

Airway Stents

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KEYWORDS

- Tube stents • Metal stents
- Airway stenosis • Aortic allograft

A stent is a hollow, cylindrical prosthesis that maintains luminal patency and provides support. It is named after Charles Stent, a British dentist, who created dental splints in the nineteenth century, and stenting of the airway has been practiced for more than a century. Stents are used for providing a barrier effect by protecting the airway lumen from tumor or granulation tissue ingrowth, for splinting effect by counterbalancing the extrinsic pressure exerted on the airway, or for both.¹ The covering provides the barrier effect, whereas dynamic and static properties determine the splinting effect.²

The first stents were implanted surgically by Trendelenburg³ and Bond⁴ for the treatment of airway strictures, which quickly progressed to endoscopic application by Brunings and Albrecht⁵ in 1915. In 1965, Montgomery⁶ designed a T-tube with an external side limb made of silicone and rubber for the treatment of subglottic stenosis. Since then, silicone has become the most commonly used material for stents. However, the designs of the silicone stents at that time abolished the innate mucociliary mechanisms essential to clear the airway of secretions. The real breakthrough in airway stenting was achieved when Dumon⁷ presented a dedicated tracheobronchial prosthesis that could be introduced with the rigid bronchoscope. These straight stents made of silicone, with studs on the outer wall that reduce interference to the ciliary action, are relatively inexpensive and can be easily removed when needed. However, these stents require rigid bronchoscopy for their placement, and only 5% of the pulmonologists surveyed in North America are trained in the procedure.⁸ Moreover, the silicone stent is poorly

tolerated in the subglottis, and it tends to migrate when used to treat complex tracheal strictures. These limitations have led to the modification of metal stents that were originally developed for the vascular system for use in the tracheobronchial tree.^{9,10} Although metal stents are easy to apply via flexible bronchoscopy, they are fraught with problems, such as tumor or granulation tissue ingrowth around the struts and epithelialization into the airway wall, which makes removal difficult and challenging.¹⁰

Therefore, the search for an ideal stent that is (1) easy to insert and remove, (2) customized to fit the dimensions and shape of the stricture, (3) able to reestablish the airway and maintain luminal patency with minimum rate of migration, (4) made of an inert material that does not irritate the airway, precipitate infection, or promote granulation tissue formation, (5) able to exhibit similar clearance characteristics like the normal airway so that mobilization of secretions is not impaired, and (6) economically affordable (**Box 1**) has become the holy grail of interventional pulmonologists, radiologists, thoracic surgeons, and otolaryngologists alike.

INDICATIONS FOR AIRWAY STENTING

Approximately 30% of patients with lung cancer present with central airway obstruction, of whom 35% will die as a result of asphyxia, hemoptysis, and postobstructive pneumonia.¹¹ Airway stenting is a valuable adjunct to the other therapeutic bronchoscopic techniques, which not only results in rapid relief of symptoms and improved quality of life but also gives time for adjuvant

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Box 1
Characteristics of an ideal stent

1. Easy to insert and economically affordable.
2. Available in different sizes and lengths appropriate to relieve airway obstruction.
3. Reestablish the airway with minimal morbidity and mortality.
4. Sufficient expansive strength to resist compressive forces and elasticity to conform to airway contours.
5. Maintain luminal patency without causing ischemia or erosion into adjacent structures.
6. Minimal migration but can be easily removed if necessary.
7. Made of inert material that will not irritate the airway, precipitate infection, or promote granulation tissue formation.
8. Preserves mucociliary function of the airway for mobilization of secretions.

chemoradiotherapy that might lead to prolonged survival.^{1,11–14} Chhajed and coworkers¹⁵ have demonstrated no survival difference between those patients without malignant airway obstruction who received palliative chemotherapy (median survival, 8.4 months) and others with airway obstruction who received treatment with laser (25%), stent (25%), or both (50%) followed by chemotherapy (median survival, 8.2 months; $P = .395$). Contrary to previous perception, airway obstruction is not a poor prognostic sign if treated appropriately.

