GENERAL THORACIC SURGERY

THE ROLE OF SILICONE STENTS IN THE TREATMENT OF CICATRICAL TRACHEAL STENOSES

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Objective: Tracheal stenting for cicatricial stenoses is reserved for patients whose lesions are deemed inoperable for local or general reasons. The aim of our study was to verify the long-term results of silicone tracheal stents in such a clinical setting.

Methods: Clinical data of 45 patients treated by tracheal silicone stents, between 1987 and 1999, were reviewed. All patients had highly symptomatic cicatricial stenoses; they were selected for stenting rather than for surgery because of local and general conditions. This series has been divided in two groups according to the purpose of stenting: bridge to surgery or definitive treatment. Follow-up ranged between 12 and 83 months. Twenty-seven patients received a Montgomery T tube (Hood Laboratories, Pembroke, Mass), 16 a Dumon stent (Novatech, Plan de Gras, France), and 2 a Dynamic stent (Rusch, Kernen, Germany).

Results: No procedure-related mortality was observed. Nine patients underwent curative resection and reconstruction after a variable stenting period; one had a recurrent stenosis and was treated for palliation with a T tube. Tracheal stenting was performed for palliation as a definitive treatment in 37 patients. Among this group, 11 patients died of unrelated causes at a median of 10 months after the endoscopic treatment. The stent was permanently removed in 10 after a median interval of 32 months (range 9-70 months); in 4 others, symptomatic recurrence of the stenosis was observed within 6 weeks of stent removal. None of the patients successfully decannulated had a completely normal tracheal lumen but all remained asymptomatic because the residual stenosis was mild or well tolerated for concomitant limitation of physical activity.

Conclusions: Long-term treatment with a silicone stent was safe and well tolerated in cicatricial tracheal stenoses. This procedure can be considered as a bridge to curative surgery or as a definitive treatment. The latter, generally performed for palliation, may provide satisfactory therapeutic results in selected patients, even in the presence of severe circumferential stenoses. (J Thorac Cardiovasc Surg 2000;120:1064-9)

Cicatricial tracheal stenoses are mainly related to iatrogenic injury (postintubation, post-tracheotomy, or postoperative). Less common lesions are due to pre-

vious infections (eg, tuberculosis, histoplasmosis, diphtheria), to inhalation burns, or to uncertain causes.

The treatment of choice for such lesions is tracheal resection and reconstruction. Surgery, however, is not always possible both for local reasons (extensive longitudinal damage, excessive subglottic involvement, aspiration pneumonia due to laryngeal dysfunction)¹ and for general contraindications; age and associated medical diseases rarely contraindicate the operation, which usually is carried out through a neck incision. Nevertheless, some patients cannot be considered surgical candidates from the outset because of poor general condition or because they are uncooperative as a result of concomitant neurologic problems related to the orig-

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inal cause of the prolonged intubation. In a few of these patients, temporary tracheal stenting allows a subsequent, safer, curative resection; surgery can thus be performed after weaning off the patient from steroids, improvement of clinical status, and resolution of local inflammation.^{2,3} Therapeutic options for the remaining patients are dilatation, laser therapy, and stenting. With very few exceptions, the effects of dilatation and laser are of short duration and repeated treatments are required.^{4,5} On the other hand, airway stenting can be considered a valid therapeutic measure for long-lasting palliation. Occasionally, prolonged splinting achieves successful tracheal stabilization and thus allows definitive removal of the stent.^{3,6,7} Long-term stenting might therefore yield good therapeutic results, but indications and technical details remain undetermined because few clinical data are available.

The objective of this report is to present our experience in the treatment of cicatricial tracheal stenoses by means of different silicone stents, with special emphasis on long-term results.

Patients and methods

In the period 1987 to 1999, 71 patients with highly symptomatic cicatricial tracheal stenoses were observed. Forty-five, including a case of postoperative recurrent stenosis, underwent airway stenting. The remaining 26, treated by immediate successful tracheal resection and reconstruction, will not be considered in this study. Patients with a follow-up shorter than 12 months were not included in this series.

Twenty-eight patients were male and 17 female with ages ranging from 8 to 79 years (median 58 years).

