Airway stenoses after lung transplantation: Incidence, management, and outcome

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Objective: Airway stenoses have been a significant cause of morbidity and mortality after lung transplantation. We reviewed our 11-year experience with dilatation and silicone stent treatment of airway strictures after lung transplantation. We adopted this approach after managing the complications of nitinol/wire mesh stents, including stent fracture, granulation tissue overgrowth, and difficulty with removal.

Methods: Between January of 1996 and December of 2007, 240 patients underwent lung transplantation (132 single lung, 108 double lung; 121 male, 119 female; mean age 49.4 ± 12.9 years). Twenty patients (8.3%) developed >50% stenosis in 22 airways over 35 to 135 days following surgery. Short and long-segment strictures were managed with rigid bronchoscopy, mechanical/laser debridement, balloon dilatation, and silicone stent placement. Mean follow-up was 4.9 ± 3.5 years after stent removal.

Results: The mean time to diagnosis of airway stenosis was 81.5 ± 26.9 days. Pulmonary aspergillosis and pseudomonal infection, age less than 45 years, and early rejection correlated with airway stenosis; however, ischemic time, side of transplant, and preoperative disease did not. Airway patency and symptom improvement were achieved in 18 of 20 patients. Sixteen patients were able to have their stents removed at a mean of 362.3 ± 126.4 days with permanent resolution of airway stenosis. Overall survival was similar for patients with and without airway stenosis.

Conclusion: Airway stenosis after lung transplantation can be successfully managed with bronchoscopic dilatation and temporary silicone stent placement. With time, most short and long airway stenoses resolve with atraumatic stenting of the affected areas. Removal of stents with permanent airway patency is achievable in most lung transplant recipients with airway stenosis.

Since the first lung transplantation in 1963, advances in operative techniques, immunosuppression, and patient care have led to improved survival and decreased postoperative complications for lung transplant recipients. However, short- and long-segment bronchial stenoses remain a source of major morbidity and mortality in lung transplant recipients. It has been reported that perianastomotic stenoses occur in 12% to 40% and nonanastomotic distal bronchial stenoses in 2% to 4% of lung transplants.^{1,2} Effective treatment reduces the impact of these complications. Traditionally, bronchial stenoses after lung transplantation have been treated with balloon dilatation and expandable nitinol (nickel-titanium: Ultraflex, Boston Scientific; Galway, Ireland) or metal (elastic-coated medical grade 304-stainless steel: Gianturco, Cook Inc; Letchworth, UK; cobalt-based stainless steel: Wallstent, Schneider Co; Minneapolis,

Minn; and medical grade 316-stainless steel: Palmaz, Johnson and Johnson; Warren, NJ) stents.^{3,4}

In our experience with the use of nitinol and wire mesh stents for bronchial stenosis, we encountered significant difficulty with 1) granulation tissue overgrowth obstructing the stent, 2) stent fracture with wires protruding in the airway that blocked airway flow and the clearance of secretions, and 3) difficulty with stent removal. The University of California San Diego has become a referral center for both surgical and nonsurgical nitinol/wire mesh stent removal, and we have removed more than 50 of these stents in the last 10 years. Since 1996, we have adopted the approach of mechanical and/or laser debridement, balloon dilatation, followed by placement of a silicone stent with external studs (Hood Silastic Stent with Posts and Mesh: Hood Laboratories, Pembroke, Mass) for the treatment of lung transplant airway strictures. In this article, we review our experience with this approach with an emphasis on functional improvement, long-term outcome, and permanent resolution of stenosis.

MATERIALS AND METHODS

Patients and Operative Technique

We reviewed the data from a consecutive series of 240 patients who underwent lung transplantation between January of 1996 and December of 2007. This series consisted of 132 single lung transplants (SLTs) and 108 double lung transplants (DLTs), for a total of 348 anastomoses. Review of patient data that comprises this article was approved by the University of California San Diego institutional review board in February of 2008.