Benign strictures secondary to postintubation injury, inflammatory diseases, and infectious diseases may require stenting if the patient's underlying disease or associated comorbidity prohibits definitive surgical repair. Lung transplant recipients who develop airway dehiscence in the immediate postoperative period may benefit from the placement of endobronchial stents. The Cleveland clinic experience of using uncovered metal stent as an alternative treatment for high-grade anastomotic dehiscence after lung transplantation in 7 patients deemed high risk for second operation demonstrated not only that airway healing is satisfactory but also that stent removal is not difficult if performed within 8 weeks before epithelialization takes place.¹⁶ **Box 2** details the indications for stent placement.

TYPES OF STENTS

A variety of stents are available for application in the tracheobronchial tree, and the biomechanical

Box 2
Indications for airway stenting

Malignant neoplasm

1. Airway obstruction from extrinsic bronchial compression or submucosal disease.
2. Obstruction from endobronchial tumor when patency is less than 50% after bronchoscopic laser therapy.
3. Aggressive endobronchial tumor growth and recurrence despite repetitive ablative treatments.
4. Loss of cartilaginous support from tumor destruction.
5. Sequential insertion of airway and esophageal stents for tracheoesophageal fistulas.

Benign airway disease

1. Fibrotic scar or bottleneck stricture after
 - a. Posttraumatic: intubation, tracheostomy, laser, and balloon bronchoplasty
 - b. Postinfectious: endobronchial tuberculosis, histoplasmosis-fibrosing mediastinitis, herpes virus, diphtheria, klebsiella rhinoscleroma
 - c. Postinflammatory: Wegener granulomatosis, sarcoidosis, inflammatory bowel disease, foreign body aspiration
 - d. Post-lung transplantation anastomotic complications
2. Tracheobronchomalacia
 - a. Diffuse: idiopathic, relapsing polychondritis, tracheobronchomegaly (Mounier-Kuhn syndrome)
 - b. Focal: tracheostomy, radiation therapy, post-lung transplantation
3. Benign tumors
 - a. Papillomatosis
 - b. Amyloidosis

properties depend on the materials used and how they are constructed (**Box 3, Table 1**). Stents are grouped into (1) tube stents which include Montgomery T-tube (Boston Medical Products, Boston, MA, USA), Dumon (Novatech, France), Polyflex (Boston Scientific, Natick, MA, USA), Noppen (Reynders Medical Supplies, Lennik, Belgium), and Hood (Hood Laboratories, Pembroke, MA, USA); (2) metal covered and uncovered stents, such as Palmaz (Cordis Corp, Miami, FL, USA) and Ultraflex stents (Boston Scientific, Natick, MA, USA); and (3) hybrid stents that are made of silicone and reinforced by metal rings,

Box 3**Characteristics of metallic stents***Balloon expandable*

Strecker (Boston Scientific)

Tantalum monofilament knitted into a wire mesh, most useful in narrow stenoses.

Palmaz (Corning/Johnson & Johnson, NJ, USA)

Stainless steel tube with rectangular slots along the long axis, may collapse with strong external pressure (eg, vigorous cough).

Self-expandable

Wallstent (Boston Scientific)

Wire mesh made of cobalt-based alloy filaments and coated with silicone, uncovered metallic ends prevent migration. Rarely used.

Ultraflex

Cylindrical wire mesh of nitinol, which is available in covered and uncovered form.

for example, Orlowski (Rüsch Incorporated, Duluth, GA, USA) and Dynamic stents (Figs. 1 and 2).