Patients were selected for stenting as first treatment rather than for tracheal resection and reconstruction according to local and general conditions. Temporary or definitive local contraindications for surgery included the following: florid inflammation at the site of the stenosis, excessive linear extent of the lesion (roughly 50% or more of the tracheal length), involvement of the proximal half of the subglottic larynx, and incompetent glottis with previous aspiration pneumonia. General conditions were usually related to the disease that caused a prolonged intubation, such as respiratory failure, sequelae of head injury, or neurosurgical procedures (impairment of mental function, post-traumatic epilepsy, quadriplegia); these problems were particularly frequent in our series since most of our patients were referred from intensive care units. High-dose steroid therapy was also considered a contraindication for immediate resection.

Long-term stenting was achieved by 3 different silicone prostheses: Montgomery T tube (Hood Laboratories, Pembroke, Mass), Dumon stent (Novatech, Plan de Gras, France), and Dynamic stent (Rusch, Kernen, Germany). We used T tubes in very long stenoses (>5 cm), in the presence of an already existing tracheostomy stoma, in uncooperative patients with ineffective cough, and in patients with previous

Table I. Endoscopic data

	No.
Site of the lesion	
Upper trachea	22
Subglottic larynx–upper trachea	10
Lower trachea	13
Longitudinal extent	
<3 cm	26
3–5 cm	15
>5 cm	4
Stenosis*	
Mild	4
Moderate	20
Severe	21
Associated malacia	18

*Mild, Residual lumen > 50%; moderate, residual lumen 30% to 50%; severe, residual lumen < 30%.

Dumon stent migration. Y-shaped stents (Dynamic) were reserved for palliation of lesions of the lower third of the trachea; in all the remaining patients we preferred the use of a Dumon stent. Airway stents were positioned through a ventilating rigid bronchoscope with the patient under general anesthesia. Before stent deployment an adequate tracheal lumen was restored (bougienage, balloon dilatation, rigid bronchoscopes of increasing diameter). In the patients eligible for Montgomery T tube stenting, the tracheostomy—if not already present—was performed in the diseased segment of the airway with the aid of a rigid bronchoscope.

Bronchial secretions for bacteriology were collected in all patients every 4 months by a flexible bronchoscope. In case of positive cultures, therapy was instituted according to specific antimicrobial sensitivity.

All patients underwent large-drop aerosol treatment. T tubes were replaced with larger bore T tubes every 12 to 15 months whenever possible. All patients submitted to stent removal underwent periodic clinical and endoscopic examinations for at least 1 year. During this period flexible video-endoscopy with recording was performed roughly every 3 months. After T-tube removal a stoma stent was positioned. The tracheostomy stoma was closed after an observation period of about 2 months.

To analyze the long-term outcome, we divided the patients according to the initial aim of the treatment: group A underwent stenting as a bridge to surgery and group B, stenting as a definitive treatment.

Results

Twenty-eight stenoses were classified as postintubation, 16 as post-tracheostomy, and 2 as postoperative (1 of which was a recurrent stenosis in a patient who had previously undergone stenting). Table I summarizes the endoscopic data collected at the first examination with a rigid bronchoscope.

Patients were selected for stenting at the time of presentation after an accurate appraisal of the local situa-

Table II. Clinical data of the patients successfully decannulated after stenting

Patient (sex, age [y])	Etiology	Site of the lesion	Longitudinal extent (cm)	Associated malacia	Degree of stenosis*	Stent	Stenting period (mo)	Residual stenosis* after decanulation	Residual malacia after decanulation
1 (F, 50)	Postintubation	Upper-middle trachea	4	Yes	Severe	T tube	60	Mild	Yes
2 (F, 73)	Postintubation	Larynx-upper trachea	4	Yes	Severe	T tube	32	Mild	Yes
3 (M, 69)	Post-tracheostomy	Upper trachea	2	No	Severe	Dumon	9	Moderate	No
4 (M, 39)	Postoperative	Upper trachea	2	No	Severe	T tube	50	Mild	No
5 (M, 30)	Postintubation	Larynx-upper trachea	3	Yes	Severe	Dumon	70	Moderate	Yes
6 (M, 70)	Post-tracheostomy	Upper-middle trachea	6	No	Severe	T tube	48	Moderate	No
7 (F, 51)	Postintubation	Upper trachea	4	Yes	Moderate	T tube	40	Mild	No
8 (M, 64)	Postintubation	Upper trachea	3	No	Severe	Dumon	23	Moderate	No
9 (M, 66)	Postintubation	Upper trachea	4	Yes	Moderate	T tube	12	Mild	Yes
10 (F, 54)	Postintubation	Larynx-upper trachea	2	Yes	Moderate	T tube	19	Mild	No

*Mild, Residual lumen > 50%; moderate, residual lumen 30% to 50%; severe, residual lumen < 30%.