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Abbreviations and Acronyms

DLT	= double lung transplant
FEV ₁	= forced expiratory volume in 1 second
FVC	= forced vital capacity
IV	= intravenously
SLT	= single lung transplant

The University of California San Diego institutional review board has waived the requirement for individual patient consent for this retrospective analysis. Donor organ procurement and lung preservation were performed as previously described.⁵ Before 2004, Euro-Collins solution supplemented with 50% dextrose solution and magnesium sulfate was used for retrievals; after 2004, Perfadex solution (Vitrolife; Englewood, Colo) was used. During the lung transplant procedure, bronchial anastomoses were done with the shortest length of donor bronchus (1 ring from upper lobe takeoff) and recipient bronchus (within 1–2 rings of carina). All anastomoses were performed with an end-to-end technique using a continuous nonabsorbable monofilament (3-0 polypropylene) suture.⁶ Cardiopulmonary bypass was used in all DLTs, whereas 31 of 132 SLTs were performed with cardiopulmonary bypass.

Immunosuppression and Infection Prophylaxis

Triple drug immunosuppression therapy was instituted within 2 hours before surgery and consisting of FK506: 5 mg orally before surgery, 0.1 mg/h intravenously (IV) administered after surgery (or oral FK506 twice daily once the patient was eating) with titration of dose to a blood level of 20 to 25 ng/mL in the first week and 15 to 20 ng/mL thereafter; methylprednisolone: 500 mg IV immediately after graft perfusion followed by 125 mg IV every 8 hours for 3 doses and institution of 0.2 mg/kg/d oral dosing on day 7; and mycophenolate mofetil: 1 g orally before surgery, 500 to 1000 mg orally twice per day thereafter, maintaining a white blood cell count greater than 4000/ μ L. Before 2001, azathioprine was used in lieu of mycophenolate mofetil with dosing of 2 mg/kg orally before surgery and 2 mg/kg/d IV or orally thereafter with adjustment to maintain a white blood count greater than 4000/ μ L.

Perioperative antibiotics were routinely administered for the first 48 hours after transplantation and then adjusted on the basis of intraoperative and donor culture data. Management of bacterial infections was based on culture results. Before 2004, fungal prophylaxis consisted of treatment with inhaled amphotericin B and oral itraconazole; subsequent to this, prophylaxis consisted of treatment with inhaled amphotericin B and oral voriconazole. For fungal infections (tracheobronchitis, pneumonia, isolated anastomotic infection) before 2004, treatment consisted of IV amphotericin B; for fungal infections subsequent to this, oral voriconazole and either caspofungin or micafungin were used. Duration of therapy was directed by patient response, radiographic findings, and appearance of the airway/anastomosis by bronchoscopic visualization.

Stricture Classification, Bronchial Dilatation, and Stent Placement

Patients were evaluated by bronchoscopy when there was clinical, radiographic, or spirometric evidence of respiratory decline. Bronchial strictures were classified as follows: type 1, anastomotic: short segment, localized to within 1.0 cm of the suture line; type 2, anastomotic: long segment, encompassing the anastomosis and more than 1.0 cm of contiguous bronchus from the suture line; type 3, nonanastomotic bronchial or branch location; and type 4, diffuse bronchial stenosis (Table 1). Balloon dilatation and stenting were accomplished with the patient under general anesthesia using rigid bronchoscopy (8–12 mm Dumon-Harrell rigid ventilating bronchoscope, Bryan Corporation; Woburn, Mass). Balloon dilators (Ultra-thin Diamond

[single-stage balloon dilatation], Boston Scientific, Watertown, Mass; and CRE Pulmonary Balloon Dilatation Catheter [3-stage balloon dilatation], Boston Scientific Microvasive, Galway, Ireland), sizes from 4 to 15 mm, were inflated using a hand injector to the appropriate pressure based on the manufacturers' recommendations for 30 to 60 seconds. Excess granulation tissue was removed by forceps or with the use of the yttrium-aluminum-garnet laser through the rigid bronchoscope.