Major advantages of tube stents are that they allow repositioning and removal without difficulty and they are relatively inexpensive. Disadvantages include stent migration, granuloma formation, mucous plugging, insufficient flexibility to conform to irregular airways, interference with mucociliary clearance, and a need for rigid bronchoscopy for their placement (Table 2). Expertise in rigid

bronchoscopy to deploy and remove tube stents poses an obstacle that limits their use because pulmonologists' training in rigid bronchoscopy has dramatically declined worldwide.⁸

TUBE STENTS***Montgomery T-tube***

After its introduction in 1965, the Montgomery T-tube has undergone only slight modifications and continues to be used for the treatment of subglottic and tracheal stenosis.⁶ Earlier models made of acrylic were later replaced with those made of silicone rubber. They are available in different diameters and variable lengths for the 3 limbs. The prerequisite for this stent is a tracheostomy, and the stent can be placed during operation or via rigid bronchoscopy. The limb protruding out of the tracheostoma is left open for cricoid or glottic stenosis, unplugged transiently for bronchial toilet, or closed to allow speech. Migration is rarely encountered, as 1 limb is fixed in the tracheostomy opening. High mucosal pressure is not required to hold the stent in position and blood and lymphatic flows to the sensitive upper trachea are not compromised, thereby making the Montgomery T-tube especially safe for high tracheal stenosis.

Dumon Stent

Dumon⁷ initially described his experience with a new dedicated tracheobronchial prosthesis made of silicone with studs. A multicenter trial¹⁷ followed 1058 patients in whom 1574 stents were performed, of which 698 were for malignant

Table 1**Characteristics of tube stents**

Montgomery T-tube	Designed for treatment of subglottic and midtracheal stenosis. Introduced through a tracheostomy with the side tube protruding through the stoma, the proximal limb within the stenosis, and the distal limb into the distal trachea
Dumon	Silicone tube with external studs to prevent migration, most widely used silicone stent. Y shaped and right main bronchus designs are available
Hood	Smooth silicone tube with flanges to prevent migration. L- or Y-shaped designs available
Noppen	Screw-thread cylindrical silicone prosthesis, more rigid than regular silicone tubes. Needs a special introducer, and cannot be folded into an applicator for bronchoscopic insertion
Dynamic	Silicone Y-stent with the anterior and lateral wall reinforced by steel struts to simulate tracheal wall. Requires special forceps with rigid laryngoscope
Polyflex	Self-expandable stent made of polyester wire mesh with a thin layer of silicone.
Alveolus	Hybrid stent that conforms to airway tortuosity without foreshortening on deployment. It can be deployed with the rigid or flexible bronchoscope

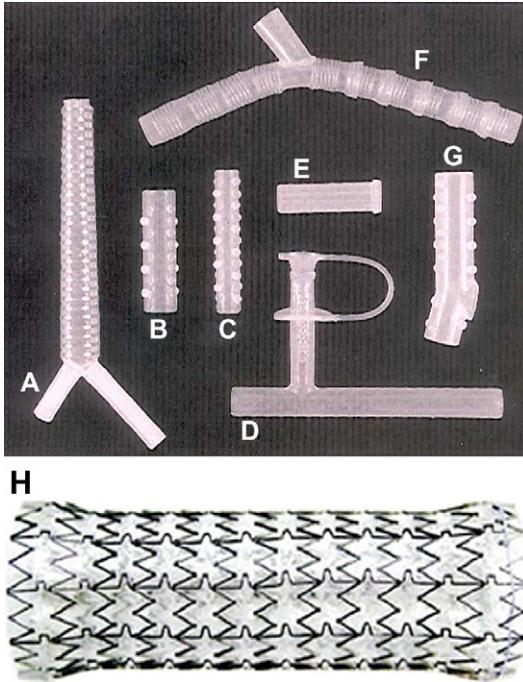


Fig. 1. Types of tube and hybrid stents. (A) Rusch stent, (B) Dumon tracheal stent, (C) Dumon bronchial stent, (D) Montgomery T-tube, (E) Hood bronchial stent, (F) Orlowski stent, and (G) Hood custom tracheobronchial stent. (H) Hybrid stent (Alveolus) can be deployed with flexible or rigid bronchoscope without foreshortening.

airway obstruction. Stent migration occurred in 9.5% of the patients, granuloma formation in 8%, and stent obstruction by mucus in 4% during a mean follow-up of 4 months for malignant stenoses and 14 months for benign stenoses. In a similar study conducted by Diaz-Jimenez and colleagues,¹⁸ 125 silicone stents were placed in 60 patients with malignant disease and 30 patients with benign tracheobronchial disease. Migration was observed in 13%, granuloma in 6%, and mucous plugging in 2% of the patients. Lower

complication rates were observed by Cavaliere and colleagues,¹¹ when a series of 393 silicone stents were placed in 306 patients with malignant airway strictures. Stent migration was observed in 5% and granuloma formation in 1%.

