Original Article

The Electrosurgical Knife in an Optimized Intermittent Cutting Mode for the Endoscopic Treatment of Benign Web-like Tracheobronchial Stenosis

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Abstract

The established endoscopic treatment of web-like tracheobronchial stenosis is laser vaporization, but the appearance on the market of a new cutting mode with a lower coagulation effect has been proposed as an alternative to laser due to less injury to the tissue.

Objectives: To study the clinical and functional consequences, as well as the side effects of this technique. Afterwards, we investigated whether the use of an electrosurgical knife with this technique is as effective and convenient as an ND-YAG-laser.

Patients and methods: Between March 2005 and July 2007, included for study were 22 patients who had undergone 34 interventional bronchoscopy procedures with the VIO-300-D radiofrequency system, using a mode of the Endo-cut I program in conjunction with the reusable knife electrode.

Results: All of the patients treated (100%) presented improvements in their symptoms, in the tracheobronchial lumen diameter and in lung function, which were statistically significant. Symptom-free time was 157 ± 93 days. There was an overall decrease observed in mean obstruction (P<.001). Improvements in FVC (P<.01), raw (P<.0016) and RV/TLC (P<.01) were significantly significant. Less than 50% of the patients needed a second intervention.

These patients were compared retrospectively with a similar group of 22 patients treated with Nd-YAG laser. The follow-up analysis showed that only 18% (4/22) of the patients treated with this new technique presented fibrin, compared with 41% (9/22) of those treated with laser therapy (P <.001).

Conclusion: The use of this technique is effective for the treatment of benign web-like tracheobronchial stenosis as all the patients showed clinical and functional improvement, and less than 50% required a second intervention. In comparison with laser therapy, an advantage of this technique is that less fibrin is produced, probably due to the reduced anti-coagulation effect.

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Tratamiento endoscópico de las estenosis benignas trakeobronquiales tipo web-like con el bisturí endobronquial en combinación con un programa de corte optimizado

Resumen

El tratamiento endoscópico establecido de las estenosis trakeobronquiales tipo web-like es el láser. La aparición en el mercado de un nuevo modo de corte con menor efecto coagulante, se ha postulado como una alternativa al láser debido a un menor daño en los tejidos afectados.

Objetivos: Estudiar las consecuencias clínicas, funcionales y los efectos secundarios de esta técnica y posteriormente compararla con un grupo similar de pacientes tratados con láser ND-YAG.

Pacientes y método: Entre marzo del 2005 y julio del 2007 se incluyeron 22 pacientes que fueron sometidos a 34 procedimientos de broncoscopia intervencionista mediante el sistema de radiofrecuencia VIO-300-D, usando un modo el programa Endo-cut I en combinación con el electrodo de cuchilla reutilizable.

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* Beatriz Amat is the recipient of the ERS/ELF fellowship number 62.
Results: The 100% of the patients treated presented a major improvement of the symptoms, with a mean decrease of 62% in respiratory function who were statistically significant. The time of the symptoms was 57±9 days, needing only 50% of the patients a second intervention. Retrospectively, we compared these patients with a group similar of 22 patients treated with the laser Nd-YAG. The analysis of the follow-up showed that only 18/4 (22) of the patients treated with this new technique presented fibrin in comparison with the 41/5 (9/22) of the treated patients with the laser (p<0.001).

Conclusions: The use of this technique is effective in the treatment of benign traqueal or bronchial stenoses, greater than 2 cm in diameter, that the majority of patients can benefit from the endoscopic interventions that may alleviate their symptoms and in this way prevent future complications.

The initial symptoms are usually cough and dyspnea, like in other respiratory pathologies; therefore, a detailed patient medical history is of vital importance for orienting the diagnosis. Depending on the degree of stenosis, it is possible that stridor may appear. If the stenosis is not treated early, the patient may develop post-obstructive pneumonia, atelectasis, and even respiratory arrest and death.

So, although the symptoms and the clinical history should guide the diagnosis, the definitive diagnosis should include imaging or endoscopic techniques. The procedure of choice is bronchoscopy, as it enables one to see the type of stenosis, its location and degree.  

The therapeutic regime depends on the type of stenosis and its extension. Diaphragm or web-like stenosis requires a completely different type of treatment than complicated hourglass stenosis. In the case of idiopathic tracheal stenosis measuring less than 2 cm located in the upper third of the trachea, the treatment of choice is resection of the stenosis and end-to-end anastomosis. However, surgical interventions carry with them associated morbidity and mortality and possibilities for relapse of the lesion. Therefore, in recent years new alternatives with endoscopic treatments are being explored. The progressive appearance of endobronchial treatments (laser, electrocautery, argon plasma coagulation) has been gaining popularity due to the limited adverse effects and the low incidence of morbidity and mortality that they present, together with the possibility for cure in a subgroup of patients. 