The length and diameter of the silicone stent were chosen on the basis of direct bronchoscopic examination of the post-dilatation airway diameter. The most common stent size used had a diameter of 10 to 12 mm and a length of 2 to 4 cm. For stenotic airways where there was significant size discrepancy between proximal and distal extents, 2-step stents with different proximal and distal diameters (Hood Silastic 2-step Stent with Posts and Mesh; Hood Laboratories) were used. Stents that would potentially cover the upper lobe bronchus were modified with a 6-mm punch hole for the upper lobe orifice. Each stent was folded into the stent applicator so that its distal extent was just proximal to the bevel of the rigid bronchoscope, positioned by direct visualization below the area of stenoses, and deployed by withdrawing the scope while pushing the stent out over the stenosis. Minor adjustments in stent location were done with alligator forceps. Patients with type 2 and 4 strictures that spanned a lobar bronchus/bronchi had a stent placed that was specifically contoured with an opening(s) on its side allowing for patency of the lobar opening(s). Rigid and flexible bronchoscopy were used to confirm stent placement and clear postobstructive secretions.

Stent removal was performed under general anesthesia by grasping the proximal edge of the stent with a rigid alligator forceps through a rigid bronchoscope. The alligator forceps were then turned coaxially until the stent folded in and the proximal portion could be pulled up to the rigid bronchoscope. The bronchoscope, forceps, and stent were then removed together. The rigid bronchoscope was inserted again and in combination with flexible bronchoscopy was used to evaluate the patency of the airway.

Statistical Methods

Continuous data are expressed as means $\pm$ standard deviation throughout the text and figures. Nominal variables are expressed as percentages.

In the "Results" section, nominal variables were analyzed by a 2-sided Fisher's exact test analysis. Preoperative and postoperative forced expiratory volume in 1 second (FEV₁), forced vital capacity (FVC), and FEV₁/FVC were compared using a paired 1-sided Wilcoxon rank-sum test. All statistical analyses were performed using R 2.6.2 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

A total of 348 anastomoses at risk were reviewed in 240 patients (132 SLT, 108 DLT). Twenty-two bronchial stenoses (6.3%) occurred in 20 patients. Patient demographics, type of bronchial narrowing, and interval to treatment of complications are described in Table 1. Eight patients had chronic obstructive airway disease, 6 patients had cystic fibrosis, 3 patients had idiopathic pulmonary fibrosis, 3 patients had bronchiectasis, 1 patient had lymphangiomatosis, and 1 patient had eosinophilic granulomatosis. Principal signs and symptoms were dyspnea in 80%, respiratory distress in 5%, pneumonia in 20%, and respiratory failure requiring ventilator support in 10%. A decline in FEV₁ was noted in 85% of patients before diagnostic bronchoscopy. The interval to the occurrence of an airway stenosis requiring treatment intervention was 81.5 ± 26.9 days, ranging from 35 to 135 days after transplantation for all patients. A spectrum of different airway stenoses were seen. Fifty-four

TABLE 1. Classification of Lung Transplant Stenosis Type and Demographics

	All Types	Type 1	Type 2	Type 3	Type 4

		Stenosis within 1cm of anastomosis	Stenosis within anastomosis and extending >1cm	Distant stenosis	Diffuse airway stenosis
#Patients strictures	22 (100%)	12 (54.5%)	5 (22.7%)	3 (13.6%)	2 (9.1%)
% Male	68.2% (15/22)	75% (9/12)	60% (3/5)	100% (3/3)	0 (0/2)
% right lung	50% (11/22)	16.7% (2/12)	100% (5/5)	100% (3/3)	50% (1/2)
Mean age	44.2 ± 13.3	48.1 ± 13.4	48.2 ± 7.4	35.3 ± 11.3	24.7 ± 1.5
Transplant Type					
DLT	11*	4	4	3	2
SLT	9	8	1	0	0
Donor ischemia time (minutes)	224.2 ± 52.1	216.1 ± 52.4	217.6 ± 48.6	263.0 ± 41.6	231.5 ± 91.2
Time to Stricture Diagnosis (days)	81.5 ± 26.9	84.3 ± 29.3	77.6 ± 17.9	67.0 ± 8.7	96.0 ± 55.2