tion, as evaluated with a rigid bronchoscope, and the clinical conditions. Six patients were deemed to have an unresectable lesion as a result of extensive destruction of the proximal half of the subglottic larynx and 4 as a result of involvement of more than half of the trachea. Three patients in this particular subgroup had previously undergone repeated laser treatments elsewhere. Four patients had significant laryngeal dysfunction related to a recent supraglottic partial laryngectomy. The remaining 31 patients had a potentially resectable lesion. In 7 of these, a tracheal stent was positioned because of florid tracheal inflammation. At the first observation, 24 patients were unsuitable for surgery because of their general clinical conditions: on referral, 6 were intubated and receiving mechanical ventilation with the endotracheal tube positioned above the stricture; 5 were comatose or had severe neurologic sequelae; 10 were affected by chronic obstructive pulmonary disease and had undergone repeated intubations with mechanical ventilation for recurrent episodes of respiratory failure; and 3 had required prolonged intubation as a result of a recent myocardial infarction.

Long-term stenting was achieved by a Montgomery T tube in 27 patients, a Dumon stent in 16, and a Dynamic stent in 2.

There has been no hospital mortality. All patients had immediate symptomatic relief after the endoscopic treatment; the mechanically ventilated patients were immediately extubated.

The median follow-up period was 36 months (12-83 months).

Complications

Migration. Three Dumon stents (18.7%) became dis-

placed in this series. This complication was solved by changing diameter or stent type.

Mucostasis. Only 3 emergency bronchial aspirations were required. Mildly symptomatic mucostasis was also observed in 14 patients. This complication occurred with all stent types and was easily solved by fiberoptic bronchial aspiration and by improving the mucolytic medication.

Granulation tissue. Asymptomatic granulomas at the edges of the stent were not considered complications. Significant granulomas inducing stenosis were observed at the proximal end of the T tube when it reached a level immediately below the glottis. This complication was managed by proper size selection and accurate smoothing of the stent's edges. We always avoided placing the proximal arm of the T tube above the level of the vocal cords because of the risk of aspiration. In 1 case of extensive subglottic destruction, a temporary Eliachar laryngeal stent (Hood Laboratories, Pembroke, Mass) was positioned.

Infection. Symptomatic airway infection by *Candida albicans* and by *Pseudomonas aeruginosa* occurred in 2 patients and was successfully managed by antibiotic therapy and stent replacement (Dumon stent and T tube).

Other complications. In 2 patients who underwent tracheostomy and immediate T-tube placement, the stent was kept unplugged for 5 or 6 days because of subcutaneous emphysema.

The long-term outcome of the two groups of patients, as previously divided, was as follows:

Group A: Stenting as a bridge to surgery. Tracheal stenting prepared 9 patients for a curative tracheal or laryngotracheal resection and reconstruction. The median interval between stent deployment and surgery

was 9 months, ranging from 4 to 67 months. As soon as the stent was removed an antibiotic regimen was instituted; after a median of 3 days the patients were re-evaluated with a rigid bronchoscope and operated on with a curative intent. The postoperative course was uneventful in all patients but 1 who received a new stent (T tube) for recurrent tracheal stenosis due to anastomotic separation (this case is also included in group B).

Group B: Stenting as a definitive treatment.

Tracheal stenting was considered the only valid alternative to tracheostomy in 37 patients who were deemed to be in inoperable condition because of local or general reasons, or both. All patients were initially treated with a silicone stent for palliation.

Four patients in this group were lost to follow-up; 11 died of the concomitant diseases without respiratory symptoms at a median of 10 months after stent placement. The stent is still in place in 12 patients, all asymptomatic.

In 14 patients we attempted decannulation after long-term splinting. Symptomatic recurrence of the stenosis was observed in 4 patients, within 6 weeks of stent removal, and a new stent was positioned. The stent was thus permanently removed in 10 patients after a median interval of 32 months (range 8-70 months). Clinical data of the patients successfully decannulated after long-term stenting are reported in Table II. Two patients in this subgroup had undergone a previously unsuccessful attempt at stent removal 14 and 23 months earlier. In all patients the bronchoscopic examination after stent removal showed acceptable regression of the stenosis, sometimes with scattered granulomas but always with satisfactory epithelialization; residual tracheal malacia was observed in 4 cases. No patient had a totally normal tracheal lumen at follow-up examination with a fiberoptic scope. However, the residual stricture was well tolerated because of its limited entity (6 patients) or the patient's restricted physical activity (4 patients). A comparative analysis of the sequential endoscopic recordings showed further mild asymptomatic narrowing of the tracheal lumen in 50% of patients, occurring within 40 days after stent removal. In 2 patients we observed resorption of the residual granulomas discovered at the edge of the prosthesis. One patient died 34 months after stent removal of unrelated causes.

