect on the laryngeal mucosa. To test the efficacy of the local anaesthesia, the catheter is used to touch the vocal cord to be injected: if the patient does not react and, above all, does not swallow, he can be considered ready for the intracordal injection without the risk of him swallowing during the injection, which would compromise the result obtained.
At this point, 1 mg of Midazolam i.v. is usually administered to prepare the patient for injection laryngoplasty; the dose of Midazolam can be increased to 2-3 mg as required, but this dose may not be exceeded to avoid causing a slowdown in breathing with oxygen desaturation and/or dissociation problems that would compromise patient cooperation. Not infrequently, especially in elderly patients, it is sufficient to administer one milligram of Midazolam before harvesting the autologous fat and it may be possible to avoid using Midazolam at all. If the patient complains of nausea, before nausea appears, it is advisable to administer Ondansetron Hydrochloride i.v. In some cases, on the other hand, especially in sequelae of partial laryngectomy in which neolaryngeal injection may be painful, it is necessary to be assisted by an anaesthetist who will combine opioids with the hypnotic sedative drugs (Remyfentanyl) administered by a continuous microdosing pump. This allows perfect analgesia and sedation, making it possible to perform any phonosurgery procedure with a practically immobile operating field, as achieved in microlaryngoscopy under general anaesthesia, but, at the same time, with a cooperative patient and therefore with the chance to observe the effects of augmentation and medialisation of the injected vocal fold on the patient's glottic closure and voice.
The operating fiberscope is not grasped at right angles, with the arm facing upwards, as in bronchoscopy, rather according to the indications of Borragan (Diaz, Riancho, Borragan 1999) it is held in a comfortable position with the arm stretching downwards, to avoid tiring the shoulder during lengthy procedures (fig.6). The first operator holds the fiberscope in his/her right hand and with the left controls the fiberscope's progression inside the nasal cavity, or holds it locked in place at the nostril while injecting the larynx. The second operator introduces the catheter for lidocaine instillation into the working channel, prepares the material to be injected by transferring it into the high-pressure pistol, fills the endoscopic needle with the material, inserts the needle into the working channel and, when the tip of the fiberscope is close to the injection site, extrudes the

catheter containing the needle from the working channel, extrudes the needle from the catheter and introduces it into the injection point (fig.6).

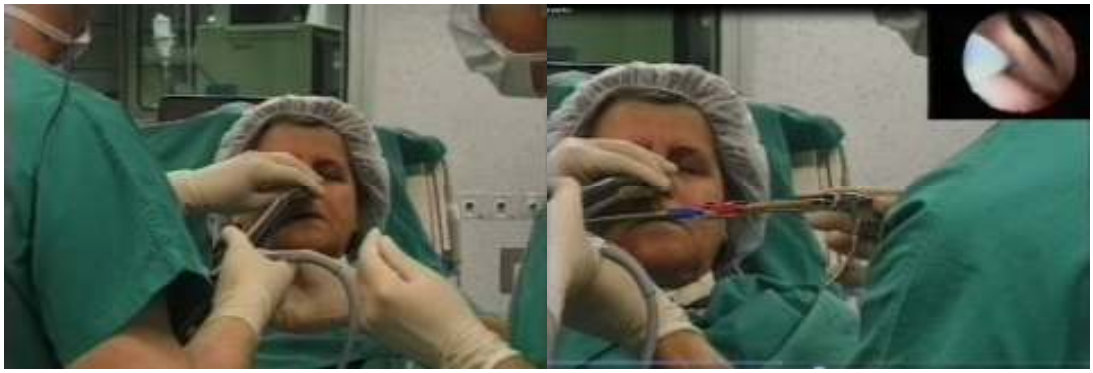

*Fig.6 Position of the operators during fiberendoscopic injection laryngoplasty. The top right-hand box shows the endoscopic picture that appears on the screen when injecting the autologous fat into the right vocal fold fixed in an intermediate position*

Otherwise, if the second operator is an instrument nurse (expert), the introduction of the needle is performed by the surgeon, who holds the fiberscope with the left hand and manoeuvres the endoscopic needle with the right. This latter technique is particularly well-suited to fiberendoscopic phonosurgery procedures involving the removal of vocal fold polyps and other small growths (De Rossi et Al., 2009).