DLT, Double lung transplant; SLT, single lung transplant. *2 DLT patients had bilateral stenoses.

one-half percent of strictures (12/22) were limited to the bronchial anastomosis (short stenosis, type 1), whereas 22.7% of strictures (5/22) encompassed the anastomosis and extended more than 1 cm into the donor bronchial tree, often extending across the upper lobe orifice on the right or left side (long stenosis, type 2). A small proportion of stenoses (13.6%; 3/22) were found to be remote to the bronchial anastomoses, all in the bronchus intermedius on the right (distal stenosis, type 3), whereas 9.1% of strictures (2/22) were classified as diffuse bronchial stenosis spanning at least 2 lobar orifices (long and diffuse stenosis, type 4). There was no correlation between donor ischemic time and side of transplant with the development of stenosis, although more diffuse (type 2 and 4) bronchial stenoses tended to predominate on the right side. There was no clear correlation between the underlying disease and the type of stenosis, except that all 3 cases of type 3 stenosis occurred in patients with cystic fibrosis. Both patients with type 4 disease had prolonged hypotension in the immediate postoperative period. Whether this factor contributes to the development of diffuse airway injury is not clear.

Several clinical parameters were found to be associated with airway stenosis after lung transplantation, including

Aspergillus fumigatus or actinomyces infection (18/20 patients with stenosis; [90%], compared with 9/220 patients without stenosis; [4.1%], $P < .001$), age less than 45 years (13 patients with stenosis; [65%], compared with 65/220 patients without stenosis; [29.5%], $P = .002$), *Pseudomonas aeruginosa* infection (6/20 patients with stenosis; [30%], compared with 11/220 patients without stenosis; [5.0%], $P = .001$), and first rejection within 3 months of transplant (6/20 patients with stenosis; [30%], compared with 5 of 220 patients without stenosis; [2.3%], $P < .001$) (Figure 1). Factors such as preoperative steroid use, reflux symptoms, preoperative disease type, and ventilator support more than 48 hours did not correlate with the development of airway stenosis.

Five patients had granulation or fibrinous infected tissue at their anastomoses contributing to initial airway narrowing, which was treated with mechanical or yttrium-aluminum-garnet laser debridement before balloon dilatation. All bronchial strictures were treated with at least 1 session of balloon dilatation before stenting (Table 2). Nine patients required 2 to 3 sequential balloon dilatations, and 2 patients required 3 to 5 sequential dilatations. All individuals experienced either symptomatic improvement (18 patients) or reduced ventilatory support (2 patients).

FIGURE 1. Clinical factors associated with bronchial stenosis.

Data on pulmonary function tests immediately before dilatation and stent placement and immediately after stent removal are detailed in Table 3. Mean FEV₁, FVC, and FEV₁/FVC at the time of diagnosis of bronchial stenosis were 1.95 L/s (range 0.6–3.86 L), 2.91 L/s (range 1.21–4.86 L), and 66.3%, respectively. After the stents were removed, mean FEV₁ was 2.76 L (mean increase of 41.5% or 0.81 L, $P = .003$), mean FVC was 3.42 L (mean increase of 17.5% or 0.51 L, $P = .009$), and mean FEV₁/FVC was 81.3% ($P = .02$).

