

# The CO<sub>2</sub>-laser in the treatment of laryngeal and tracheal stenosis

## Our personal experiences



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### The CO<sub>2</sub>-laser in the treatment of laryngeal and tracheal stenosis. Our personal experiences.

**AIM:** In the last twenty years, the statement of the CO<sub>2</sub> laser in laryngeal microsurgery has proved particularly useful in the surgical treatment of laryngotracheal stenosis. The Authors report their surgical experiences and discuss them considering the location, size and pathologic features of the disease. The aim of this study was to evaluate the results that may be obtained in the treatment of laryngotracheal stenosis by endoscopy using the CO<sub>2</sub> laser, and analyze the advantages and limitations of surgical methods implemented.

**MATERIAL OF STUDY:** It includes 128 patients treated from 1981 to 2016 by endoscopy using the CO<sub>2</sub> laser.

**RESULTS:** The healing occurred in 121 of the 128 patients (94.5%); in the remaining 7 cases (5.5%) - 4 subjects (3.1%) with supraglottic cicatricial stenosis and 3 patients (2.3%) with widespread laryngotracheal stenosis - it had to integrate the technique of endoscopic surgery with a traditional surgery of recovery. In particular, it has observed as follows:

*In supraglottic stenosis:*

- oedematous forms healed without difficulty, a limited number of controls (1-2) was necessary to practice and any type of stent has not been used;
- cicatricial forms required a greater number of controls (3-6) and the execution in 2 cases (1.6%) of an arytenoidectomy, we had 4 failures (3.1%) for which it had to implement a recovery surgery of traditional type;

*In glotticlipoglottic stenosis:*

- all oedematous forms healed with a number of checks less than 3, without use of stents;
- scarring forms resolved after a higher number of controls (3-6), in 4 of them (3.1%) it was necessary to practice an arytenoidectomy (associated to exeresis of 1/3 posterior ipsilateral true vocal cord) and in 4 (3.1%) had to applied an endolaryngeal guardian (in one case a Traissac stent and in 3 ones a Montgomery T-tube);

*In tracheal stenosis has occurred healing in all cases, more specifically:*

- in limited forms to the third anterior of the trachea were enough 1-2 checks and it was not necessary using stent;
- in extended forms (involvement of the 2/3 anterior and/or of the whole tracheal circumference) a higher number of controls (3-6) was necessary;
- in concentric forms, with total obstruction of the lumen, the application of endoluminal stent (3 Montgomery T-tubes and 2 tracheal cannulas of Silastic) was always necessary in addition to a number of controls superior to 7.
- In laryngotracheal spread forms, 3 failures (2.3%) recorded, in all cases, however, many controls (greater than 7) was necessary and a Montgomery T-tube was placed.

**CONCLUSIONS:** The introduction of the CO<sub>2</sub> laser in the surgical treatment of laryngotracheal stenosis has undoubtedly improved the chances of endoscopic surgery; it is currently able to offer significant advantages compared to traditional techniques (cures

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faster, less traumatic interventions, post-operative elapsed better tolerated by patients, etc.) but it is also indisputable that to ensure the success of these operations is essential a correct understanding of the size and pathologic features of the same stenosis: the data, in fact, affect the choice of surgical addresses to adopt in individual cases and the prognostic judgment.

KEY WORDS: Airway management, Airway problems, CO<sub>2</sub> laser, Direct laryngoscopy, Endoscopy, External surgical approach, Laryngotracheal stenosis, Minimally invasive surgery, Montgomery Safe T-tube, Tracheal stenosis, Tracheostomy

## Introduction

The term laryngotracheal stenosis refers to a large group of pathological condition affecting the laryngeal and tracheal tissues that can cause severe patient morbidity due

to airway obstruction and related breathing impairment with respiratory distress<sup>1,2</sup>.

In 2015 the consensus paper of the European Laryngological Society proposed a five-step endoscopic airway assessment and a standardized reporting system