**Technical details in the various indications for fiberendoscopic injection laryngoplasty.**

Unilateral vocal fold paralysis

As described previously, the materials used are autologous fat, slow-resorption hyaluronic acid and calcium hydroxylapatite.

For autologous fat a 19 Gauge, 21 Gauge or 23 Gauge needle is used, as use of a 25 Gauge needle causes excessive adipocyte destruction. The 19 Gauge needle should only be used when the practitioner is sure that injection will be performed in a single point, as if a subsequent adjacent injection is made, in most cases, the majority of the fat will come out of the large first injection hole.

For slow-resorption hyaluronic acid, a 25 Gauge needle is used.

For hydroxylapatite, a 23 Gauge needle is used, as the material is very dense; moreover, the endoscopic needle first has to be lubricated by introducing hyaluronic acid (even of the non-cross-linked, fast-resorption type, which is less expensive) until it comes out of the tip of the needle. At the end of the injection, to avoid wasting the expensive material left in the needle (0.5 ml of material in a flexible needle 80 cm long), more hyaluronic acid is introduced, again using the pistol.

The main injection site is the back third of the fixed vocal fold, laterally to the vocal process of the arythenoid cartilage. In addition to get an increase in volume, this manoeuvre involves a medial rotation with vocal cord adduction. The manoeuvre to be performed is as follows: once it has been positioned in the back third of the glottis, with the working channel on the side of the fixed vocal fold, the catheter containing the endoscopic needle is made to protrude and it is rested against the false vocal fold; the fiberscope is turned 90° towards the posterior commissure of the glottis, directing its tip towards the posterior paraglottic space with downward movements. The needle is made to protrude and laterally introduced into the vocal process; while the second operator injects the material, the first operator tries to displace the vocal process medially, by pressing on the tip of the fiberscope (and on the tip of the needle inserted into the vocal fold) with an upward movement (fig.5). The material is injected in excess because, as mentioned previously, fiberendoscopic injection laryngoplasty uses resorbable or partally resorbable materials and it is therefore necessary

to inject at least 1/3 more than the amount needed for normal correction. In actual fact, the injection should be interrupted when the injection site is no longer able to receive further material, to prevent the material leaking from the needle entry hole or from the previous injection hole or from moving towards other sites, such as the false vocal fold or subglottic area.
The injection must progress very gradually, to allow the material to distribute adequately in the host tissue and prevent it from leaking from the entry hole. Once the intercordal injection is complete, the needle must stay inserted into the vocal fold for about 15 seconds, to allow the material to distribute in the injection site. The needle is therefore retracted into the protective catheter and drawn back through the working channel. Once the secretions have been aspirated, a fiberendoscopy or, better still, a fiberlaryngostroboscopy is performed, to check the result obtained: glottic closure must be complete with a convex vocal fold profile and the voice must be pressed and hoarse. Very good voice quality at this moment indicates insufficient hypercorrection and therefore a few weeks later, glottic insufficiency will appear.
Usually, a single injection site is used (laterally to the vocal process) to obtain vocal fold medialisation and augmentation, as the material migrates towards the middle third of the fold. If, however, the monitoring intraoperative fiberendoscopy reveals the need, a second injection can be made in the middle third of the fixed fold, in very lateral position and preventing the leakage of material from the previous hole, or alternatively, another injection can be made in the middle third of the mobile contralateral vocal fold. Some phonosurgeons always perform bilateral intracordal injection because it favours better contact between the edges of the vocal folds, if the paralysed vocal fold is on a different level. We only use this approach when absolutely essential, as phonatory vibration is reduced in both vocal folds for several days and the patient could become so anxious as to hinder postoperative speech therapy. Breathing problems may appear in the first 24 hours, associated with severe glottic swelling, that are usually absent in the case of unilateral vocal fold injections.
Figure 7 shows the pre- and post-operative laryngostroboscope images for the patient shown in figure 6, who underwent fiberendoscopic injection laryngoplasty with autologous fat for the treatment of glottic insufficiency secondary to intermediate right vocal fold paralysis.