Discussion

Despite widespread use of low-pressure/high-volume cuffs, postintubation trauma is still the main cause of benign tracheal stricture. These lesions have been

attributed to impairment of blood flow caused by mucosal or full-thickness tracheal pressure necrosis due to the cuff.⁸ Furthermore, other causes, as well as some kind of individual predisposition, are to be postulated since this problem may occur after a wide variability of traumas. The deeper the tissue injury, the tighter the ensuing stenosis; thinning or destruction of the cartilages will lead to a circumferential stricture and associated malacia.

Laryngotracheal stenoses may be related to trauma from intubation with a tube that is too large, causing mucosal tear at the cricoid level, generally the narrowest segment of the upper airway, especially in female patients.

Post-tracheostomy stenoses are usually caused by poor surgical technique. A stoma that is too large, with excessive destruction of the anterior cartilaginous arch, may produce a generally resectable triangular stenosis. Much more difficult to correct are lesions of the subglottic larynx, caused by incorrect position of the stoma for technical or anatomic reasons (short neck, severe kyphosis).

Most postoperative stenoses are caused by excessive tension on the anastomosis or, less frequently, by other technical defects (eg, inadequate blood supply, florid inflammation of the tracheal stumps). Secondary resection, even though sometimes feasible,⁹ can be extremely difficult.

In cicatricial tracheal stenoses, 3 different clinical patterns may be described.

Well-circumscribed lesion: Patient with good performance status. In this group early resection must be considered. Dilatation with bougies, balloons, and rigid bronchoscopes can be indicated to allow elective surgery with safer intraoperative control of the airway and to measure the lesion and its distance from the vocal cords, cricoid, and carina, as we¹⁰ previously reported. Repeated endoscopic treatments are contraindicated because the effect of dilatation does not last very long.^{4,5} Laser treatment is effective only for isolated inflammatory granulomas or thin weblike stenoses,¹¹ and its indiscriminate use can jeopardize the subsequent curative surgical resection.^{5,8,12} Stent insertion is to be avoided because it delays the curative treatment.

Florid inflammation and excessive scar tissue are discovered all around the stricture or the patient requires rehabilitation. In such circumstances, temporary tracheal stenting with a silicone stent is a suitable treatment until the local situation and the patient's general condition allow a safer surgical resection. In fact, it is wiser to gain time in order to permit resolu-

tion of active inflammation of the operative field and to obtain a significant improvement of the clinical status. Six months are usually enough for the first purpose. With silicone stents it is possible to provide a stable respiratory lumen without repeated procedures, avoiding an open tracheostomy stoma.^{3,13}

More than 50% of the trachea is damaged, the subglottic larynx is entirely involved, or the patient has post-traumatic irreversible sequelae or associated disabling diseases. Surgical correction, whenever feasible, is risky and technically very difficult. Most of the patients have unresectable lesions, and a tracheal stent can be the only reliable alternative to a tracheostomy cannula.

We believe that the combination of tracheal resection and reconstruction is the best treatment for most cicatricial stenoses. The aim of this study is not to demonstrate that long-term stenting may be an alternative to surgery. Roughly 50% of the patients in our series did not undergo surgery—either immediate or delayed—because most of them were referred from intensive care units with associated severe medical problems. In uncooperative patients with resectable tracheal stenoses but with mental deterioration, and/or severe limitation of physical activity, and/or ineffective cough, silicone stenting may be considered a good therapeutic measure. Even though in our institution tracheal stenting was always used for palliation, surprisingly we found that stent removal was possible, in the long term, in some severe circumferential stenoses with associated malacia.

Many questions concerning long-term silicone stenting as potentially curative are still matters of debate.

Are all cicatricial tracheal stenoses amenable to cure by long-term stenting? The answer is probably no, but certainly all these lesions do have a chance of significant improvement after prolonged stenting. The use of silicone stents with curative intent has been reported, probably on the basis of endoscopic criteria.⁶ Such criteria are related to the depth of damage: Superficial tracheal injury, involving only the mucosa with granuloma formation, is more likely to improve after splinting with a highly tolerated material; permanent recovery of full-thickness lesions with total destruction of tracheal cartilages is of course much more difficult to achieve. In our series none of the patients with severe lesions had a totally normal tracheal lumen after stent removal.