TABLE I - Laryngotracheal stenosis: clinical diagnosis and surgical treatment

Site	Pathological characteristics	Etiopathogenesis	Type of operation
Supraglottic	Edematous forms	<ul style="list-style-type: none"> <li>– Lymphatic stasis consequent to supraglottic laryngectomy</li> <li>– Late effects of inflammation in specific and unspecific forms</li> <li>– Interventions of neck dissection</li> <li>– Radiotherapy</li> <li>– Cervical trauma</li> </ul>	<ul style="list-style-type: none"> <li>– Vaporization</li> <li>– Excision of affected mucosa by edema in extended forms</li> </ul>
	Scarring forms	<ul style="list-style-type: none"> <li>– Ingestion of caustic substances</li> <li>– Specific and aspecific inflammation</li> <li>– Prolonged intubations</li> <li>– Interventions of supraglottic laryngectomy in the case of extended excision to the posterior commissure, of associated inflammatory reactions or complications (mistakes during the reconstruction phase, laryngeal paralysis, ankylosis of the cricoarytenoid joints)</li> </ul>	<ul style="list-style-type: none"> <li>– Vaporization</li> <li>– Removal of scarring tissue and sometimes and bone or cartilaginous fragments</li> </ul>
Glottic/subglottic	Edematous forms	<ul style="list-style-type: none"> <li>– Reinke's edema related to vocal abuse and improper voice setting</li> </ul>	<ul style="list-style-type: none"> <li>– Removal of the exuberant mucosa</li> </ul>
	Scarring forms	<ul style="list-style-type: none"> <li>– Excision of tumour localized in correspondence of anterior commissure or performed with incorrect technique</li> <li>– Locoregional trauma</li> </ul>	<ul style="list-style-type: none"> <li>– Vaporization</li> <li>– Attachment of endolaryngeal guardians (Traissac stent, Montgomery T-tube)</li> <li>– Aritenoidectomy with removal of the 1/3 posterior ipsilateral true vocal cord (in case of vocal fold immobility)</li> </ul>
Tracheal	Scarring forms	<ul style="list-style-type: none"> <li>– Cervical trauma</li> <li>– Tracheotomy performed with incorrect technique</li> <li>– Granulomas or scarring diaphragms secondary to tracheotomic tube or prolonged intubation</li> </ul>	<ul style="list-style-type: none"> <li>– Easy removal of scarring tissue if the lesion affects the anterior third of the trachea</li> <li>– Removal of scarring tissue with applying endotracheal guardian, if it interests the 2/3 of the tracheal circumference or extends to its posterior wall.</li> </ul>
Laryngotracheal	Scarring forms	<ul style="list-style-type: none"> <li>– Subsequent to partial laryngectomies or complex interventions on skeleton laryngotracheal</li> <li>– Cervical trauma</li> <li>– Fracture of Skeletal structures</li> </ul>	<ul style="list-style-type: none"> <li>– Removal of scars or Granulations</li> </ul>

to better differentiate fresh incipient from mature scarring laryngotracheal stenosis, simple one-level from complex multilevel and finally “healthy” from “severely morbid” patient. A scoring system integrating all these clinical parameters has been shown very useful in classifying the different types of laryngotracheal stenosis in order to choose the best treatment modality<sup>3</sup> that includes a wide range of endoscopic and open techniques, as laryngotracheal resection with anastomosis and laryngotracheal reconstruction with expansion grafting/augmentation<sup>4,9</sup>, that are really difficult to compare since the specific type of operation varies by surgeons, both between institutions and within the same institution<sup>10-12</sup>.

The introduction of the CO<sub>2</sub> laser for the endoscopic treatment of laryngotracheal stenosis was first proposed by Strong et al<sup>13</sup> in 1979 who reported a complete recovery in 78% of their 23 patients. Subsequently different successful rates, ranging from 57% to 84% and related to different topographical and morphological features of the stenosis, are described in other clinical series<sup>1,2,5,14,15</sup>.

In our Institute a wide range of laryngotracheal stenosis were treated by the CO<sub>2</sub> laser over these years<sup>15-17</sup> and the various issues related to this treatment were discussed in many reports, underlining the necessity to plan the surgical procedure according to the following anatomical and clinicopathological parameters (Table I):

- a) site of the stenosis in the laryngotracheal tract and its extension;
- b) relative anatomy and pathologic features;
- c) pathogenesis.

In our retrospective study the experiences over these years to treat acquired laryngotracheal stenosis using the CO<sub>2</sub> laser are reported, mainly evaluating:

- the preferred surgical techniques to choose according to the site, anatomy and pathological characteristics of the stenosis;
- the results obtained in the treatment of various types of stenosis;
- the advantages and the limits of the techniques employed.