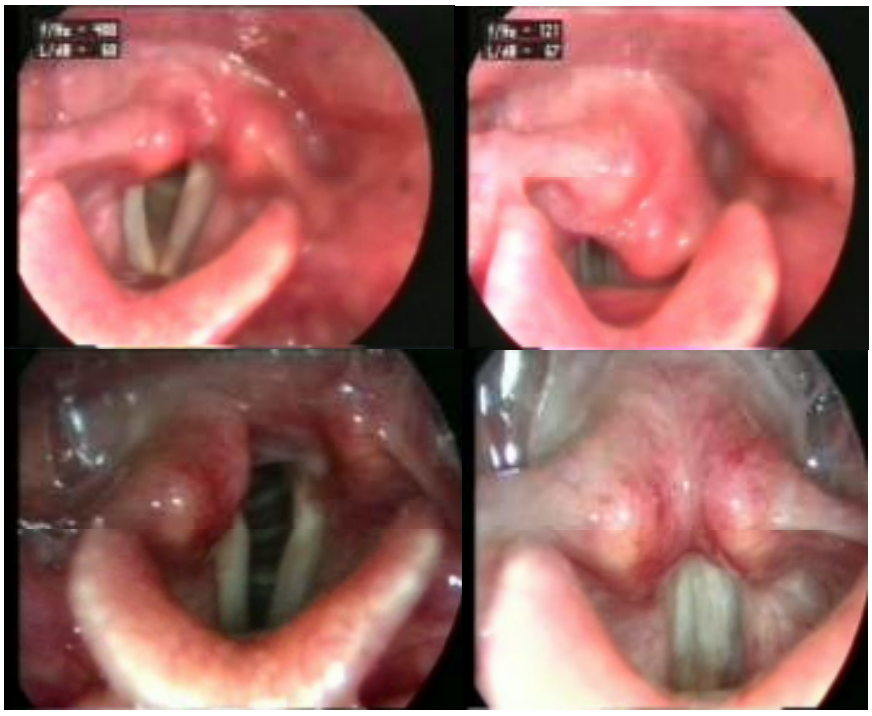

*Fig. 7 Laryngostroboscopy performed before (above) and eight months after (below) the procedure in a 63-year-old patient with glottic insufficiency secondary to thyroidectomy right vocal fold*

*paralysis, undergoing fiberendoscopic injection laryngoplasty with autologous fat. Left: respiration phase; right: glottic closure phase. The fixed vocal fold goes from an intermediate to a paramedian position and from very incomplete glottic closure it becomes complete. The result is stable over time.*

Figures 8 and 9 show images of the pre- and post-operative laryngeal endoscopy and operating endoscopy with Radiesse Voice® for the medialisation of the left vocal fold (post-thyroidectomy paralysis).