In oncologic patients, the objective is to improve the symptoms and, consequently, quality of life. Nevertheless, in the case of endobronchial treatment of benign stenoses, it is considered that the treatment is a success if we are able to achieve that the patient remains asymptomatic during long periods of time with few or minimal adverse effects.
follow-up bronchoscopies that were done in a group of patients with similar initial characteristics who had been treated with laser.

Inclusion and Exclusion Criteria

We selected patients over the age of 18 with benign steno-
sis of the tracheobronchial tree, diagnosed by bronchoscopy, who met with the following criteria: symptoms secondary to tracheo-
bronchial stenosis, benign trachea stenosis and web-like bronchial
stenosis with no contraindications for doing rigid bronchoscopy.
Patients with malignant stenosis, those with pacemakers and patients who were candidates for surgical resection were excluded.

Procedure

The procedure was done according to the standard protocol of our hospital for interventionist bronchoscopy. Rigid bronchoscopy
was done in all cases under general anesthesia with an initial bolus of propofol at 2 mg/kg and remifentanil at 1 μg/kg. Later, an
intravenous perfusion of propofol (0.2 μg/kg/min) and remifentanil
(0.25 μg/kg/min) was used. For muscle relaxation, mivacurium was
used at a dose of 0.1 mg/kg. The patients were constantly monitored
with electrocardiogram, blood pressure and oxygen saturation.
Once the patients were intubated with a tracheoscope or rigid bron-
choscope, bronchoscopy (Olympus, Japan) was performed with a
rigid bronchoscope (Wolf, Germany). The patients were ventilated
with jet ventilation, using the Mistral respirator (Acutronic, Hirzel,
Switzerland). During the activation of the electrocautery, the inspira-
atory fraction of oxygen (FiO₂) was lowered to below 0.4 to prevent
ignition in the airway.

The treatment of the stenosis itself was done with an endo-
bronchial scalpel connected to a VIO-300-D (ERBE, Germany)
high-frequency current system. This device has different programs
designed for different instruments and clinical problems; in our
case, we used the Endo-cut I program (Fig. 1). Previously, a neu-
tral electrode (NESSY Omega-ERBE, Germany) was placed on each
patient in order to close the electrical circuit and for the monopo-
lar cutting instrument to activate. With the Endo-cut I program,
different cutting effects can be selected with different degrees of
coaagulation. The cutting interval (coagulation time between the
two cutting phases) presents a scale from 1 (very short) to 10
(very long interval). The duration of the cut also varies from 1 to 4
(4 is the longest cut). Based on previous in vitro experiments, we
opted for the following configuration: coagulation effect 1, cutting
interval 3 and cutting time 3. With this program, a well-controlled,
soft cut of the stenoses was documented.

The power of the Endo-cut I is adjusted by adjusting the effect,
the duration of the cut and the interval of the cut. With Endo-cut I, it
is not necessary to adjust the wattage or to set an upper power limit
because the high-frequency current is regulated depending on the
resistance of the tissue. Thus, compared with electrocautery or ICC
technology, in which the power is pre-selected, the VIO generator
allows for optimal power using an intelligent self-regulating sys-
tem. In other words, in the VIO generator the electrosurgical current
is adjusted automatically depending on the electrical resistance of
the tissue. Thus, the range of power is variable and depends
on the tissue. The output of the actual power is not indicated on
the screen as it depends on the resistance. This means that, with
the Endo-cut I combined with the VIO generator, the necessary current
is calculated by the VIO generator automatically depending on the
resistance of the tissue to be treated (Fig. 1B).

The majority of the patients were treated with the endo-
bronchial scalpel (KD-31C-1, Olympus, Tokyo), which is a scalpel
blade with a non-isolated, re-usable tip. New isolated-tip
diendobronchial scalpel blades (IT Knife KD-610-L, Olympus,
Japan, and EMR-Knife 99020271, MTW, Germany) were also used
(Fig. 2).

