Refractory post-transplant airway strictures: successful management with wire stents

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Abstract

Objective: Bronchial stenosis, malacia and dehiscence are major airway complications of lung transplantation. Our success in managing this problem evolved from the use of semi-rigid dilators, to balloon dilation and placement of a stent, which were initially silicone, thereafter wire balloon-expandable and finally wire self-expandable.

Methods: From May, 1994 until July 1997, we performed a total of 49 single and 58 bilateral lung transplants. Symptoms of shortness of breath, verified by a drop in the forced expiratory volume in one second (FEV1), led to bronchoscopic inspection of the airway in lung transplant patients. Eighteen patients (16%) suffered a severe form of airway complication (dehiscence or stenosis) in 24 of 151 airways at risk (15.9%). These anastomotic strictures were recalcitrant to conventional therapy. Intervention consisted of rigid bronchoscopy, dilation of the stricture and placement of a stent. Flexible bronchoscopy and fluoroscopy were used for precise placement of the stent. As the initial stent, the Hood silicone stent was placed five times in four patients and the Dumont studded stent five times in four patients. The Palmaz wire stent was used as the initial stent 10 times in seven patients and the Wallstent used eight times in seven patients. Four patients had multiple stents. Balloon inflation moulded the wire stent to the airway.

Results: There was no mortality resulting from the airway complication or any intervention. The most serious complication was a perforation of the airway using the semi-rigid dilator that necessitated immediate thoracotomy and re-anastomosis of the bronchus. Other complications necessitated repeat interventions due to restenosis or failure of the stents. The success of the stent placement was measured subjectively by the immediate ease of breathing enjoyed by each patient and objectively by the significant increase of the FEV1 from a pre-operative mean of 1.19 l (SD 0.64 l) to a post-operative mean of 2.06 l (SD 0.70 l) (P < 0.0001). The mean number of interventions according to the type of wire stent first used was significantly fewer with Wallstent insertion (1.28 (SD 0.48)) than in those patients in whom a Palmaz stent was inserted (5.22 (SD 2.38)) (P < 0.0008).

Conclusion: The airway complication of stricture, broncho-malacia or dehiscence following lung transplantation can be managed effectively and easily with the use of balloon catheter dilation followed by precise placement of a self-expandable wire stent. The Wallstent is the superior stent for this application. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Lung transplantation; Bronchial stricture; Wire stents; Silicone stents; Balloon dilation; Airway complication

1. Introduction

One of the challenging problems of lung transplantation is that of airway complications [1]. Breakdown of the tracheal or bronchial anastomosis was a major factor that delayed its emergence as a standard of therapy [2]. Bronchial complications occurred in 13 of 17 patients in the first...
ture and/or partial dehiscence is often undertaken in a conservative fashion with the use of a flexible fiberoptic endoscope. Debridement of necrotic tissue with forceps, dilation of a stricture with a balloon [13] and surveillance biopsies can all be performed as an outpatient.

Clues to the recognition of a significant airway problem are shortness of breath, cough, fever and malaise. A drop in the spirometric measurement of the forced expiratory volume in one second (FEV₁) and biconcave changes of the flow-volume loop [14,15] provides an objective measurement that indicates the development of significant post-transplant problems such as rejection, infection or airway obstruction. A chest radiograph may show an infiltrate or distal atelectasis. A CT scan may identify and estimate the severity of a bronchial dehiscence and the length and degree of a bronchial stenosis [16].

In an earlier report of our experience with 90 lung transplant patients from 1990 to 1993, we had bronchial complications in six of 66 (9%) bilateral lung transplant anastomoses and in eight of 57 (14%) single lung transplant anastomoses [17]. One post-operative death was attributed to bronchial dehiscence. During the current period (1994–1997), airway complications occurred in 18 of 116 (15.5%) bilateral lung transplant anastomoses and in six of 49 (13.8%) single lung transplant anastomoses. These strictures were recalcitrant to the usual treatment approach of dilation, debridement and stenting with silicone stents.