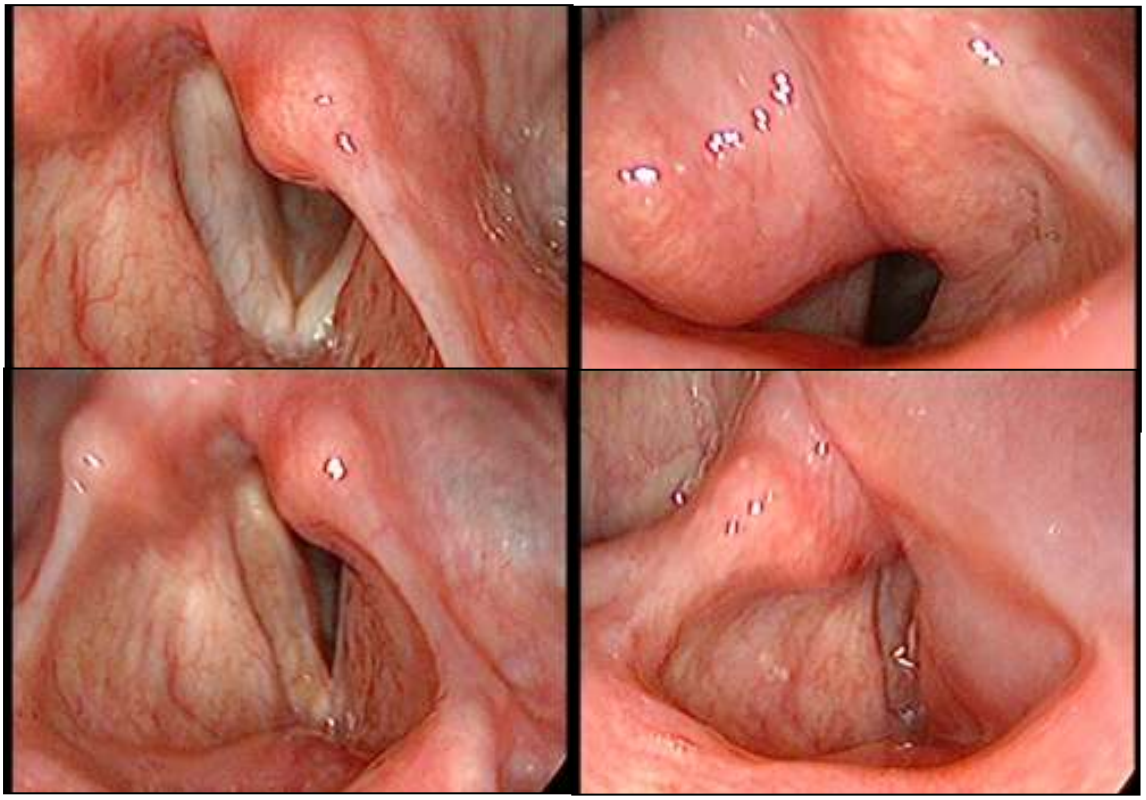

*Fig. 8 Pre-operative (above) and post-operative laryngeal endoscopy one week after fiberendoscopic injection laryngoplasty with Radiesse Voice® (below) during breathing (left) and phonation (right). The fixed vocal fold goes from a lateral to a paramedian position and from very incomplete glottic closure it becomes complete.*