After its introduction, the Dumon stent has become the most frequently used stent worldwide and is considered the “gold standard” by many experts. Stents with different diameters and lengths are available for structural stenoses of the trachea, mainstem bronchus, and bronchus intermedius of adults and children. A recent addition is a bifurcated model known as Dumon Y stent (Tracheobronxane Y, Novatech, France) which can be applied to palliate lower tracheal and/or main carinal stenoses. However, because good contact pressure between the airway wall and the studs is required to prevent stent migration, it is not ideal for tracheobronchomalacia or to bridge tracheoesophageal fistula.

Noppen Stent

The Noppen stent is made of Tygon (Reynders Medical Supplies, Lennik, Belgium) and has a cork-screw-shaped outer wall that prevents migration by generating friction between the airway and stent. Results of a study that compared the use of Noppen stents with the Dumon stents demonstrated lower migration rate for benign tracheal stenoses with use of the former.¹⁹

Polyflex Stent

The Polyflex stent is a self-expanding stent made of cross-woven polyester threads embedded in silicone. Its wall to inner diameter is thinner than the Dumon or Noppen stents. This stent can be used to treat benign and malignant strictures and tracheobronchial fistula. Stents of different lengths and diameters and tapered models are available for sealing stump fistula. Incorporation of tungsten into the stent makes it radiopaque; however, the

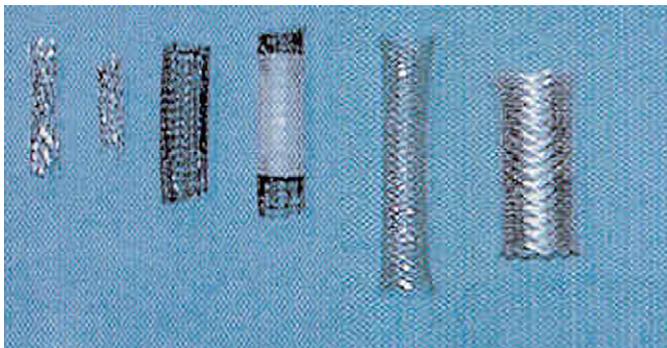


Fig. 2. Types of metallic stents. (Left to right) Palmaz stent, Tantalum Strecker stent, uncovered Ultraflex stent, covered Ultraflex stent, uncovered Wallstent, and covered Wallstent.

Table 2
Comparison of the Dumon stent and the covered Ultraflex stent

Characteristics	Dumon Stent	Covered Ultraflex Stent
<i>Mechanical considerations</i>		
High internal to external diameter ratio	–	+++
Resistant to recompression when deployed	+	++
Radial force exerted uniformly across stent	+	++
Absence of migration	–	++
Flexible for use in tortuous airways	–	+++
Removable	+++	–
Dynamic expansion	–	++
Can be customized	+++	–
<i>Tissue-stent interaction</i>		
Biologically inert	++	++
Devoid of granulation tissue	+	–
Tumor ingrowth	++	+
<i>Ease of use</i>		
Can be deployed with flexible bronchoscopy	–	+++
Deployed under local anesthesia with conscious sedation	–	++
Radiopaque for position evaluation	–	+++
Can be easily repositioned	++	–
<i>Cost</i>		
Inexpensive	+	–

–, poor; +, fair; ++, good; +++, best.