## Materials and Methods

A clinical series of 128 patients (83 men and 45 women, age ranging 23-78 ys, mean age 45 ys) with acquired laryngotracheal stenosis underwent surgery from 1981 to 2016 at the ENT Department of the University “Federico II” of Naples by endoscopic procedure using CO<sub>2</sub> laser focused in the super pulse mode and a power of 10-12 W, connected to an operative microscope with a 400 mm focus lens and a magnification of 16-24. Of these patients, 27 subjects were previously tracheotomized (21.1%) for a supraglottic stenosis in 5 of them

TABLE II - Results

Site	Cases N°	Anatomopathological characteristics	Controls N°			Stent		Success	Unsuccess
			1-2	3-6	>7	Traissac	Montgomery		
Supraglottic	50 (39%)	Edematous 38 (29,6%)	38 (29,6%)	-	-	-	-	38 (29,6%)	-
		Cicatricial 12 (9,3%)	-	12 (9,3%)	-	-	-	6 (6,2%)	4 (3,1%)
Glottic/ subglottic	50 (39%)	Edematous 23 (17,9%)	13 (10,1%)	-	-	-	-	23 (17,9%)	-
		Cicatricial 27 (21%)	-	27 (21%)	-	1 (0,8%)	3 (2,3%)	27 (21%)	-
Tracheal	11 (8,5%)	Cicatricial 2 (1,5%) 1/3 ant	2 (1,5%)	-	-	-	-	2 (1,5%)	-
		Cicatricial 4 (3,1%) 2/3 ant	-	4 (3,1%)	-	-	-	4 (3,1%)	-
		Extensive cicatricial 5 (3,9%)	-	-	5 (3,9%)	-	5* (3,9%)	5 (3,9%)	-
Laryngo-tracheal	17 (13,5%)	Extensive cicatricial 17 (13,5%)	-	-	17 (13,5%)	-	17 (13,5%)	14 (11%)	3 (2,5%)
Total	128 (100%)	128 (100%)	53 (41,4%)	43 (33,5%)	22 (17,1%)	1 (0,8%)	25 (19,5%)	121 (94,5%)	7 (5,5%)

\* in 2 cases used a tracheotomy Silastic cannula

(18.5%), a tracheal stenosis in other 5 (18.5%) and a complex laryngotracheal stenosis in the remaining 17 (63%).

Acquired laryngotracheal stenosis was a consequence of trauma from intubation or prolonged intubation, infections, surgical outcomes or tracheostomy. Only patients with "mature" scarring stenosis corresponding to well-established airway narrowing were included in the study. The pre- and post- therapy assessment of the patients' respiratory conditions was documented by evaluation of stridor, physical ability (stairs climbing) and lung function testing (including flow-volume loops and determination of peak expiratory and inspiratory flows).

To differentiate a simple intrinsic stenosis with intact laryngotracheal framework (suitable of endoscopic treatment) from a concentric stenosis involving all the wall with laryngotracheal framework deformity or collapse (generally requiring an open surgical procedure) a thin slices CT-scan of the larynx and trachea was made.

According to the anatomical site, stenosis was classified as:

- supraglottic
- glottic-subglottic
- tracheal
- laryngotracheal

In our clinical series the stenosis was localized (Table II):

- in 50 cases (39%) in the supraglottic region: 38 patients had oedematous forms (29.6%), with involvement of the interarytenoid area in 7 (5.4%), whereas in the remaining 12 patients a scarring stenosis (9.3%) was evident, with extension to the posterior commissure in 10 of them (7.8%) had an extension to the posterior commissure and fixed true vocal cords in the remaining 2 patients (1.5%);

- in 50 patients (39%) in the glottic or hypoglottic area: 23 oedematous forms (17,9%) with involvement of the anterior commissure; 27 scarring lesions (21%), with involvement of the anterior commissure in 20 patients (15.6%), fixed true vocal cords in 4 cases (3.1%) and limited glottic adhesions, without commissure involvement, in the remaining 3 patients (2.3%);

- in 11 cases (8.5%) in the trachea and in 17 patients (13.5%) the whole laryngotracheal tract was included. All the stenoses were scarring forms, involving the third anterior tracheal wall in 2 patients (1.5%), extended to the 2/3 anterior of the tracheal wall in 4 cases (3.1%) and with a concentric spread to the entire trachea in the remaining 5 subjects (3.9%). In the laryngotracheal forms, both larynx and trachea were diffusely involved by the scarring process, with total subversion of the related anatomical structures.

Clinical and pathological data of all the patients were discussed in a multispecialty board composed by otolaryngologists, thoracic surgeons, pneumologists and anesthesiologists in order to plan the best surgical option, since the endoscopic surgical techniques with the use of the CO<sub>2</sub> laser varied according to extension, site and pathologic features of the stenosis.