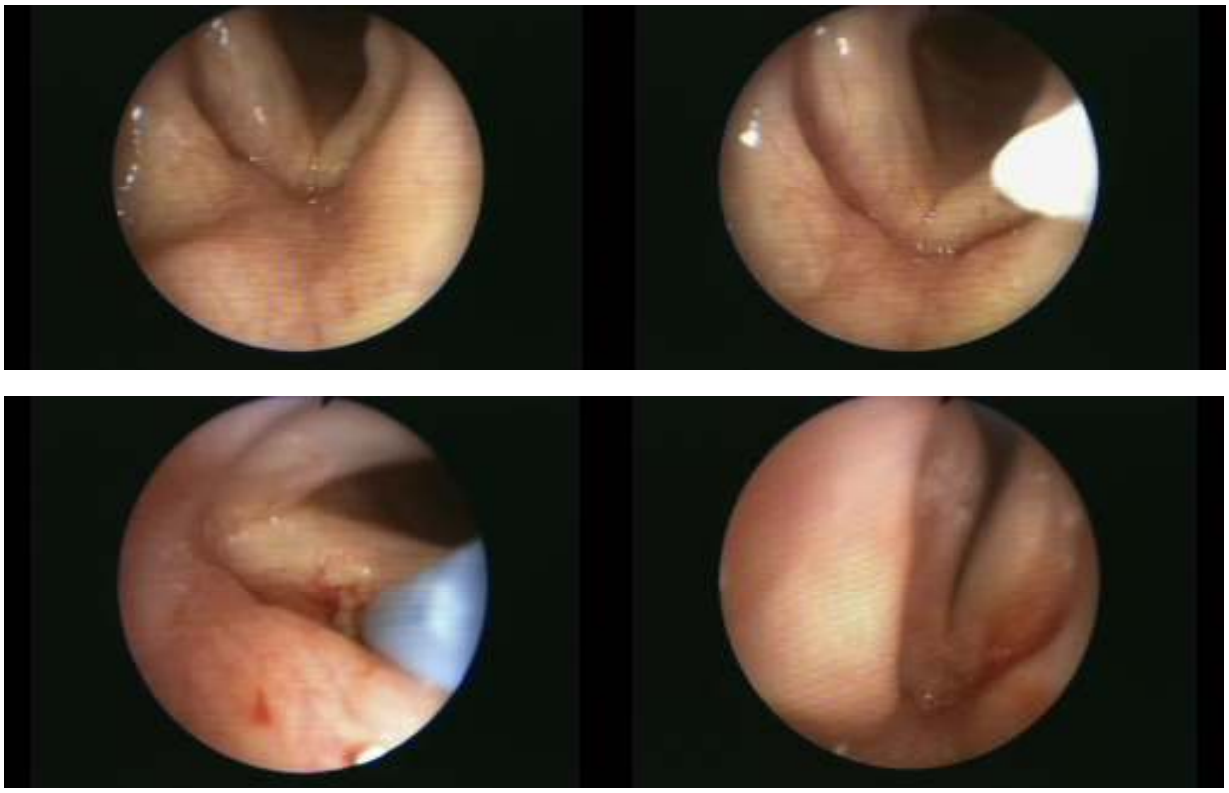

*Fig. 9 Intraoperative pictures of injection laryngoplasty with Radiesse Voice® performed on the patient with left vocal fold paralysis whose diagnostic endoscopy is shown in figure 8. Above left: pre-injection endoscopic examination; above right: the needle is protruded from the protective catheter; below left: intracordal injection of Radiesse Voice®; below right: post-injection endoscopic examination*

Vocal fold hypotrophy and hypertrophy

The procedure for the augmentation of the hypotrophic vocal fold is similar to that described for unilateral vocal fold paralysis, with the difference that the main injection site is the middle third of the vocal fold, not in the paraglottic space, but in the vocalis muscle. Once again in this case the material of election is autologous fat (optionally combined with PRP), however it is also possible to use slow-resorption hyaluronic acid or calcium hydroxylapatite (the latter must be injected into the paraglottic space to avoid stiffening the vocalis muscle). Great care must be taken to make sure that the material does not enter Reinke's space (superficial layer of the lamina propria), because this would cause a serious obstacle to the mucosal wave during phonatory vibration.

A subepithelial injection, on the other hand, is indicated when vocal fold hypotrophy is associated with a congenital (vergeture) or acquired (scar) epithelial adhesion to the vocal ligament. This detaches the adhesion by introducing a layer of lubricant material that replenishes the superficial layer of the lamina propria (which is usually rich in hyaluronic acid) and prevents the reformation of the mucosal adhesion (fig. 10). The best-suited material is fast-resorption (non-cross-linked) hyaluronic acid; we currently use Sinovial®. Subepithelial injections (into the superficial layer of the lamina propria or Reinke's space) of cross-linked hyaluronic acid hinders the vocal fold's mucosal wave and often causes swelling. Mild scarring adhesions can be effectively treated with subepithelial injection of a short-half-life corticosteroid (to avoid causing vocal muscle hypotrophy). In cases such as these (vergeture, scar, atrophy), we are currently trialling subepithelial injections of PRP, which is also injected into the atrophic vocal muscle, for the regeneration of the vocal fold, with promising results. (Ricci Maccarini et Al., 2014)

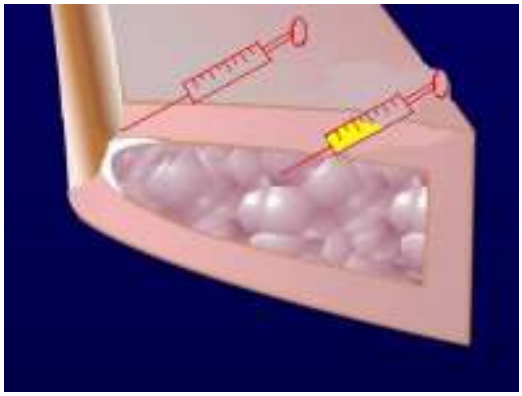

*Fig.10 Intracordal injection of autologous fat into the vocal muscle and injection of fast-resorption hyaluronic acid into the superficial layer of the lamina propria in a case of atrophic vocal fold with vergeture.*