Before performing the procedure, bronchoscopy was done to
evaluate the airway and especially to evaluate and mea-
sure the longitude of the stenosis. In the case of high-grade
stenoses, occasionally pediatric bronchoscopy (BF-P160 or 3C-160,
Olympus, Japan) was necessary in order to pass along the endo-
bronchial lumen afforded by the stenosis. It is very important to be
able to see the beginning and end of the stenosis in order
in order to ensure a precise cut. Once the stenosis was analyzed, a broncho-
scope with a larger working channel (diameter 2.8 mm) was used,
which was necessary to be able to introduce the endobronchial
scalpel.

The scalpel was introduced through the working cannel, after
which the scalpel was applied to the lesion. Next, after stepping
on the yellow pedal, the current was applied (Fig. 1A), cutting the
stenosis with direct vision. In the cases in which the end of the
stenosis was not visualized, a cutting electrode with an iso-
lated tip was used to avoid either lesions or burns to healthy
areas. As seen on microscope, the spark discharged by the high-
frequency current vaporizes the intracellular water and causes the

Fig. 1. (a) VIO-300-D (ERBE, Germany) high-frequency current system and the Endo-cut I program and (b) technical data of the Endo-cut I.
disintegration of the cell. Macroscopically, a clean cut is observed in the tissue. The instrument works by contact and needs to be cleaned repeatedly throughout the procedure in order to obtain optimal performance.

One single cut was generally sufficient although occasionally two cuts were necessary to be able to achieve complete recanalization. Generally, these cuts are done in the direction of the angle that joins the pars membranacea with the pars cartilaginosa, because it is where the greatest recovery of the tracheobronchial diameter prior to the lesion is obtained.

With the intention of obtaining a greater and immediate opening effect, the technique described was combined with the use of dilation balloons (Boston Scientific, USA) (Fig. 2), or instead the tip or bezel of the rigid bronchoscope was used (Fig. 3).

48 h after the intervention, the patients underwent clinical evaluation, lung function testing, baseline arterial blood gas and control bronchoscopy with local anesthesia and sedation with midazolam. Photos and videos of the endoscopic images were taken, evaluating the degree of narrowness and the presence of fibrin plates.

Later, a comparison was done with the reports and recorded images from a group of patients with similar initial characteristics who were treated with laser. Table 1 shows the etiology, clinical data and location of the patients treated with either endobronchial scalpel or ND-YAG laser.

### Analysis

Data were compiled on patient demographics, diagnoses, symptoms, location of the stenoses, degree of stenosis and complications. The patients were followed-up for at least 6 months. In order to extract statistical data, we classified the stenoses depending on their location and degree of stenosis. The production of fibrin was classified on a two-point scale (0: without fibrin, 1: fibrin plates).

The statistical analysis was done with the SPSS program, version 12.0, for Windows (SPSS Inc., Chicago, IL, USA). The data are presented as mean±standard deviation (SD – range). The Kolmogorov–Smirnov test was used to study the variable distribution. The differences between groups were compared using the Mann–Whitney U-test in the case of variables with normal distribution and the Wilcoxon test in the case of the variables with non-normal distribution. P-values <.05 were considered statistically significant.

### Table 1

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Endo-Cut-I Values*</th>
<th>Laser Values*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiogenic scar</td>
<td>6 (27%)</td>
<td>2 (9%)</td>
</tr>
<tr>
<td>Prolonged intubation</td>
<td>6 (27%)</td>
<td>5 (23%)</td>
</tr>
<tr>
<td>Wegener’s granulomatosis</td>
<td>3 (14%)</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Post-surgery (bronchoplasty)</td>
<td>2 (9%)</td>
<td>3 (14%)</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>2 (9%)</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Idiopathic</td>
<td>1 (5%)</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Microscopic polyangiitis</td>
<td>1 (5%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Amyloidosis</td>
<td>1 (5%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Mustard gas intoxication</td>
<td>0 (0%)</td>
<td>6 (27%)</td>
</tr>
<tr>
<td>Sarcoidosis</td>
<td>0 (0%)</td>
<td>2 (9%)</td>
</tr>
<tr>
<td>Diphtheria</td>
<td>0 (0%)</td>
<td>1 (5%)</td>
</tr>
</tbody>
</table>

### Clinical information

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Pre-treatment</th>
<th>Post-treatment</th>
<th>Stridor</th>
<th>Cough</th>
<th>Expectoration</th>
<th>Inability to expectorate</th>
<th>Location of the lesions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trachea</td>
<td>10</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main bronchus</td>
<td>8 (3 right)</td>
<td>6 (3 right)</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Values presented as number of patients and percentage.
Results