On average, patients underwent flexible bronchoscopy every 3 to 4 months after stent placement. Although secretions were found within stents, only 2 patients required emergency bronchoscopy for secretion obstruction, over a total follow-up of 16.8 patient years (Table 2). Three stents required repositioning at least once over the same follow-up period. Five stenoses (22.7%) required a longer stent than originally placed, and this upsizing was done over a mean time frame of 6.3 ± 4.7 months. Granulation tissue was debrided from the airway next to stent orifices in 2 patients, both with type 2 strictures at a mean of 274 ± 85 days after stent placement. Between approximately 10 and 12 months after stent placement, all stents were removed and the airways were inspected. Twelve anastomoses were widely patent and required no further intervention at this time, whereas 9 anastomoses required repeat stent insertion after airway evaluation (1 patient died during this interval). Thereafter, every 4 months, stents were removed and the airway was re-examined for patency until permanent stent removal was achieved.

The majority of patients who had aggressive early stent placement and treatment of underlying fungal/bacterial infections had resolution of their bronchial stenoses with permanent stent removal within 362.3 ± 126.4 days (range

185–567 days). All but 4 patients had successful removal of their stents with resolution of their bronchial strictures. Two individuals died with a bronchial stent in place. One patient had persistent left main bronchial stenosis that on autopsy (after death from pneumonia and hepatic failure) was found to have been large cell lymphoma infiltrating the airway wall compressing the bronchial lumen at that site, whereas the other patient, who had diffuse bronchial stenosis treated with 2 stents in parallel in the right bronchial tree, died of chronic rejection and pneumonia. Two recent patients in our series currently have stents in place that have not been removed yet. At a mean follow-up of 4.9 ± 3.5 years after stent removal, all patients had patent airways with resolution of stricture requiring no further treatment.

Overall, 3-year survival of transplant patients without stenosis during the study period was 68% (150/220), compared with 85% (17/20) for patients with stenosis/stent ($P = .058$). Although there is no statistical difference in survival, the results suggest a possible trend toward survival benefit. The conditional 3-year survival of patients without stenosis who lived more than 3 months posttransplant was 87%. In comparing long-term outcome of the 2 patient groups, the use of conditional survival may be more appropriate because deaths in the immediate posttransplant period were related to early complications, before the development of bronchial stenosis.

DISCUSSION

Airway stenoses are a continuing problem in lung transplant recipients. Previous studies have reported an incidence of perianastomotic stenosis in up to 40% and nonanastomotic distal bronchial stenoses in up to 4% of patients after lung transplantation.^{1,2} However, these studies did not

TABLE 2. Airway Manipulations Before and During Stenting

	All Types	Type 1	Type 2	Type 3	Type 4
Dilatations per patient prior to stenting	1.8 ± 1.1	1.5 ± 0.8	2.2 ± 1.6	2.3 ± 1.4	2.0 ± 1.4
# Patients requiring stent repositioning or upsizing	8	4/8 (50%)	1/8 (12.5%)	1/8 (12.5%)	2/8 (25%)
# Patients requiring emergency bronchoscopy for secretion clearance	2	0	1/2 (50%)	0	1/2 (50%)
Mean time from diagnosis to stent removal (days)	362.3 ± 126.4	386.1 ± 139.8	313.2 ± 94.3	354.5 ± 149.2	NR
Mean length of follow-up after stent removal (years)	4.9 ± 3.5	4.9 ± 3.5	4.0 ± 4.0	7.7 ± 1.4	NR
Stent					
Average diameter		10 mm	10 mm	10 mm	10 mm
Average length		3 cm ± 6 mm opening for RUL orifice	3 cm ± 6 mm opening for RUL orifice	3 cm	4 cm

Data expressed as mean ± standard deviation or number of patients affected/total number of patients (%). NR, Not removed.

differentiate clinically significant stenosis from mild non-progressive anastomotic narrowing that rarely results in clinical compromise. On the basis of our experience in both transplant recipients and patients without transplant, airway narrowing without concomitant underlying lung disease rarely causes clinical symptoms unless the occlusion exceeds 50%. By using this criterion, we report a 6.3% incidence of clinically significant airway stenosis in a single-center experience of 240 consecutive lung transplant recipients.