outer surface is smooth, which increases the risk for migration. In a small series of 12 patients in whom 16 Polyflex stents were used for benign airway disorders, such as anastomotic stenosis after lung transplantation, tracheal stenosis, tracheobronchomalacia, tracheobronchopatia osteochondroplastica, relapsing polychondritis, and bronchopleural fistula, the reported complication rate was alarmingly high at 75% even though immediate palliation was achieved in most cases (90%). Stent migration was the most common complication that occurred between 24 hours and 7 months after deployment. Notably, all 4 patients with lung transplant-related anastomotic stenoses encountered complications with the Polyflex stents; 2 had significant mucous plugging requiring emergent bronchoscopy, whereas the stents migrated in the other 2 patients. The investigators have since abandoned the use of Polyflex stents in their practice.²⁰

Hood Stent

The Hood stent is made of silicone, and it can be dumbbell shaped for bronchial anastomosis or tube shaped with flanges customized to an L- or Y shape.

Dynamic Stent

The dynamic stent (Rüsch Y stent, Rüsch AG Duluth, GA) is a bifurcated silicone stent that is constructed to simulate the trachea. It is reinforced anteriorly by horseshoe-shaped metal rings that resemble tracheal cartilages and a soft posterior wall that behaves like the membranous trachea by allowing inward bulge during cough. Stent fracture from fatigue and retained secretions are rarely encountered, and the stent is used for strictures of the trachea, main carina and/or main bronchi; tracheobronchomalacia; tracheobronchomegaly, and esophageal fistula.

METALLIC STENTS

Metallic stents are gaining popularity because of their ease of insertion. They can be placed at an outpatient setting via flexible bronchoscopy and under local anesthesia.^{21,22} They are categorized into 2 by the method of deployment: balloon expandable and self-expanding. A balloon-expandable stent consists of a stent balloon assembly and relies on the balloon to dilate it to its correct diameter at the target site. A self-expanding stent has a shape memory that enables it

to assume its predetermined configuration when released from a constraining delivery catheter.

Advantages of metallic stents for the management of malignant tracheobronchial obstruction include their (1) radiopaque nature that allows radiographic identification, (2) greater airway cross-sectional diameters because of thinner walls, (3) ability to conform to tortuous airways, (4) preservation of mucociliary clearance and ventilation when placed across a lobar bronchial orifice, and (5) ease of insertion when compared with tube stents. Major disadvantages include granulation tissue formation within the stent and difficulty in removal or repositioning after stent epithelialization, which usually occurs in 6 to 8 weeks (see **Table 2**).

Palmaz and Strecker Stents

The balloon-expandable stents (Palmaz and Strecker) can be dilated to diameters of 11 to 12 mm, and they are primarily restricted for use in children. The Palmaz stent is not indicated for adults because strong external force from vigorous cough or compression from an enlarging tumor or adjacent vascular structure can cause stent collapse, obstruction, and migration.²³

The Strecker stents are available in 20- to 40-mm lengths and are used for precise stenting of short-segment stenoses because they do not foreshorten on deployment.²⁴ Palmaz and Strecker stents are uncovered and are therefore unsuitable for malignant lesions because they do not protect against tumor ingrowth and may become loose when these stenoses improve after chemoradiotherapy.

The Wallstent and Ultraflex stents are self-expanding stents. They do not require hooks to prevent migration because they have outward radial force that is uniformly applied over the bronchial wall, which stabilizes the stent and reduces the risk of perforation. They are easy to deploy and are available in covered forms.

The Wallstent is a self-expandable wire mesh made of cobalt-based superalloy monofilaments (**Fig. 3**). Dasgupta and coworkers⁹ used 52 uncovered Wallstents in 37 patients, 20 with malignant airway obstruction and 17 with benign disease. Stent-related obstructive granuloma occurred in 11% of patients; 2 patients developed staphylococcal bronchitis which necessitated stent removal in 1 patient. Stent migration and mucous plugging were, however, not observed.