Between February 2005 and June 2007, 22 patients with benign web-like tracheobronchial stenosis underwent 34 therapeutic procedures. Twelve patients (54%) required one procedure, 8 patients required 2 (36%) and 2 patients required 3 procedures (10%). Twenty-two patients were treated (13 men and 9 women), with a mean age of 54±14 SD (range: 23–72). The etiology of the stenosis, clinical information and location of the stenoses are shown in Table 1. Mustard gas intoxication refers to soldiers who participated in the Iran–Iraq War (1983–1988), in which mustard gas was used, also known as sulfur mustard (bis-[2-chloroethyl]), sulfur, yperite (Ypres was where it was first used by the military), LOST (acronym for the German chemists Lommel and Steinkopf, who researched the military use of this chemical composition) and “yellow cross” (German shells were marked with a yellow cross, meaning an agent that was dangerous to the skin). This gas produces, among other toxic effects, eye, skin and respiratory lesions. In the respiratory tract, it may cause many lesions, but the case at hand dealt with patients who presented a severe alteration in the tracheal mucosa with inflammation and necrosis, which caused stenosis in the membrane of the tracheobronchial level.\textsuperscript{15,16}

The procedures were done without any observed immediate or later complications attributable to the technique.

The degree of pre- and post-op stenoses was evaluated visually, taking into account the diameter of the bronchoscope used and the comparison between the stenosis area and the nearby healthy airway, in accordance with the last classification proposed about stenosis of the airway.\textsuperscript{7} The degrees of pre and post-treatment stenoses were 4.05±1.21 and 1.05±0.65, respectively, with a P<.001 (Fig. 3 and Table 2).

The control bronchoscope showed minimal fibrin plates, seen in only 4 out of the 22 patients (18%). These findings were compared with the results of 22 patients with web-like stenosis who were treated with ND-YAG laser. In this last group, the control bronchoscopy done between 48–72 h after laser showed fibrin plates in 9 of the 22 patients (41%). In addition, 4 of these patients presented formation of tissue with granulomas (P<.001). With regards to the patients treated with the endobronchial scalpel with an optimized cut-mode (Endo-cut I) in which fibrin plates were detected, removal of said plates was not necessary because, rather than plates, these were actually limited lesions in the intervention area. However, out of the 9 patients treated with laser in whom fibrin plates were observed, in 7 patients it was necessary to extract them with flexible forceps as they were circumferential fibrin plates that caused concentric stenosis; in 4 of these patients, a unidirectional valve behavior was observed that produced a sensation of blockage upon inspiration.

The procedure was considered a success if no new procedures were necessary in the following 6 months. Following this criterion, the process was documented as successful in 18 out of the 22 (82%) patients.

In all the patients treated with the Endo-cut I combined with the endobronchial scalpel when possible (specifically 18 of the 22 patients), baseline blood gas analysis and respiratory function tests were determined before and after treatment (Table 3). Fig. 4 shows the pre- and post-treatment flow-volume curve of a patient with radiogenic stenosis in the upper third of the trachea. These data

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**Fig. 3.** Comparison of a pre- and post-treatment tracheal stenoses.

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**Table 2**

Pre- and Post-treatment Degree of Stenosis.

<table>
<thead>
<tr>
<th>Degree</th>
<th>Pre-treatment</th>
<th>Post-treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0: No stenosis</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>1: &lt;25%</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>2: 25%–50%</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>3: 51%–75%</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4: 76%–90%</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>5: &gt;90%</td>
<td>10</td>
<td>0</td>
</tr>
</tbody>
</table>

According to the classification of the central stenoses of the airway.\textsuperscript{7}
could not be collected for the patients treated with laser because, as it was retrospective, the majority of the patients had only one complete functional study either previous or posterior to the intervention, but not both.

As shown in Table 3, the majority of the patients presented improvement in all the lung function parameters, and the forced vital capacity (P=0.01), total airway resistance (P=0.016) and ratio between residual volume and total lung capacity (P=0.01) were statistically significant.