Which stent is preferable? Metallic stents should be avoided in benign lesions because they are often very difficult to remove and can produce severe tracheal wall damage after a prolonged stenting period.^{11,14,15}

Furthermore, the inflammatory stricture often recurs by ingrowth through the wire mesh.¹⁶ Experimentally, we¹⁷ recently observed full-thickness bronchial perforations after long-term metallic stenting; after the same period of silicone stenting, only chronic reversible inflammatory changes were discovered. The choice of the appropriate silicone stent depends on several factors: topography and extension of the lesion, the patient's general condition, and pre-existing tracheostomy. We prefer to use the T tube in high, extended tracheal or laryngotracheal strictures, in patients with repeated migration of a Dumon stent, in uncooperative patients with severe neurologic problems, and in patients in whom it is safer to keep the tracheostomy open (ie, patients likely requiring mechanical ventilation or repeated general anesthesia for the treatment of associated diseases). T tubes of gradually increasing sizes are used whenever possible to obtain optimal airway splinting. Lesions of the lower third of the trachea are best treated by bifurcated prostheses (Dynamic stent, Dumon type, Hood stent). In nearly all the other situations we consider the Dumon stent as a first choice because it avoids a tracheostomy or allows the closure of a pre-existing stoma. Dumon stent migration rate can be kept quite low by choosing the proper stent diameter. The largest size accepted by the airway is indicated because the prosthesis probably will not have to be replaced (only 1 patient in our series required replacement of the prosthesis, for symptomatic *Candida* infection). In benign stenoses a certain Dumon stent migration rate should be expected¹⁸ because the diameter of the diseased trachea gradually increases as a result of the dilatation pressure of the stent.

How long should the stent be kept in place before attempting its removal? Some authors recommend keeping the stent in place for at least 6 to 12^{3,19} or 18 months.⁶ Probably the optimal period of stenting is related to the severity of the lesion. In full-thickness damage, the diseased trachea can be converted into a floppy tube, and stabilization, whenever possible, usually takes some years to occur. Resolution of stenosis and stabilization of malacia are seldom entirely achievable, but in the long term it is possible to obtain an adequate airway lumen, especially for those patients with limited physical activity due to the trauma-related neurologic sequelae. We believe that at least 2 years are necessary before attempting stent removal in severe circumferential stenoses with associated tracheal malacia. In some patients an even longer time may be necessary.

How do such lesions undergo stabilization? Localized granulomas can be cured either by laser or

by mechanical removal.^{11,20} Diffuse circumferential granulation tissue and fibrous scar tissue are usually the result of extensive mucosal necrosis. A satisfactory mucosal healing process requires complete re-epithelialization. Stabilization of malacia is certainly much more difficult to understand, especially if the tracheal rings are totally destroyed. As already mentioned, a completely stable and patent airway is impossible to obtain in such circumstances. On the other hand, with long-term silicone stenting an unpredictable improvement leading to stent removal is sometimes observed. The foreign body, chronically contaminated by bacteria, may play a role in this process, causing perivisceral adhesions. In conclusion, long-term stenting can produce resolution of active inflammatory mucosal changes, which gradually evolve into a full-thickness chronic infiltrate; the latter may be reversible after stent removal with fibrous healing.¹⁷

Which are the criteria for attempting stent removal? Clinical and endoscopic criteria are to be considered. Among the former, the elapsed time is very important because only long-term stenting may provide a stable and patent airway. Performance status should also be considered because a residual tracheal stricture may be well tolerated by patients unable to carry out normal daily activity.

The correct interpretation of endoscopic data is the key to satisfactory results. Epithelialization, airway diameter, and residual chondromalacia should be carefully evaluated. It is better to remove the T tube under sedation and local anesthesia to allow subsequent examination with a fiberoptic bronchoscope, which is essential for evaluating residual malacia.

The degree of residual stenosis cannot be a reliable criterion, since the stricture, dilated by long-term splinting, may not be fully appreciated immediately after decannulation. Satisfactory patency at this stage should not be considered definitive owing to the possibility of subsequent gradual luminal narrowing. For this reason it is extremely important to schedule a strict follow-up program, based on sequential video-recorded endoscopies, to monitor the condition of the airway. As soon as signs and symptoms of airway obstruction recur, the patient should receive a new stent positioned with a rigid bronchoscope. A failed decannulation after long-term stenting does not necessarily mean that the lesion will not be amenable to cure after prolonged splinting. In 2 patients in our series, a stable airway lumen was achieved 14 and 23 months after a first unsuccessful attempt at stent removal.