It must be underlined that precise information on the site, grade and cranio-caudal extent of the stenosis are indispensable elements to plan an accurate surgical procedure. Under general anesthesia the larynx was visualized using a laryngoscope or a tracheoscope to assess the exact location of the stenosis using an 8-mm telescope inserted into the endoscope and advanced until the stenosis level. Using a suction tube previously marked the upper and lower margins of the stenosis were recorded, either its distance from the tracheal stoma and carina.

Video recordings with an HD-digital camera connected to the endoscope were routinely done to choose the best surgical option for each individual patient and to perform an accurate follow-up.

The grade of the stenosis was measured by passing different sizes telescopes or endotracheal tubes through the stricture. Myer-Cotton Airway Grading System is routinely used: Grade I refer to less than 50% of airway obstruction, Grade II to 51-70 %, Grade III to 71-99 %, Grade IV to no detectable lumen<sup>3</sup>.

The preoperative assessment of the patient included esophagoscopy and inspection of the lower airway through a flexible broncho fiberscope.

## SURGICAL PROCEDURES

### *Supraglottic stenosis*

Supraglottic stenosis were divided in oedematous and scarring forms. The CO<sub>2</sub> laser treatment for oedematous type involved the vaporization of the affected mucosa in limited forms or, in more extended lesions, the removal of the whole segment of oedematous mucosa, taking care to avoiding damage to the interarytenoid region. In scarring stenosis, cicatricial bridles localized on the lateral walls of the laryngeal vestibule were removed by cutting or steaming at the base, and vaporizing the areas affected by reactive oedema. Bone or cartilage fragments that may be dislocated for traumatic accident thus favouring a further reduction of the respiratory space were always removed with the scarring tissue. Always keep in mind that the respect of the posterior commissure is imperative, therefore when this laryngeal region is involved by the stenosis a careful endoscopic follow up in the postoperative period is mandatory in order to remove fibrin clots potentially leading to relapse. In case of a fixed arytenoid (one or both sides) due to ankyloses of the cricoarytenoid joint for scarring or neural damage a unilateral arytenoidectomy was performed to enlarge the respiratory space.

In the immediate postoperative period repeated endoscopic examinations were planned every 4-7 days (their frequency and number depending on the extension of the stenosis, the surgical involved area and individual reactive habits) in order to remove fibrin clots thus preventing the occurrence of scarring stenosis. Healing process was generally ultimate in 30-40 days, but some

patients needed even 2-3 months from surgery to recover and repeated controls over the time.

In massive stenosis where large tracts of the mucosa had to be removed and the risk of recurrence was much higher, the insertion of an endolaryngeal stent (Traissac stent, Montgomery's silicon T-tube) was mandatory: the device was left in situ for 1-6 months in order to guide healing process and prevent possible recurrences. On our experience the Traissac stent, a silastic device, self-maintaining for the two lateral flaps located within the ventricles of Morgagni, has been demonstrated to be a valid tool for the treatment of laryngeal vestibule stenosis where no involvement of anatomical structures impairing laryngeal elevation was present. The Montgomery T-tube was advisable in more extensive stenosis, primarily those involving the laryngeal aditus, even though some problems in the early postoperative days occurred. In fact, the tracheobronchial expectorate was abundant, dense and congealing in crusts, easily occluding the Montgomery's tube with the risk of severe dyspnea: in these cases, it was advisable to introduce a tracheal metal cannula, provided of a removable inner cannula, in the horizontal and in the descending branches of the stent, thus allowing aspiration of bronchial secretions or removing mucous plugs. The metallic cannula was removed once the tracheobronchial secretion was reduced and fluidized.

Whenever a laryngeal stent had to be kept in situ for longer periods, endoscopic excision of granulations occurred under the stent surface was performed every 30-40 days, temporarily removing the device during the surgical procedure and evaluating the healing process and correct placement of the stent.

#### *Glottic and/or subglottic stenosis*

As in supraglottic stenosis, we distinguish oedematous and scarring forms. The first ones were generally due to massive Reinke's oedema or excision of larger lesions and their treatment involved the removal of the exuberant mucosa and oedema, avoiding injury to the underlying lamina propria and/or excision of large tracts of mucosa, in order to prevent the occurrence of scars of mucosa of vocal folds, with evident functional damage due to impairment of the undulating mucosal wave. The mucosa of the vocal cord near to the anterior commissure must be carefully preserved in Reinke's oedema CO<sub>2</sub> laser surgery to prevent the occurrence of fastidious synechia. When not possible, as in case of dyskeratosis or dysplastic lesions, repeated endoscopic controls in the immediate postoperative period were performed to remove fibrin clots and evaluating the healing process. Scarring stenosis as true vocal cords diaphragm or synechia were simply vaporized, whereas, in more extended lesions involving the hypoglottis or the trachea the correct treatment required, after the widening of the breathing space, the insertion of endo-

laryngeal stents, generally a Montgomery T-tube when the stenosis affected the interarytenoid area or larger laryngeal areas. Since this stent often needed to be kept in situ for several months, the previous described metal cannula provided of a removable inner one was used to avoid lumen obstruction by mucous plugs. Even in these cases endoscopic excision of granulations occurred under the stent surface was performed every 30-40 days, with the same surgical procedure described for supraglottic scarring stenosis.