Discussion

Symptomatic tracheobronchial stenoses require treatment that produces minimal side effects and minimal complications. Ideally, it should be a definitive treatment or at least one with a low rate of recurrences. Web-like cicatricial stenoses can be treated endoscopically with a small incision and dilation techniques. The ND-YAG laser is the established method for this type of stenosis. Argon-plasma coagulation has been considered a safe alternative, but its cutting capacity is limited as it has a low tissue penetration capability, ranging from 2 to 3 mm.14,15,18–23

In our study, a more sophisticated device has been used, with a custom program. When the new Endo-cut I cut mode is used with the endobronchial scalpel, its effects are observed to be comparable to those achieved with laser15,18–23 but with a lower production of fibrin, probably due to its lesser penetration and to the fact that the power used depends on the resistance of the tissue to be treated (Fig. 1B). Specifically, what happens with the use of laser is that the deep coagulation damages the blood flow, which reduces the viability of the chondrocytes and alters the re-epithelialization. This tissue damage caused by laser therapy promotes fibrosis, scarring and granulation tissue, and consequently re-stenosis. Both necrosis and the production of fibrin plates are endoscopically visible signs of tissue lesion. Thus, it is reasonable to believe that a lower production of fibrin plates entails a lower risk of re-stenosis.15,18–23

Evaluating these data, statistically significant differences were found in fibrin production in the cases of patients treated with the new cut-mode in comparison with the group of patients treated with laser. Thus, while in the patients treated with the Endo-cut I the production of plates de fibrin was small on the cutting areas and their removal by forceps was not required, in the case of the patients treated with laser the fibrin plates were more considerable in size and required removal with flexible forceps.

An excellent response was obtained with regards to the symptoms, the degree of stenosis and lung function, all probably due to the careful selection of the cases as the ideal candidates for this technique are patients with short (<1 cm) web-like benign stenoses who are not candidates for surgery. It is possible that it may be useful in the case of malignant web-like stenoses, but new studies would be necessary in this direction.

The results in the patients with radiogenic stenosis were excellent, with no evidence of new recurrences after the resection of the
scar tissue. In our series, 5 out of the 22 patients had inflammatory diseases: one patient with amyloidosis, 3 with Wegener’s granulomatosis and one with microscopic polyangiitis. In these patients, the endoscopic treatment improved the symptoms locally, at least temporarily. Nevertheless, the disease-free time was less than that of other tracheobronchial stenoses. From our standpoint, these are systemic diseases and we are merely intervening locally; therefore, the treatment of the underlying disease is of vital importance in these patients. In the case of Wegener’s granulomatosis, treatment has been recommended with a combination of azathioprine and corticosteroids with the aim of minimizing the manipulation of the airways during the episodes of activity of this systemic disease. 24–26

As for patients with amyloidosis, the lack of success in the treatment is probably due to the frequent bleeding that is produced in this disease because of the increase in the friability of the artery walls. In these patients, it is preferable to use instruments with a deeper coagulation effect, like ND-YAG laser.

The results obtained in this study enable us to recommend the use of endobronchial scalps in all the bronchoscopic units in Spain, in combination with the Endo-cut I (ERBE) cut mode available on the VIO generator (ERBE, Germany). This technique allows for urgent solutions in cases of tracheal stenoses that put the lives of patients at risk, especially those in whom tracheostomy would not be a solution. It would be indicated for short web-like stenoses of the airway while a more complete treatment is scheduled, which could be a surgical treatment or a complete endoscopic treatment. The completed endoscopic treatment should be complemented with mechanical balloon dilation or rigid bronchoscopy. In addition, in recent years, it has been proposed to use topical triamcinolone with the help of a transbronchial needle that could contribute to avoiding re-stenosis. In addition, Cosano-Povedano and García-Martín, et al. have published an article about the efficiency of mitomycin C after-recanalization with electrocautery and balloon dilation with the aim to avoid re-stenosis in patients with lung transplantation. 27–31 Both treatments can be considered in patients with recurring stenosis after having performed recanalization with the endobronchial scalpel in combination with the dilation balloon and/or the bevel of the rigid bronchoscope.

In conclusion, and based on the Latin expression primum non nocere, the use of this new intermittent and optimized cutting mode, Endo-cut I, in combination with the endobronchial scalpel and the isolated-tip scalpel, is a safe and effective treatment in the case of patients with web-like tracheobronchial benign stenoses. This technique produces clinical and functional improvement in all patients, requiring a second intervention in less than half of the patients. In comparison with ND-YAG laser, it causes less fibrin plates. This is probably because the cuts done with the endobronchial scalpel are thinner and because the Endo-cut I presents a smaller coagulating effect as the power emitted by said cutting program adjusts to the resistance of the tissue. This breaks the vicious circle of scarring and re-stenosis, which at the same time leads to a greater disease-free interval and, in certain cases, such as in radioangiogenic scars, to a cure.

Conflict of Interests

The authors declare having no conflict of interests.

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