For the treatment of the hypertrophic vocal fold the procedure is the same one just described, but we inject a long-action steroid (Triamcinolon) in order to obtain a decrease of the volume of the vocal fold. In women with low vocal pitch caused by vocal muscle hypertrophy and in androphonia we inject the middle third of the vocalis muscle: in Reinke's edema we inject Triamcinolon into the Reinke's space.

Cordectomy sequelae

As indicated previously in the "indications" section, once again, autologous fat is the material of election for this procedure: a large amount must be harvested as in most cases 4-5 cc of concentrated fat are injected into the neocord and, where necessary, in the contralateral vocal fold and/or into the false vocal folds, in an effort to solve the glottic insufficiency. If the neocord is thin and scarred, it is preferable to use slow-resorption hyaluronic acid; this makes it possible to use a 25 Gauge needle, which softens the neocord and does not require much vascularisation in the implant site (Ricci Maccarini et Al., 2011, Molteni et Al., 2010). Figures 11 and 12 show a clinical case of glottic insufficiency in a 55-year-old patient who, six months previously, had had a transmucosal partial cordectomy (type 3), in whom a fiberendoscopic injection laryngoplasty with autologous fat was performed.

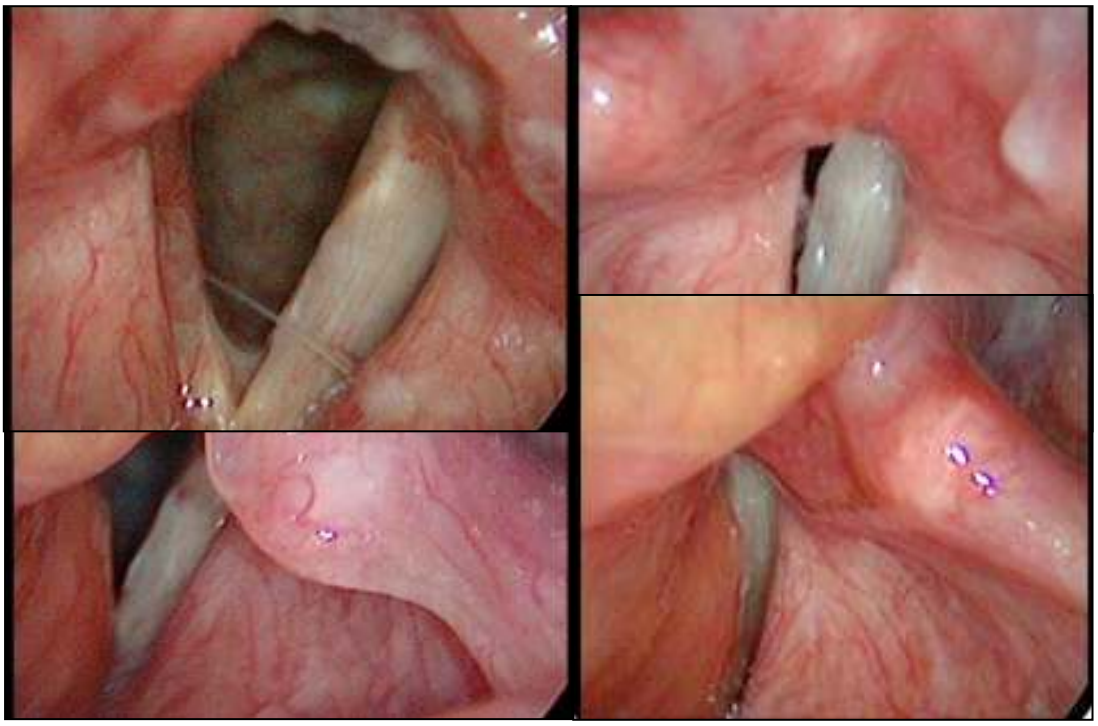

*Fig. 11 Glottic insufficiency secondary to partial cordectomy right. Pre-operative laryngostroboscopy (above) and post-operative laryngostroboscopy (below) one week after fiberendoscopic injection laryngoplasty with autologous fat during breathing (left) and phonation in the glottic closure phase (right). After the procedure, glottic closure is complete due to an increase in the volume of the right neocord and false cord.*