#### *Tracheal stenosis*

The site and the extent of the scarring stenosis influenced the choice of the surgical technique. In case of limited involvement of the anterior half of the trachea, removal of scarring tissue and accurate postoperative endoscopic surveillance to remove deposits of fibrin was an adequate procedure. Scarring lesions affected the two thirds of the tracheal circumference or extended to the posterior tracheal fibrous wall were more troublesome, requiring, after removal of the stenosis, the insertion of a soft plastic or Silastic cannula when the stenosis was located below the tracheostomy, whereas the silicon Montgomery T-tube was the ideal stent when the scarring lesion involved the tracheal area of the tracheostomy or that one immediately above or in case of very wide tracheostomy that required the removal of an extended part of the tracheal wall. In the last condition the use of the T-tube of Montgomery favours the gradual reduction of the stoma size, without scarring stenosis, and ensures the persistent patency of the lumen above and below the stoma itself.

#### *Diffuse laryngotracheal stenosis*

These lesions were very difficult to treat because of the total subversion of the normal laryngeal anatomy and the absolute lack of anatomical landmarks. Both the laryngoscope and the tracheoscope were necessary instruments for a correct surgical procedure to visualize the affected tracheal areas and create a new laryngotracheal cavity where to insert the Montgomery's T-tube, maintained in situ for a relatively long period of time (2-8 months) to allow healing and patency of the new respiratory space.

### **Results**

Our results are summarized in Table III and were presented according to the topographical classification of stenosis and anatomopathological characteristics of lesions, the number of endoscopic controls and evaluation of failures.

## A) RESULTS IN RELATION TO THE TOPOGRAPHICAL CLASSIFICATION OF STENOSIS AND ANATOMO-PATHOLOGICAL CHARACTERISTICS OF LESIONS

### *Supraglottic stenosis*

The oedematous forms were all successfully treated (38 cases) without need of stent insertion and with a limited number of postoperative controls. The scarring forms were resolved in 8 cases, whereas in 2 of them an arytenoidectomy was necessary. In the remaining patients (4 cases) traditional open surgery was necessary.

### *Glottic-ipoglottic stenosis*

In the oedematous forms the CO<sub>2</sub> laser surgery was completely successful. In the scarring forms a complete resolution was obtained but the insertion of a stent (1 prosthesis of Traissac and 3 tubes of Montgomery) in 4 cases and the performance of an arytenoidectomy in other 4 patients were necessary and more postoperative endoscopic controls were required in comparison to the oedematous lesions.

### *Tracheal stenosis*

The CO<sub>2</sub> laser surgery allowed a complete recovery in the scarring forms involving the third or two-thirds anterior of the trachea, without requiring stent insertion, and the number of postoperative endoscopic controls was obviously proportional to the severity of the stenosis. In the all previously tracheotomised patients with extensive scarring forms resolution of the stenosis was obtained but insertion of the endolaryngeal stent to prevent recurrences and a higher number of postoperative controls were indispensable.

### *Laryngotracheal stenosis*

Extension of the stenosis and the characteristics of scarring made these lesions very difficult to treat in our patients, who were all previously tracheotomised, and the stent insertion stent (Montgomery T-tube) was always necessary as numerous repeated postoperative endoscopic controls. Satisfactory healing occurred in 94,5% of the cases.