Traditionally, bronchial stenoses after lung transplantation have been treated with balloon dilatation and expandable nitinol or stainless steel mesh stents. They have been, and are still, a popular choice in many centers for the management of airway stenoses, largely because of the ease of stent placement. However, our experience, as well as others, indicated that wire mesh stents are associated with significant and frequent complications, including 1) granulation tissue overgrowth within stent interstices,⁷ 2) stent fracture with wires protrusion,⁸ 3) stent erosion through the airway,⁹ 4) longitudinal stent collapse,¹⁰ 5) and trouble with stent removal.¹¹

Because of these problems, we chose to use studded silicone stents to manage our lung transplant recipients with bronchial stenosis. Several unique features of the Hood stent design include 1) a self-expanding capacity making it easy to deploy; 2) a thin wall structure providing a larger lumen than the other silicone stents; 3) the presence of silicone studs on the surface of the outer diameter, which effectively reduce stent migration; 4) a comparatively low incidence of severe granulation tissue formation; and 5) the ability to be easily beveled at an angle or cut with a side hole to allow the stent to conform to anatomy and preserve ventilation of adjacent lobes. This last feature is especially

important in lung transplant recipients because of the short distance between anastomosis and subsequent lobar bronchial bifurcation.

Our study demonstrated significant objective functional improvement in patients who were managed with our approach. By using a combination of balloon dilatation, mechanical/laser debridement, and temporary silicone stent placement, our patients showed a significant increase in FEV₁ (mean improvement: 41.5%, *P* < .01). Similarly, FVC was increased by an average of 17.5% (*P* < .01) from baseline. The larger increase in FEV₁, compared with FVC, is consistent with the obstructive nature of airway stenosis, which would be expected to cause similar physiologic changes observed in other obstructive diseases, such as chronic obstructive pulmonary disease (COPD). The normalization of FEV₁/FVC ratio after therapy, from 66.3% to 81.3%, provides further objective evidence of efficacy with our approach.

In regard to factors that may be associated with the development of airway stenosis, a strong correlation was found between the presence of *Aspergillus fumigatus*, actinomyces, and *Pseudomonas aeruginosa* and the subsequent occurrence of airway complications. The reason for this association is not clear. We postulate that these organisms may cause airway inflammation and scar formation at the level of the anastomosis, particularly if they are present in the early postoperative period. The inflammation may also compromise blood supply to the allograft bronchus, resulting in ischemia and subsequent scarring. An alternative explanation may be that the abnormal ischemic or stenotic airways may predispose colonization and subsequent illness from different infective agents.

Clearly, there are different morphologic types of airway stenosis post-lung transplant. We propose a classification

TABLE 3. Follow-up After Stent Placement and Removal*

	All Types	Type 1	Type 2	Type 3	Type 4
Pre-Stent FEV ₁ (L)	1.97	2.12	2.84	1.76	0.6
Post Stent FEV ₁ (L)	2.76	2.89	3.00	2.97	1.33
Mean change FEV ₁ (L)	0.80	0.77	0.16	1.22	0.73
Pre-Stent FVC (L)	2.91	3.09	3.56	2.9	1.21
Post-Stent FVC (L)	3.42	3.58	3.59	3.79	1.59
Mean change FVC (L)	0.52	0.50	0.03	0.89	0.38
Pre-Stent FEV ₁ /FVC (%)	66.27	68.6	79.6	61.2	78.8
Post-Stent FEV ₁ /FVC (%)	81.28	81.3	83.7	49.3	83.4
Mean change FEV ₁ /FVC (%)	15.01	12.77	4.1	17.65	34.1
% 3 year patency after stent removal	100	100	100	100	NA
# Deaths within 3 years of stent removal	1	0	1	0	NA