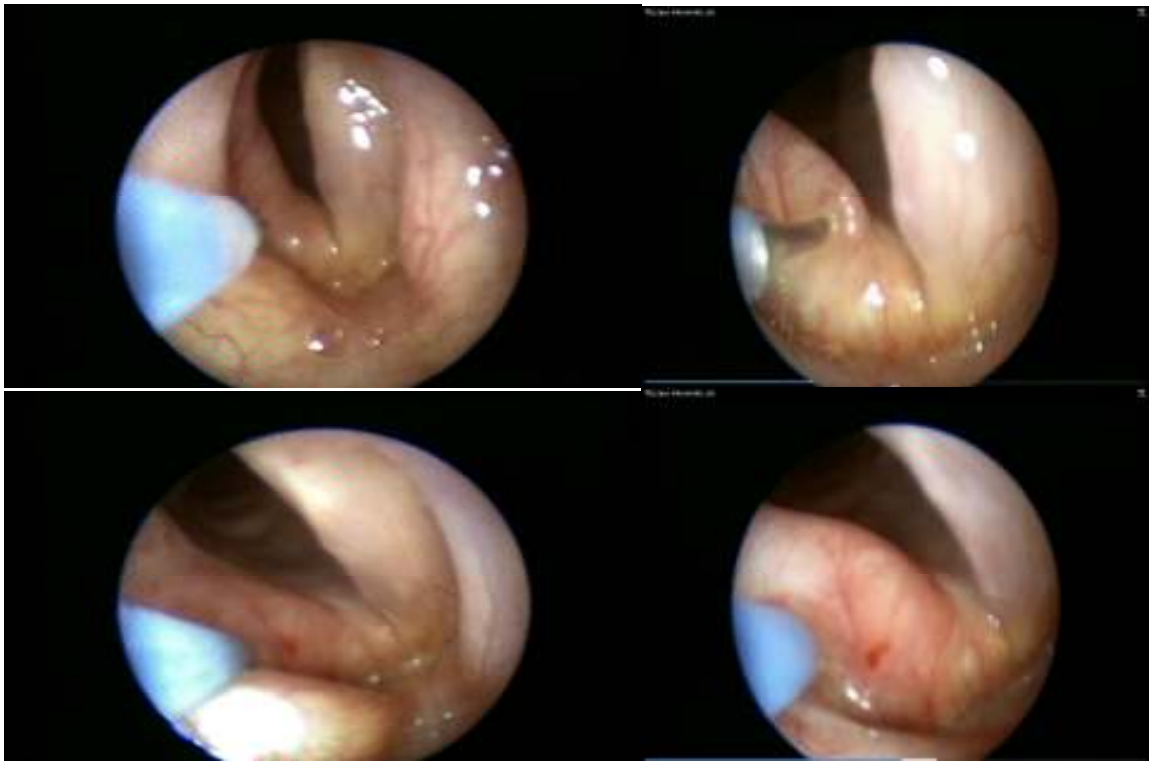

*Fig. 12 Surgical pictures of injection laryngoplasty using autologous fat in the patient with glottic insufficiency secondary to partial cordectomy right, whose diagnostic endoscopy is shown in figure 11. Above left: the catheter containing the endoscopic needle is protruded from the working channel of the fiberscope; above right: the needle is protruded from the protective catheter; below left: initial phase of fat injection into the neocord; below right: final phase of fat injection, which, as the neocord is heavily scarred and stiff, takes very little material and consequently the false vocal fold is medialised to optimise the result in phonatory terms.*