Our initial management with insertion of Hood silicone bronchial stents (Hood Laboratories, Pembroke, MA) had not been satisfactory. These stents were unforgiving and difficult to insert and maneuver into proper position. In our experience, it required frequent intervention to replace or adjust these stents. Besides migrating, they also often become inspissated with mucus and caused airway obstruction. Dumont silicone studded stents (Bryan, Woburn, MA) were utilized next because they were thought to migrate less due to the studs. But these problems recurred. Granulation tissue also built up around the orifice of the silicone stents, requiring debridement with forceps or with the Nd:YAG laser. As a result, we turned to treating these strictures and dehiscences with expandable metal stents and this is the subject of our report.

2. Materials and methods

2.1. Patients

From May 1, 1994 to July 31, 1997, we performed lung transplantation in 107 patients. Fifty-eight patients underwent bilateral single lung transplant (BSL), 24 patients had a right single lung transplant (RSL) and 25 patients had a left single lung transplant (LSL). The technique of lung donor harvesting and recipient transplantation was uniform throughout this period and followed the technique as described by Cooper [7]. The recipient bronchus was cut flush with the mediastinum and the donor bronchus cut flush within two cartilagenous rings proximal to the takeoff

<table>
<thead>
<tr>
<th>No.</th>
<th>Age</th>
<th>Sex</th>
<th>Diagnosis</th>
<th>Transplant date</th>
<th>Transplant type</th>
<th>Time to complication (days)</th>
<th>Complication</th>
</tr>
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<tbody>
<tr>
<td>1.</td>
<td>47</td>
<td>Male</td>
<td>IPF</td>
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<td>BSL</td>
<td>17</td>
<td>L Stenosis/Malacia</td>
</tr>
<tr>
<td>2.</td>
<td>52</td>
<td>Male</td>
<td>COPD</td>
<td>9/2/94</td>
<td>LSL</td>
<td>91</td>
<td>L Stenosis/Malacia</td>
</tr>
<tr>
<td>3.</td>
<td>64</td>
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<td>COPD</td>
<td>9/2/94</td>
<td>RSL</td>
<td>91</td>
<td>R Stenosis</td>
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<tr>
<td>4.</td>
<td>56</td>
<td>Female</td>
<td>PPH</td>
<td>9/16/94</td>
<td>BSL</td>
<td>35</td>
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</tr>
<tr>
<td>5.</td>
<td>65</td>
<td>Male</td>
<td>IPF</td>
<td>9/21/94</td>
<td>RSL</td>
<td>34</td>
<td>R Dehiscence/Stenosis</td>
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<tr>
<td>6.</td>
<td>43</td>
<td>Male</td>
<td>CF</td>
<td>10/18/94</td>
<td>BSL</td>
<td>86</td>
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</tr>
<tr>
<td>7.</td>
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<td>10/31/94</td>
<td>BSL</td>
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<td>8.</td>
<td>18</td>
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<tr>
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<td>CF</td>
<td>12/10/94</td>
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</tr>
<tr>
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<td>40</td>
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<td>CF</td>
<td>6/5/95</td>
<td>BSL</td>
<td>94</td>
<td>R Stenosis/L Stenosis</td>
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<tr>
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<td>COPD</td>
<td>11/14/95</td>
<td>LSL</td>
<td>152</td>
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<td>83</td>
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<tr>
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<td>OB (CF)</td>
<td>3/4/96</td>
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<td>L Stenosis</td>
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<td>50</td>
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<tr>
<td>16.</td>
<td>52</td>
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<td>AAT</td>
<td>10/14/96</td>
<td>BSL</td>
<td>39</td>
<td>R Dehiscence/Stenosis/L Dehiscence</td>
</tr>
<tr>
<td>17.</td>
<td>34</td>
<td>Male</td>
<td>CF</td>
<td>1/27/97</td>
<td>BSL</td>
<td>72</td>
<td>R Stenosis/L Stenosis</td>
</tr>
<tr>
<td>18.</td>
<td>28</td>
<td>Male</td>
<td>CF</td>
<td>4/21/97</td>
<td>BSL</td>
<td>98</td>
<td>L Stenosis</td>
</tr>
</tbody>
</table>
of the upper lobe bronchus. The membranous portion on both sides was left generously long as a flap. The bronchial anastomosis was end-to-end. The posterior layer (membranous portion) was anastomosed everting the edges with a running layer of 4-0 polyglyconate suture. The cartilaginous portion was brought together with simple interrupted sutures. In case of disparity of size, the smaller (usually donor) bronchus was telescoped into the larger lumen. The anastomosis was covered by peribronchial tissues or donor pericardium. Omentopexy was not utilized. Bronchoscopy was performed at the end of the procedure to verify patency. Triple drug immunosuppression included the use of steroids given intra-operatively and continued post-operatively.