FEV₁, Forced expiratory volume in 1 second; FVC, forced vital capacity; L, liters; NA, not applicable. *2 patients stented while on mechanical ventilation not included in analysis.

system based on morphologic characteristics. The most common type of stenosis is an isolated anastomotic narrowing (type 1) without an obvious association to the underlying lung disease. We also found preliminary evidence of an association between isolated distal stenosis (type 3) and cystic fibrosis. It is possible that the chronically infected proximal airways of these patients may lead to rapid focal colonization of the recipient lung. Finally, we believe that diffuse airway stenosis (type 4) may be associated with prolonged hypotension in the immediate postoperative period and may require lifelong stent placement. With better characterization of all types of airway stenoses, we hope that more data can be generated from the transplant community to improve understanding of these conditions in the future.

We have adopted an aggressive approach of surveillance bronchoscopy for all lung transplant recipients with stents to manage and prevent complications. On average, we performed bronchoscopic examinations every 3 to 4 months after stent placement and for at least 6 months after stent removal. We also treated all cases of *Aspergillus* found on bronchoscopy, often with lifelong therapy. In the past, it has been reported that anastomotic strictures after lung transplant were a lifelong problem.¹² However, we found that, with our approach, most airway stenoses were curable with stenting and treating of underlying infections, usually within a 1-year timeframe. We show that aggressive, early stenting leads to less long-term stricturing of the airway and ultimately to resolution of this problem in almost all patients. Once airway remodeling has occurred, stents could be removed and luminal patency maintained. Stenting was safely accomplished in the presence of gross anastomotic infections and was associated with long-term improvement in FEV₁. Finally, we found that the use of studded silicone stents avoided many of the complications of wire mesh stents and allowed us to easily remove the stents after the lesions matured.

Previously available tracheobronchial prostheses made of silicone had drawbacks resulting from rigidity, wall thick-

ness, and propensity for stent migration. Since 1996, we have used a thin-walled expandable silicone airway stent with external 3-mm protrusions spaced every 0.5 square cm.¹³ The rounded protrusions help anchor the stent to the bronchial wall without granulation ingrowth.¹⁴ With this stent, we have not experienced infolding of the stent or major stent dislodgement. However, several drawbacks to the Hood-studded silicone stent should be pointed out. Minor problems with stent encrustation did occur; however, these were handled easily with flexible bronchoscopy. The occurrence of this problem has been minimized with a nebulized saline airway humidification regimen and, in severe cases, the addition of recombinant human deoxyribonuclease I (Pulmozyme; Genetech; San Francisco, Calif) nebulized regimen. Stent migration, although uncommon, is seen. Finally, placement and removal of these stents require rigid bronchoscopy and general anesthesia. It should also be noted that, in our hands, stenting in the 2 patients with diffuse airway stenosis improved symptomatology but was not curative. This challenging subset of patients required more frequent stent manipulation and surveillance bronchoscopy compared with patients with other post-lung transplant stricture types.

Despite these caveats, short and longer segment bronchial stenoses were effectively treated with this modality. We were able to remove 18 of 22 stents from our patients. To our knowledge, this is the largest published series of stent removal in the adult lung transplant population. Similar encouraging results with silicone stent removal after anastomotic complications in the adult lung transplant population¹⁵ and pediatric lung transplant population¹⁶ have also been reported in small numbers of patients.

CONCLUSIONS

A multimodality approach to bronchial stenosis after lung transplant, which uses balloon dilatation, debridement, and silicone stenting, is curative in most patients. Patients with

suspected airway problems should be referred for early bronchoscopy with the potential for stent placement. Our experience with studded silicone stents in the setting of post-transplant airway obstruction demonstrates the safety, ease of placement, and potential for stent removal with permanent cure of bronchial stenosis. The good long-term outcome of most of the patients in our series who were treated with these stents justifies their expanded use for anastomotic strictures after lung transplant.

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