Sequelae of sub-total laryngectomy

The ideal material for fiberendoscopic injection laryngoplasty in these cases would be heterologous or homologous collagen (Zyplast®, Cosmoplast®) as it integrates perfectly with the collagen fibres of the arythenoid mucosa and scarred mucosa covering the cricoid cartilage or the first ring of the trachea (Ricci Maccarini et Al., 2007) (fig.13); as collagen is no longer available on the market, the material of election is now slow-resorption hyaluronic acid (Ricci Maccarini et Al., 2011). A 25 Gauge endoscopy needle is used, again with the high-pressure pistol. The injection points were described previously ("INDICATIONS"); if autologous fat is injected into the base of the tongue a 23 Gauge needle is used. It is advisable to perform the procedure under assisted local anaesthesia as the arythenoid and cricoid mucosa is very fragile and injection of the neolarynx can be painful; therefore the administration of opioids (Remyfentanyl) using a microdosing pump prevents patient movements that could cause a tear in the mucosa during the injection, with a consequent leakage of material. In these conditions, it is also possible to inject calcium hydroxylapatite to fill the upper

edge of the cricoid ring, using a 23 Gauge needle previously lubricated with hyaluronic acid. For the injection of polydimethylsiloxane (Vox Implants®), being a non-resorbable material, it is preferable to be performed in microlaryncoscopy under general anaesthesia (Bergamini et Al., 2009, 2011).

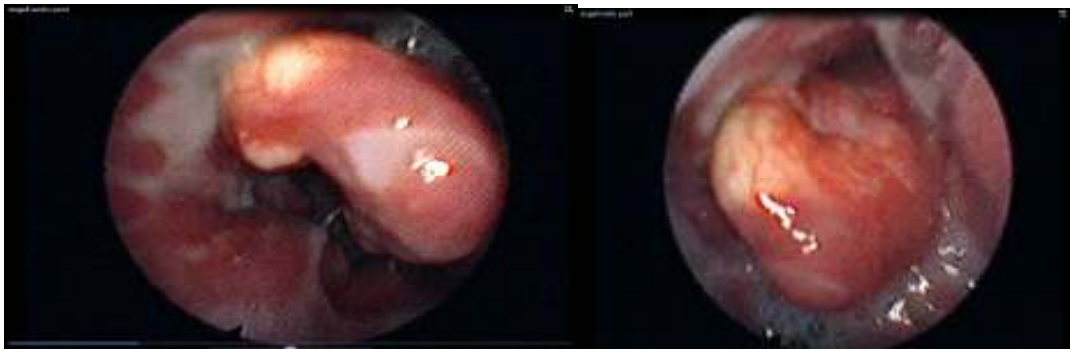

*Fig. 13 Patient with neoglottic insufficiency after reconstructive subtotal laryngectomy with tracheohyoidopexy and preservation of the left arythenoid. Above left: neoglottis during phonation, the residual arythenoid remains posteriorised with a wide neoglottic gap, aphonia and dysphagia, with stagnation of saliva in the hypopharynx and food aspiration (as seen on the transtracheostomic laryngeal fiberendoscopy) (Ricci Maccarini et Al., 2007); above right: injection of collagen into the left arythenoid and into the mucosal hood of the removed right arythenoid cartilage); below: laryngeal endoscopy during breathing (left) and phonation (right), the size of the left arythenoid is doubled and it moves forward and medially to perfectly close the neoglottis; the trans-tracheostomic laryngeal fiberendoscopy during swollowing does not show any food aspiration into the trachea.*

COMPLICATIONS

In addition to the intraoperative complications mentioned during the description of the procedure, it is necessary to mention the potential appearance of subcutaneous haematoma in the fat harvesting site, which the practitioner will attempt to avoid using ice, a compressive dressing and application of a cream containing escin for ten days. Dysphonia may appear during the first few hours from the procedure, due to the formation of glottic oedema; to prevent this from happening, at the end of the injection laryngoplasty (unless contraindicated) administer i.v. corticosteroid, which will be continued by mouth in the following 2 – 3 days. Another important precaution is the administration of antibiotics 1 – 2 hours before the procedure and for 5 days afterwards, in an attempt to avoid the appearance of bacterial infections in the fat harvesting site and in the intracordal implant site.

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