During this period, 18 of 107 patients (16.8%) suffered airway complications of anastomotic stricture and/or dehiscence. Of 165 airway anastamoses at risk, 24 were affected (14.5%). If we separate our patients into two time periods (Phase I: 5/94 to 12/95 and Phase II: 1/96–7/97) we see that the incidence of airway complications declines with greater experience in lung transplantation. The overall incidence during Phase I was 18.5% (15/81 anastamoses) and during Phase II was 10.7% (9/84 anastamoses) (Table 1). The demographics of these patients are shown in Table 2.

Surveillance bronchoscopy and treatment by debridement and balloon dilation was initially performed by the pulmonologist. The strictures and other airway complications that were recalcitrant to conservative management were then referred to surgery for aggressive therapy. Subjective symptoms of shortness of breath, malaise, cough and fever and a drop in FEV₁ were present in all of these patients. The presence of stricture, granulation tissue and/or dehiscence was confirmed by bronchoscopy.

2.2. Technique

Patients were taken to the operating room and under general anesthesia underwent rigid bronchoscopy. The largest scope possible (usually 10.5 mm) was used. In this way, good control of the airway was ensured. Ventilation was intermittent or by use of jet inhalation. A flexible bronchoscope was then passed through the rigid bronchoscope and the airway was assessed (Fig. 1A), secretions suctioned and a flexible guidewire passed through the stricture area. A tapered semi-rigid rubber dilator (American Endoscopic Dilator; Bard Interventional, Billerica, MA) was passed along the guidewire to dilate the stricture. These dilators were used during our early patient experience. Sizes up to 24-26 Fr. were the maximum dilation achieved.

More versatility and safety, however, was provided by the use of balloon dilators. Balloons (Blue Max, Meditech; Boston Scientific, Waterton, MA) were used in variable sizes from 6 to 15 mm. The balloon was inflated using a hand injector to the maximum recommended inflation pressure between 4 and 16 atm for 30–60 s (Fig. 1B). Excess granulation tissue or necrotic debris was removed by forceps through the rigid scope or with the use of the YAG laser with the filament introduced through the flexible scope.

The types of stents used in the early experience were silicone (Hood or Dumont). The silicone stent was placed over the end of the rigid bronchoscope, positioned and then deployed by withdrawing the scope all the while holding the stent in its place with a larger endotracheal tube loaded over the bronchoscope [1,18]. Then balloon expandable wire stents (Palmaz; Johnson & Johnson Interventional Systems, Warren, NJ) or self-expandable wire stents (Wallstent; Schneider (USA), Pfizer Hospital Products Group, Minneapolis, MN) were deployed.

The Palmaz stent was placed using fluoroscopic guidance for positioning and balloon dilation for expansion. The self-expanding radial wire stent Wallstent was first used when problems of collapse and buckling of the Palmaz stent occurred. Flexible fiberoptic bronchoscopy allowed for direct visualization of the deployment of this stent (Fig. 1C) and fluoroscopy was unnecessary for placement of this stent. Multiple stents could be placed sequentially and one stent could be deployed within another stent. The balloon used to dilate the stricture was used to further dilate the wire stent and mould it into the airway. The flared ends of the Wallstent prevented it from migrating (Fig. 1D) (as was noted with previous stents).

The purpose of dilation and stenting was to open the airway, prevent its’ further collapse and increase airflow across the stenotic portion of the airway. The subjective
evidence of success was manifested in the immediate relief of dyspnea in the extubated patients and relief of agitation and desaturation in those that were ventilator-dependent pre-op and remained so post-stenting. The objective evidence of success was the increase in the spirometry (FEV₁) after stenting [19].