The Ultraflex is a self-expanding stent made of nitinol (**Fig. 4**). Nitinol is an alloy with shape memory, which deforms at low temperatures and regains its original shape at higher temperatures. Miyazawa and coworkers²⁵ deployed 54 Ultraflex

stents in 34 patients with inoperable malignant airway stenoses via flexible or rigid bronchoscopy. Immediate relief of dyspnea was achieved in 82% of the patients, who also had corresponding improvements in spirometry. Retained secretions and migration were not observed. Stent removal and repositioning was possible in 1 case of misplacement, and the Ultraflex stent was found to be safe for subglottic stenosis. Herth and colleagues²⁶ further demonstrated that the Ultraflex stents could be placed satisfactorily without fluoroscopy, thus minimizing radiation exposure to patients and staff.

Long-term outcome of patients with malignant and benign airway strictures treated with Wallstents and Ultraflex stents was analyzed. Median follow-up was 42 days for patients with lung cancer, 329 days for lung transplant recipients, and 336 days for other benign conditions. No cases of mucous plugging, fistulous formation, or fatal hemoptysis were observed. Overall observed complication rate was 0.06 complications per patient-month. The most common complication

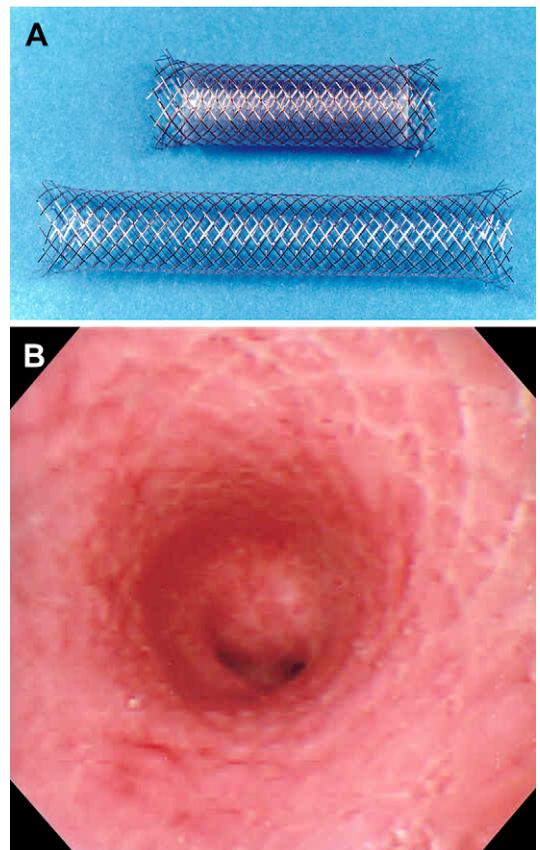


Fig. 3. (A) Covered and uncovered Wallstents. (B) Wallstent in main bronchus.

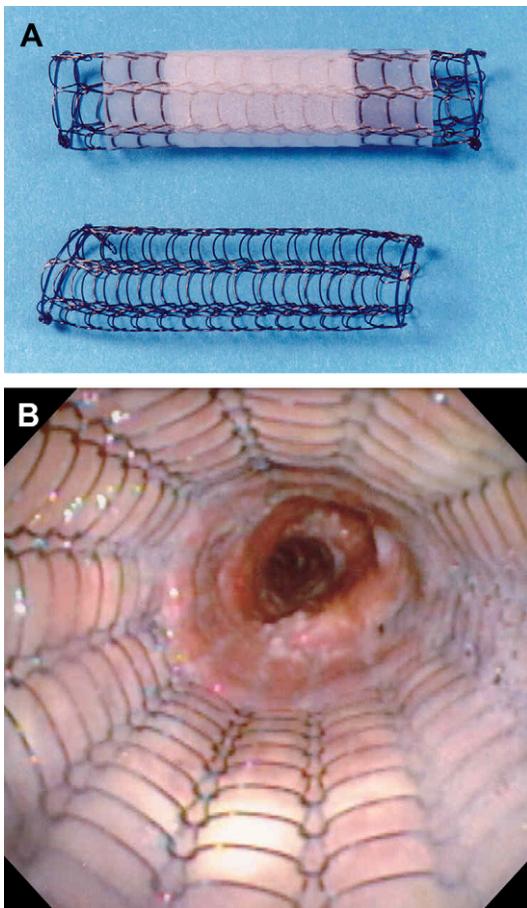


Fig. 4. (A) Covered and uncovered Ultraflex stents. (B) Ultraflex stent in trachea.