## B) RESULTS ACCORDING TO THE NUMBER OF ENDOSCOPIC CONTROLS

The 128 patients treated were divided into three groups according to the number of postoperative endoscopic controls that were remarkably indicative of the complexity of the surgery performed and the troubles occurred after the surgical procedure. It is noteworthy that: 1) in Group A, composed by 63 cases (44,9%), remo-

val of fibrin clots was performed during the first or second endoscopic controls and complete healing occurred without need of stent insertion. In this group 38 patient (29,6%) had supraglottic oedematous stenosis, 23 (17,9%) glottic oedematous stenosis and the remaining 2 (1,5%) were affected by a stenosis involving the anterior third of the tracheal wall;

2) in Group B, composed by 43 patients (33,5%), 3-6 endoscopic controls were performed. The patients of this group were affected by:

- supraglottic scarring stenosis in 12 cases (9,3%) and two of them (1,5%) needed unilateral arytenoidectomy while in the remaining four (3,1%) the laser surgery was unsuccessful;

- glottic scarring stenosis in 27 patients (21%) and an endolaryngeal stent (1 prosthesis of Traissac and 3 tubes of Montgomery) was inserted in 4 of them (3,1%), whereas in 4 cases (3,1%) a unilateral arytenoidectomy with removal of the posterior third of the ipsilateral true vocal cord was done to ensure a sufficient breathing space;

- tracheal stenosis involving the two anterior thirds of the tracheal wall in 4 cases (3,1%).

3) in Group C, composed by 22 patients (17,2%), more than 7 postoperative endoscopic controls were necessary and an endolaryngeal stent was always inserted, more precisely, three Montgomery tubes and two Silastic canulas in 5 cases (3,9%) of tracheal concentric stenosis, and only Montgomery's tubes in 17 subjects (13,5%) with diffuse laryngotracheal stenosis, even though in 3 of them (2,5%) there was a failure of the procedure.

## C) EVALUATION OF FAILURES

CO<sub>2</sub> laser surgery was a successful procedure in 121 of the 128 patients treated (94,5%), whereas in the remaining 7 subjects (5,5%) the failure of the endoscopic surgery to definitively widen the respiratory space made them to recur to traditional open surgery. Of the unsuccessful patients 4 of them (3,1%) were affected by a severe supraglottic scarring stenosis that required a traditional open supraglottic laryngectomy (in 3 cases the open surgery was performed in others surgical institutes), whereas only 1 (0,8%) of the remaining 3 patients (2,3%), affected by diffuse laryngotracheal stenosis, accepted to undergo resection of the stenotic tract and subsequent anastomosis of the tracheal stump and removal of the tracheostomy once healed, refusing the other two tracheotomised patients (1,5%) any further surgery.

## Discussion

In the clinical approach and in the choice of the idoneous treatment for laryngotracheal stenosis many diagnostic and prognostic aspects are to be faced<sup>1,2,18</sup>, mainly related to the various therapeutic options pro-

posed in literature and their results, often uncertain, especially for the more severe forms<sup>3,6,7,12,18</sup>. The introduction of the CO<sub>2</sub> laser in the surgical treatment of these troublesome lesions has been demonstrated to have significant advantages (minor tissue trauma, reduced pain, shorter hospital stay, etc.) opening new therapeutic perspectives, but, at the same time, a revision of the clinical classification and the diagnostic criteria was necessary to plan the better surgical procedure according to the anatomopathological form of stenosis<sup>2,3,5,8,9,10</sup>.

An accurate preliminary investigation on the morphological and topographical characteristics of the disease is mandatory since it remarkably contributes to a proper surgical planning, thus reducing potential fastidious inconveniences during the procedure.

Video endoscopy, microlaryngoscopy, CT and MRI are the diagnostic examinations most commonly used in the study of laryngotracheal stenosis since they allow to assess the morphological characteristics of the stenosis, the entity of the involvement of the various laryngeal structures affected and the disorders of the laryngeal motility resulting from skeletal and neuro-muscular impairment<sup>3,18</sup>.

According to the data of literature the choice of the surgical procedure more suitable of a better prognosis is generally related to the severity of the stenosis, i.e. the anatomical structures affected, the localization at various levels of the laryngotracheal tube (supraglottic, glottic, hypoglottic, tracheal etc.) and its extension in length. Undoubtedly, these are very important information, but on our opinion, other clinical aspects must be preoperatively investigated, mainly, the histopathological characteristics of the stenotic tissue (oedematous and hyperplastic forms are usually easily removed with successful definitive results, whereas scarring forms are a hard task to face, especially for the high rate of recurrence) and the location of the stenosis on the horizontal plane (lateral, anterior, posterior, widespread) which is, according to our experience, a fundamental parameter in the surgery planning by CO<sub>2</sub> laser. In fact:

- 1) in the stenosis involving the lateral walls of the larynx without distortion of the anterior corner or the posterior commissure, as in the supraglottic or glottic stenosis due to oedema or scarring, the surgical step generally consists in the simple removal of the stenosis, eventually associated to a unilateral arytenoidectomy, without requiring further endoscopic surgery;
- 2) if the stenosis involves the anterior corner of the larynx (scarring glottic or hypoglottic stenosis) or the anterior wall of the trachea (scarring tracheal stenosis), the excision by CO<sub>2</sub> laser of the scar tissue is not quite difficult, but repeated postoperative microlaryngoscopic evaluation are mandatory to control the healing process and to remove the fibrin clots that are the main causes of recurrence;
- 3) in the stenosis involving the posterior commissure or the posterior part of the trachea and in concentric forms

(undoubtedly the most serious lesions because of their involvement of large areas of the laryngotracheal tract), the severe alterations of the anatomical structures and the absence of precise anatomic landmarks make the surgical excision by CO<sub>2</sub> laser extremely difficult, especially when a true vocal cord paralysis in adduction, due to ankyloses of the crico-arytenoid joints or recurrent nerves damage, is associated. In these cases, when the stenosis is complex for its localization and its features, the long-lasting permanence of a stent in the recreated cavity is indispensable, generally a Montgomery's T-tube, which will guide the healing process, remodelling the laryngotracheal cavity and preventing relapses. Even though the difficulties of the procedure and the need of repeated postoperative endoscopic controls, we strongly support the use of the CO<sub>2</sub> in these stenotic forms because of its significant advantages compared to the traditional open techniques that consist in the removal of the stenosis and the anastomosis of the two stumps, a surgery requiring mobilization of the tracheal portions with intrathoracic manoeuvres potentially dangerous for the patient, especially if his general conditions are poor. It is to be underlined that the anastomosis is not always easily feasible if the stenosis extensively involves the laryngeal lumen and plastic reconstructive surgery are very often extremely complex procedures.

Therefore, open surgery should be reserved only when endoscopic methods were unsuccessful, and the patient is clinically suitable to undergone open surgery.

## Conclusions

The use of CO<sub>2</sub> laser in the surgical treatment of laryngotracheal stenosis is a valid advantageous alternative to the traditional open techniques. Its field of application and the achievable results must be always evaluated taking carefully into account the site and the extent of the stenosis, nonetheless, the morphological characteristics of the pathological process responsible of the stenosis occurrence.

According to our surgical findings the laryngotracheal stenosis can be distinguished in:

- stenosis from oedematous reactions in supraglottic and glottic site, where the surgical procedure is easy to accomplish, the hospital stay is short and successful results are expected;
- scarring stenosis, that are more troublesome lesions to be treated endoscopically, especially for the lesions involving the anterior corner of the larynx or the anterior tracheal wall whose surgical success is remarkably related to repeated postoperative endoscopic controls for the removal of fibrin clots favouring recurrence of the disease;
- more complex stenosis, involving the posterior commissure or the posterior wall of the trachea or in diffuse lesions, that represents a hard-surgical task for the complete anatomic subversion and the lack of landmarks.

In these cases, an associated unilateral arytenoidectomy and the insertion of an endolaryngeal stent (Traissac stent, Montgomery's T-tubes) to be maintained in situ for long time are often required. Even though prolonged hospital stay and frequent postoperative endoscopic controls are mandatory in these patients, however, this type of surgery is less traumatic if compared with the open traditional surgical techniques requiring large tracheal resection and plastic reconstruction when the anastomosis between the tracheal stumps is not feasible, with unavoidable risk of severe complications due to the intrathoracic approach.

The main limit of the CO<sub>2</sub> laser endoscopic surgical technique is related to the approach to the stenosis, which is faced by the surgeon progressing from the top to the bottom, thus preventing a complete vision of the areas involved. prevents him to have an overview of the pathological events responsible for stenosis themselves. Very often an extension greater than assumed is detected during surgery and more complex treatment are therefore required.

These are the reasons why it is of fundamental importance in the planning of laryngotracheal stenosis surgery an accurate preoperative examination of the patient, also including imaging techniques, to better assess the characteristics of the pathological process, especially its extension in height, thus allowing the choice of the optimal procedure and more precise information to the patients.

### Riassunto

Negli ultimi vent'anni, l'affermazione del laser CO<sub>2</sub> nella microchirurgia laringea si è dimostrata particolarmente utile nel trattamento chirurgico della stenosi laringotracheali. Gli autori riportano la loro esperienza chirurgica e la discutono in relazione alla posizione, alle dimensioni e alle caratteristiche patologiche della malattia.