2.3. Statistical analysis

Standard spirometric measurements were obtained according to a routine post-transplant testing schedule. Interventions recorded were those performed by the authors. Data were expressed as the mean ± SD. Comparisons were performed using paired or non-paired t-tests using statistical software (Stat View 4.01; Abacus Concepts, Berkeley, CA); P values less than or equal to 0.05 were considered significant.

3. Results

3.1. Operative interventions

The mean time from transplantation to development of recalcitrant airway stricture/dehiscence was 70 days (SD 30 days) (Table 3). The number and types of interventions are demonstrated in detail in Fig. 2. Each operative encounter is noted and consists of rigid and flexible bronchoscopy with a combination of dilation, debridement and stent placement. The experience can be divided into the earlier patients who had silicone stents placed initially (and multiple times thereafter) and those patients who had wire stents placed. The Hood silicone stent as the initial stent was placed five times in four patients and the Dumont studded stent five times in four patients. All were removed: one patient had no further therapy (Patient 3), one underwent additional balloon dilation (Patient 6), two required re-anastomosis of the bronchial dehiscence as a result of manipulation of the stent (Patients 8 and 9), and one (Patient 7) underwent re-anastomosis of the disrupted bronchus due to use of semi-rigid dilators.

In an effort to improve on the efficacy of stents in the airway, we placed a wire stent for the first time on 2/9/95. Patient 4 had seven interventions with multiple placement of silicone stents, dilation and debridement of the right and left bronchial strictures. The inability to achieve a lasting solution with these stents led us to place 30 × 8 mm Palmaz stents in the right and left mainstem bronchus and then to successively dilate these stents with a 12 mm balloon. This patient had an improvement in the FEV₁ from 1.38 to 2.30 l immediately post-op. She remains well to this date with the stents in place.

The Palmaz was the initial wire stent placed 10 times in seven patients. It remained the ultimate stent in four of these patients. The Wallstent as the initial stent was used eight times in seven patients. Two (Patients 5 and 9) had multiple stents (right main, intermedius and lower bronchi) and

Table 3
Time from transplant to airway complications (n = 18) (May 1, 1994–July 31, 1997)

<table>
<thead>
<tr>
<th>Time from transplant to airway complication (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Median</td>
</tr>
<tr>
<td>Range</td>
</tr>
</tbody>
</table>

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Fig. 2. Interventions in lung transplant patients with airway complications.
another (Patient 11) required overlapping stents in the left mainstem bronchus (placed a year apart). The last four Wallstents placed were silicone covered (Permalume®). Four patients had both silicone and wire stent(s).

The YAG laser was utilized to debride granulation tissue in nine patients (50%) in this series. It was used as the initial therapy along with balloon dilation (twice) to debulk the obstructing granulation tissue and subsequently to debride granulation tissue obstructing the silicone stents (four times) and granulation tissue growing through the wire stents (10 times).

3.2. Frequency of intervention

We compared the frequency of intervention before and after both Palmaz and Wallstent wire stent placement. Palmaz stent placement did not decrease the number of interventions required. The number of interventions before and after Palmaz stent insertion were similar. Wallstent insertion, however, tended to decrease the number of subsequent interventions required, although this did not reach statistical significance.

Comparing the total number of interventions according to the type of stent first used, we found that strictures managed primarily with Wallstent insertion required significantly fewer interventions ($P < 0.0008$) than ones in which a Palmaz stent was initially used (Fig. 3). An average of nearly four fewer procedures was required when a Wallstent was used. To date, there have not been any dislodgement or migration of the Wallstent in this series of patients.

3.3. Spirometry

The results of the spirometry (FEV$_1$) before and after stent intervention are in Fig. 4. The FEV$_1$ mean went from a pre-stent value of 1.19 l (SD 0.64 l) to a post-stent value of 2.06 l (SD 0.71 l) ($P < 0.0001$) within 30 days and increased further in the next 6 months to 2.32 l (SD 0.74 l) ($P < 0.0001$) (Table 4). This is based on data in 12 patients. Three patients remained ventilated and three did not have complete data. There was a highly significant increase in FEV$_1$ following stent insertion that approached 900 cc and was maintained during the subsequent months.