(15.9%) was infectious tracheobronchitis, and 1 patient had the stent removed because of persistent *Staphylococcus aureus* tracheobronchitis. Obstructing granuloma (14.6%) was the second most common complication necessitating multiple interventions to restore airway patency. Tumor ingrowth was seen in 6.1% of patients, early migration in 4 patients treated with Wallstents, and stent fracture in 1 patient after 2 years.²⁷ Long-term data on the use of Ultraflex stents for complex malignant airway stenoses have demonstrated low complication rates over a median follow-up of 91 days, which included mucous plugging in 8%, stenosing granulation tissue in 5%, tumor ingrowth in 5%, and stent migration in 5% of patients.²⁸ Ultraflex stent seems to be a good prosthesis for complex malignant airway stricture because of the ease of placement, excellent flexibility, and biocompatibility. In benign airway disease, experience with Ultraflex stent remains scarce, and its use is cautioned against.

Alveolus Stent

Alveolus stent (Alveolus Inc, Charlotte, NC, USA) is a new self-expanding, completely polyurethane-covered metallic stent that has been designed for use even in nonneoplastic airway strictures, as it can be easily removed. Accurate sizing for the stent can be achieved with an Alveolus stent-sizing device (Alveolus Inc), which can be introduced through the working channel of a therapeutic flexible bronchoscope. It consists of a sliding external sheath and an inner wire. The device has a measuring tool on one end and a handle on the other. When the internal wire is retracted from the handle, the wings of the measurement device open and are capable of measuring diameters between 6 and 20 mm. Once contact with tissue is made, the color bars that code for specific lumen diameters appear, which aid the bronchoscopists in the selection of appropriate stents.

The Alveolus stent is laser constructed from a single piece of nitinol, with concentric rings held in position by nitinol strands. Due to its structure, it is amenable to length modification. Because it does not foreshorten with deployment and is completely covered in polyurethane coating, the stent keeps to its trimmed length and structural integrity.²⁹ Despite its advantages, stent collapse caused hemoptysis and dyspnea in a woman who was treated for postintubation tracheal stenosis.³⁰

CHOICE OF STENT

Besides the site, shape, and length of stenosis, presence or absence of malacia or fistula determine the choice of stent; the underlying cause of airway pathology is also an important consideration. Proper sizing of the stent (length and diameter) in relation to the dimensions of the trachea or bronchus is also important to avoid stent-related complications, such as migration, mucous plugging, granulation, and tumor ingrowth.

Tube stent placement requires specialized equipment, training, and competency in rigid bronchoscopy, whereas metal stents can be inserted via flexible bronchoscopy and in an outpatient setting. The ease of placement should not lead to the erroneous choice of the easiest stent over the best one to treat a given condition. Considering the immediate and long-term complications associated with indwelling stents, the endoscopist should run through a checklist: (1) is a stent required? (2) will the patient benefit from stent placement in terms of quality of life or prognosis? (3) does the stent interfere or prohibit a curative surgical procedure later? (4) do I have the

expertise, equipment, and team to place the stent? (5) what is the underlying airway pathology and which stent is ideal? (6) is it safe to place a stent in this anatomic site? (7) what are the required stent dimensions (length and diameter)? and (8) do I have the optimal stent or should I order a more appropriate one?