Lo scopo di questo studio è di valutare i risultati che possono essere ottenuti nel trattamento della stenosi laringotracheale mediante endoscopia utilizzando il laser a CO<sub>2</sub> e analizzare i vantaggi e i limiti dei metodi chirurgici impiegati.

**MATERIALE DI STUDIO:** La casistica presentata comprende 128 pazienti trattati dal 1981 al 2016 mediante endoscopia utilizzando il laser CO<sub>2</sub>, in particolare:

- 50 casi (39,1%) con stenosi sopraglottica, di cui 38 con edema (29,7%). Di essi 7 (5,5%) hanno mostrato coinvolgimento dell'area interaritenoidea e 12 forme cicatriziali (9,4%), di cui 10 (7,8%) aveva un'estensione alla commessura posteriore e 2 (1,6%) una fissità del piano glottico;

- 50 casi (39,1%) con stenosi glottico-ipoglottica, di cui 13 forme di edema (10,2%) (tutti con coinvolgimento della commessura anteriore) e 27 stenosi cicatriziale (21,1%) (di essi 20 (15,6%) hanno mostrato il coinvol-

gimento della commessura anteriore e 4 (3,1%) una fissità delle vere corde vocali);

- 11 soggetti (8,6%) con stenosi tracheale (in 2 casi (1,6%) erano stenosi limitate a 1/3 della parete tracheale anteriore, in 4 (3,1%) si estendeva ai 2/3 anteriori e in 5 casi (3,9%) si diffondeva concentricamente sull'intera trachea;

- 17 pazienti (13,3%) in cui il restringimento interessava l'intero asse laringotracheale.

La guarigione è avvenuta in 121 dei 128 pazienti (94,5%); nei restanti 7 casi (5,5%) (4 soggetti (3,1%) con stenosi cicatriziale sopraglottica e 3 pazienti (2,3%) con stenosi laringotracheale diffuse) è reso necessario un reintervento di recupero.

In particolare, ha osservato quanto segue:

- Nella stenosi sopraglottica: a) nelle forme edematose si è osservata la guarigione senza difficoltà, con un numero limitato di controlli (1-2) e non è stato utilizzato alcun tipo di stent; b) nelle forme cicatriziali si rendeva necessario un numero maggiore di controlli (3-6) e l'esecuzione in 2 casi (1,6%) di un'aritenoidectomia. In questo gruppo abbiamo avuto 4 fallimenti (3,1%) per i quali è stato effettuato un intervento chirurgico di recupero di tipo tradizionale;

- Nella stenosi glottica / ipoglottica: a) tutte le forme edematose sono guarite con un numero di controlli inferiore a 3, senza l'uso di stent; b) le forme cicatriziali si sono risolte dopo un numero maggiore di controlli (3-6), in 4 di essi (3,1%) è stato necessario praticare un'aritenoidectomia (associata a exeresis di 1/3 del vero cordone vocale ipsilaterale posteriore) e in 4 (3,1%) hanno dovuto applicare un tutore endolaringeo (in un caso uno stent Traissac e in 3 un tubo di Montgomery);

- Nella stenosi tracheale si è verificata la guarigione in tutti i casi, in particolare: a) in forme limitate al terzo anteriore della trachea sono stati sufficienti 1-2 controlli e non è stata necessaria l'applicazione di stent; b) nelle forme estese (coinvolgimento dei 2/3 anteriori e/o dell'intera circonferenza tracheale) è stato necessario un numero maggiore di controlli (3-6); c) in forme concentriche, con ostruzione totale del lume, è stata sempre necessaria l'applicazione di uno stent endoluminale (3 tubi a T Montgomery e 2 cannule tracheali di Silastic) oltre a un numero di controlli superiori a 7;

- Nelle forme con diffusione laringotracheale, 3 sono guariti (2,3%) tuttavia, sono stati necessari molti controlli (maggiori di 7) ed è stato inserito un tubo a T Montgomery.

**CONCLUSIONI:** L'introduzione del laser a CO<sub>2</sub> nel trattamento chirurgico della stenosi laringotracheale ha indubbiamente migliorato le possibilità di chirurgia endoscopica; è attualmente in grado di offrire vantaggi significativi rispetto alle tecniche tradizionali (cure più veloci, interventi meno traumatici, post-operatorio trascorso meglio tollerato dai pazienti, ecc.) ma è anche indiscutibile che per garantire il successo di queste operazioni sia essenziale una corretta comprensione delle dimensioni e delle



caratteristiche patologiche della stessa stenosi: i dati, infatti, influenzano la scelta degli indirizzi chirurgici da adottare nei singoli casi e il giudizio prognostico.

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