3.4. Complications

Complications were seen with the use of the semirigid rubber dilator, silicone stent and the Palmaz wire stent. Three patients required immediate thoracotomy and re-anastomosis of the bronchial anastomosis: Patient 7 due to a disruption caused by the rubber dilator; Patient 9 due to the forcing of a Dumont stent through a dilated stricture, and Patient 8 following an attempt to place a Hood stent across an anastomotic stricture. Patient 16 underwent a thoracotomy and re-anastomosis of the bronchus due to bronchial bleeding. No vascular injury was found and the patient had no further bleeding but died four months later from sepsis.

The Palmaz stent has not been without problems. In two patients, this stent buckled, deformed and obstructed the airway. In Patient 3, this was removed and replaced with another Palmaz stent. Four months later, this second stent collapsed and could not be removed. The bronchus was dilated with a balloon and a 10 × 20 mm Wallstent was successfully deployed over it and redilated. The patient’s FEV$_1$ improved from 0.85 to 1.33 l.

Patient 9 developed stenosis of both bronchial anastomosis 68 days after bilateral lung transplantation for cystic fibrosis. After dilation, a Dumont stent was successfully placed in the right mainstem bronchus. Placement of a stent into the left bronchus resulted in dehiscence and tension pneumothorax leading to emergent thoracotomy and re-anastomosis of the left bronchus. Three weeks later, the right Dumont stent became obstructed, was removed and a 12 × 8 mm Palmaz stent was placed in the bronchus intermedius and an 18 × 8 mm Palmaz stent was placed in the right mainstem bronchus and dilated. He subsequently required debridement of granulation tissue with the YAG laser, balloon dilation and placement of an 8 × 20 mm Wallstent.

There have been no operative deaths as a result of bronchoscopy or the manipulation of the airways with the dilators and stents. Four patients in this group died of various post-transplant problems. Two patients died early due to sepsis and multi-organ failure. Two patients died late due to lymphoma and progressive bronchiolitis obliterans.
Possible causative factors of airway complications that have been shown by investigators not to be significant include ischemia time of the donor lung [7,11,12,26] and number of rejection episodes [11,12]. Time spent on mechanical ventilation, however, was a significant factor in the development of airway complications in some series [7,24], but not in others [26].

Surgical technique plays a very important role in preserving healthy bronchial tissue and that consists of minimal dissection of the peribronchial tissues [26] and keeping the bronchial segment as short as possible [27]. The technique of bronchial artery re-anastomosis has been championed by a number of investigators as leading to decreased airway problems [3,28,29]. Schafers et al. [12] have shown that pharmacologic manipulation using continuous administration of heparin, prostacycline and corticosteroids improved pulmonary collateral flow and thereby promoted bronchial healing. Their subsequent experience showed an airway complication of only 4% [7]. The report of the St. Louis International Lung Transplant Registry for April 1997 (M. Pohl, personal communication) shows that the number of deaths within 60 days following transplantation due to airway dehiscence is less than 1% and is only 5% of all transplant deaths (37 of 751 patient deaths).

Our overall number of airway complications was 24 out of 165 anastomoses (14.5%) in 18 out of 107 patients (16.8%). This compares to the previously reported series at our institution from 1990 to 1993 of 14 out of 123 anastomosis (11.3%). There was a period of time in 1994 of an increased incidence of airway complications probably related to a variation of our standard harvesting technique with resultant bronchial ischemia. Although not approaching the excellent results of some centers (0–5%) [6,7,11], our latter experience shows a trend towards improvement and well within the range of other experienced centers [10,30].