For benign strictures, stents that are easy to remove and replace (eg, tube stent) are preferred to minimize mucosal damage that might otherwise preclude subsequent surgery. For malacia caused by relapsing polychondritis or tracheomegaly syndrome, uncovered wire mesh stents are preferred because they do not interfere with mucociliary clearance and have a low migration rate.^{31,32} In expiratory dynamic airway collapse associated with chronic obstructive pulmonary disease, a removable stent is considered for use only after standard therapy, including noninvasive ventilation failures,³³ whereas covered metal and tube stents are indicated in malignant stenoses^{11,17,18,21,29} and tracheoesophageal fistulae.³⁴

STENT INSERTION TECHNIQUES

Before stent insertion, dilatation of the stricture to its optimal diameter should be attempted using a rigid bronchoscope, bougie, or balloon. Tumor tissue should be removed with either laser or electrocautery. The largest possible prosthesis should be selected, and even if it does not completely unfold, it can be opened with a balloon or forceps.

Special catheters and deployment systems have been developed for metal stents. The Palmaz and Strecker stents are mounted on balloon catheters. These stents are deployed over the stenotic areas and expanded to their specified dimensions by means of balloon inflation. The Ultraflex stent is a self-expanding stent that is mounted on an introduction catheter with crochet knots. Pulling on a thread unravels the knots and releases the stent. The distal release model is easier to deploy than the proximal release design.

The Polyflex stent with its pusher system is deployed with the help of a rigid bronchoscope. Insertion of the Dumon stent is facilitated by the use of the dedicated Dumon-Efer rigid bronchoscope and stent applicator set (Efer, France). Placement of dynamic and other bifurcated stents is facilitated with dedicated forceps.

A stent alert card detailing the type and dimensions of the stent and its location in the tracheobronchial tree should be given to the patient. It should also indicate the appropriate size of endotracheal tube to be used if emergent intubation is required with the stent in situ.

A NOVEL TREATMENT OF TRACHEAL MALIGNANCY WITH AORTIC ALLOGRAFT

Primary tracheal tumors can arise from the respiratory epithelium, salivary glands, and mesenchymal structure of the trachea. Primary tracheal tumors account for up to 0.4% of malignant diseases, with 2.6 new cases per million people every year.^{35,36} In adults, 90% are malignant with squamous cell carcinoma, and adenoid cystic carcinoma accounts for two-thirds of these tumors.³⁶ The adult trachea measures 12 cm in length and is 1.5 to 2.5 cm wide. Depending on an individual's anatomic and physiologic factors, up to 50% of the trachea (ie, not more than 7 cm) can be resected. Tracheal resection with end-to-end anastomosis is the treatment of choice unless the tumor involves more than 50% of trachea, invades mediastinal structures and lymph nodes, or metastasizes to distant sites or the mediastinum has received a maximum radiation of more than 60 Gy.^{37,38} In these circumstances, patients do not undergo surgery but receive palliation with endotracheal stents, debridement, external beam radiation, or brachytherapy.³⁹

Preliminary animal studies using allogenic aortic allografts to replace the trachea have demonstrated promising results, as there were no occurrences of anastomotic leak, dehiscence, stenosis, or rejection over a period of 1 to 16 months.^{40,41} Recipient cells colonized the aortic graft. The tracheal epithelium that developed is composed of basal, secretory, and ciliated cells. A posterior membrane and cartilage rings could also be detected.

Tracheal transplantation is shown to be feasible in humans. Two patients with chemoradiotherapy-resistant mucoepidermoid and adenoid cystic carcinomas underwent tracheal resection and replacement with aortic allografts. Silicone Y-stents were left in place postoperatively to prevent collapse of the aortic grafts. Biopsy specimens of the aortic allografts in both patients at 1 year showed development of respiratory epithelium, although it was unclear if host mesenchymal stem cells had engrafted the aortic allograft and undergone cartilaginous differentiation. No complications of graft ischemia, suture dehiscence, infection, or graft rejection were observed despite notable omission of immunosuppressive therapy.⁴²

SUMMARY

Airway stenting is a valuable adjunct to other therapeutic bronchoscopic techniques used for relieving central airway obstruction. Notwithstanding that

various stents are available, each has its complications, and the search for the ideal stent continues. Moreover, clinical studies are required to identify patients who will derive the greatest benefit from stenting. Creation of biocompatible stents that can be customized and airway replacement using aortic allograft may offer promise in the future for patients with complex strictures of the tracheobronchial tree.

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