REFERENCES

- Mathisen DJ, Grillo HC. The trachea: tracheostomy, tumors, strictures, tracheomalacia, and tracheal resection and reconstruction. In Baue AE, editor. Glenn's thoracic and cardiovascular surgery. Stamford: Appleton and Lange; 1996. p. 665-90.
- Gaissert HA, Grillo HC, Mathisen DJ, Wain JC. Temporary and permanent restoration of airway continuity with the tracheal T tube. *J Thorac Cardiovasc Surg* 1994;107:600-6.
- Cooper GD, Pearson FG, Patterson GA, Todd TRJ, Ginsberg RJ, Goldberg MP, et al. Use of silicone stents in the management of airway problems. *Ann Thorac Surg* 1989;47:371-8.
- Freitag L. Tracheobronchial stents. *Eur Respir Mon* 1998;9:79-105.
- Maddaus M, Pearson FG. Postintubation injury. In: Pearson FG, editor. Thoracic surgery. New York: Churchill Livingstone; 1995. p. 251-65.
- Martinez-Ballarín JJ, Díaz-Jiménez JP, Castro MJ, Moya JA. Silicone stents in the management of benign tracheobronchial stenoses: tolerance and early results in 63 patients. *Chest* 1996;109:626-9.
- Bisson A, Bonnette P, Ben El Kadi N, Leroy M, Colchen A, Personne C, et al. Tracheal sleeve resection for iatrogenic stenoses (subglottic, laryngeal, and tracheal). *J Thorac Cardiovasc Surg* 1992;104:882-7.
- Grillo HC. Management of non-neoplastic diseases of the trachea. In: Shields TW, editor. General thoracic surgery. 5th ed. Baltimore: Lippincott Williams & Wilkins; 2000. p. 885-97.
- Donahue DM, Grillo HC, Wain JC, Wright CD, Mathisen DJ. Reoperative tracheal resection and reconstruction for unsuccessful repair of postintubation stenosis. *J Thorac Cardiovasc Surg* 1997;114:934-9.
- Daddi G, Puma F, Avenia N, Santoprete S, Casadei S, Urbani M. Resection with curative intent after endoscopic treatment of airway obstruction. *Ann Thorac Surg* 1998;65:203-7.
- Edell ES, Colt HG, Dumon JF. Tracheobronchial prostheses. In: Prakash UBS, editor. Bronchoscopy. 1st ed. New York: Raven Press; 1994. p. 301-11.
- Shankar S, George PJM, Hetzel MR, Goldstraw P. Elective resection of tumours of the trachea and main carina after endoscopic laser therapy. *Thorax* 1990;45:493-5.
- Landa L. The tracheal T tube in tracheal surgery. In: Grillo HC, Eschappasse H, editors. International trends in general thoracic surgery. Mayor Challenge, volume 2. Philadelphia: WB Saunders; 1987. p. 124-32.
- Nashef SAM, Dromer C, Velly JF, Labrousse L, Couraud L. Expanding wire stents in benign tracheobronchial disease: indications and complications. *Ann Thorac Surg* 1992;54:937-40.
- Hramiec JE, Haasler GB. Tracheal wire stent complications in malacia: implications of position and design. *Ann Thorac Surg* 1997;63:209-13.
- Gaissert HA, Patterson GA. Tracheobronchial stents. In: Pearson FG, editor. Thoracic surgery. New York: Churchill Livingstone; 1995. p. 223-33.
- Puma F, Farabi R, Urbani M, Santoprete S, Daddi N, Di Meo A, et al. Long-term safety and tolerance of silicone and self-expandable airway stents: an experimental study. *Ann Thorac Surg* 2000;69:1030-4.
- Dumon JF, Cavaliere S, Diaz-Jimenez JP, Vergnon JM, Venuta F, Dumon MC, et al. Seven-year experience with the Dumon prosthesis. *J Bronchol* 1996;3:6-10.
- Dumon JF. A dedicated tracheobronchial stent. *Chest* 1990;97:328-32.
- Personne C, Colchen A, Leroy M, Vourc'h G, Toty L. Indications and technique for endoscopic laser resections in bronchology: a critical analysis based upon 2284 resections. *J Thorac Cardiovasc Surg* 1986;91:710-5.