Our approach to managing airway complications of stenosis and dehiscence that are recalcitrant to conservative therapy consist of management in the operating room with rigid bronchoscopy and general anesthesia. The rigid bronchoscope provides a secure airway and gives better control in the event of untoward complications such as hemorrhage. It provides a large area through which other instruments may be passed. The flexible fiberoptic bronchoscope provides excellent visualization of the operative field and is easily passed through the rigid bronchoscope. Management decision depends on thorough evaluation of the lesion and consists of these choices: no treatment; YAG laser resection of granulation tissue; balloon dilation of stenotic segments; placement of an appropriate stent. A stent is placed if there is > 50% obstruction of the lumen, or if obstruction is < 50% and there is a large amount of secretion accumulating distally. If malacia is present in the bronchial wall, a stent is placed to maintain airway patency.

Use of the semi-rigid dilator is not advised as increased

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### Table 5

Causative factors in airway complications of lung transplantation

<table>
<thead>
<tr>
<th>Donor ischemia time (min)</th>
<th>Airway complications</th>
<th>Present</th>
<th>Absent</th>
<th>( P )</th>
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<tr>
<td>Single lung transplant (SLT)</td>
<td>( n = 6 )</td>
<td>( n = 43 )</td>
<td></td>
<td>0.832</td>
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<tr>
<td></td>
<td>242.5</td>
<td>248.77</td>
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<tr>
<td></td>
<td>( \pm 57.07 ) SD</td>
<td>( \pm 68.68 ) SD</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>( \pm 23.30 ) SE</td>
<td>( \pm 10.47 ) SE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bilateral single lung (BSL)</td>
<td>1st Lung</td>
<td>( n = 13 )</td>
<td>( n = 45 )</td>
<td>0.907</td>
</tr>
<tr>
<td></td>
<td>223.3</td>
<td>225.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( \pm 70.24 ) SD</td>
<td>( \pm 54.6 ) SD</td>
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</tr>
<tr>
<td></td>
<td>( \pm 19.48 ) SE</td>
<td>( \pm 8.28 ) SE</td>
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<tr>
<td></td>
<td>355</td>
<td>353.3</td>
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<td>0.686</td>
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<td></td>
<td>( \pm 131.83 ) SD</td>
<td>( \pm 85.38 ) SD</td>
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<td></td>
<td>( \pm 36.50 ) SE</td>
<td>( \pm 12.87 ) SE</td>
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<td></td>
</tr>
</tbody>
</table>

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### Table 4

Changes in FEV\(_1\) following stent insertion (\( n = 12 \)) (May 1, 1994–July 31, 1997)

<table>
<thead>
<tr>
<th>FEV(_1) (l/s)</th>
<th>Pre-stent</th>
<th>Post-stent</th>
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<tbody>
<tr>
<td></td>
<td>(&lt; 30 ) days</td>
<td>(1–6 ) months</td>
</tr>
<tr>
<td>1.19 ± 0.64</td>
<td>2.06 ± 0.70</td>
<td>2.32 ± 0.74</td>
</tr>
<tr>
<td>( P &lt; 0.0001 )</td>
<td>( P &lt; 0.0001 )</td>
<td></td>
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</table>
complications occur with its use. There are various sizes of balloons that may be inserted and under direct visualization can safely be inflated to the appropriate pressure and very successfully dilate most strictures. We used semi-rigid dilators early in our experience, but abandoned them in short order.

Silicone stents were used in the early part of our experience. The Hood stent was used initially, but we found that there were problems associated with this, especially migration of the stent and dislodgement when patients coughed vigorously. We then tried the studded Dumont stent hoping to help prevent migration, however, these were more difficult to insert, especially with distorted bronchial anatomy. We found that silicone stents often became inspissated with mucus. Others have used the silicone stents with good success [26,31]. Colt [26] and colleagues report on 270 Dumont stents placed with excellent results. They had good long term persistence of improved function. Stents were well tolerated and if secretions occluded the stent, it was replaced. Because our experience with the Dumont stents had not been good, we proceeded with the use of wire stents in the management of these difficult strictures.

The Palmaz stent was used first and was successful in achieving an open airway. Trinkle was one of the earliest to discuss the advisability of using a wire stent instead of silicone stents [10]. The problem associated with the Palmaz stent was that of deformity and buckling of the stent because of the forces of the bronchus compressing the stent. Since it has no resiliency nor an outward radial force, once the Palmaz wire stent is compressed, it cannot resume its original shape [30,32,33]. For this reason, we tried the Wallstent (Fig. 5) and found a number of advantages with its use [34–36]. This self-expanding radial wire stent moulds to the shape of the bronchus and provides constant outward tension. It is easily deployable under direct vision with the use of a flexible fiberoptic bronchoscope. Another advantage is that it does not migrate. Granulation tissue that may come through the interstices of the stent have been resected using a YAG laser. The newest type of Wallstent has a silicone covering (Permalume®) that may prevent the heaping up of such granulation tissue.

Patterson [9] discusses the difficulty of stenting the distal left main bronchus because of the possibility of obstructing the left upper lobe bronchus. The Wallstent is especially applicable to this situation for two reasons: (1) the distal end of the stent may be precisely placed just beyond the anastomosis, but proximal to the takeoff of the upper lobe bronchus; and (2) should there be an overlap of the stent across an open bronchus, an opening can easily be made with the YAG laser burning several filaments and creating an opening at the lobar orifice.

Success in any technique of stenting can be measured by bronchoscopic demonstration of a patent airway, an increase in objective measurements of airflow (FEV1), and by subjective improvement in the patient’s breathing. The success of a particular procedure is related to the expediency with which it can be performed and the permanence of the therapy. Following placement of stents, the patients must continue to have surveillance bronchoscopy and routine spirometric measurements that will then guide the necessity for any further therapy. We found that with the use of the Wallstent as the primary stent, the number of re-interventions are significantly decreased. Finally, other factors have to be considered in the evaluation of the success of stent placement, as failure can be due to the disease process itself and complications such as rejection, sepsis or other organ compromise.

In summary, although the incidence of airway complications in lung transplantation is decreasing, it continues to be a significant problem. However, once a problem of airway stenosis or dehiscence occurs, management is quite effective. The Transplant Registry shows that these complications are rarely a cause of death in lung transplant recipients. The Wallstent is an excellent wire stent that may be used to successfully deal with these complications and has the potential for limiting the number of re-interventions.

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Appendix A. Conference discussion

Dr A. Haverich (Hannover, Germany): There seems to be a lot of progress made regarding this very significant complication, especially in your group. It is a bit difficult to look at the incidence of bronchial stenosis in your group because you have presented the material differently from what you wrote in the abstract, but I think I did understand it rightly, that the incidence overall over the past years came down.

Dr Lonchyna: Yes. We had a particularly bad experience in 1994 with multiple complications, but thereafter the incidence went down.

Dr Haverich: What do you think the reason for that lower incidence is? And maybe you could comment on what kind of suturing you did and you do now for the bronchial anastomosis.

Dr Lonchyna: The suturing has been fairly standard: an end-to-end anastomosis with polyglyconate, the posterior layer being continuous and the cartilaginous portion being simple interrupted. I think early on we did do now for the bronchial anastomosis.

Dr Haverich: There seems to be a lot of progress in the field of bronchial stenosis after lung transplantation. What do you think the rationale for that lower incidence is? And maybe you could comment on what kind of suturing you did and you do now for the bronchial anastomosis.
to now we are happy with the Dumon stent to solve these problems, but I agree that Wallstents have a better indication, especially when the stenosis is very close to the bifurcation of the bronchus.

I didn’t understand if you used covered or uncovered Wallstent, and if you used uncovered Wallstent, did you have any problem with growing of tissue through the mesh?

**Dr Lonchyna:** One of the slides showed the growth of granulation tissue through the interstices of the Wallstent, and this is a problem. In the last three patients that I have placed a Wallstent in I used a silicone-covered stent, which has just become available to us, and I hope that in the future we’ll find that this will solve this problem.

**Dr Venuta:** I have one more question. You talked about stenosis but you showed also a picture of dehiscence. How did you treat these cases?

**Dr Lonchyna:** Most dehiscences we treat conservatively. Unless there is a massive air leak causing a pneumomediastinum or pneumothorax that needs to be treated with a chest tube, we can treat dehiscences conservatively and hope that as time goes on the healing process will occur. This particular patient required reanastomosis of the less involved side because of a bleeding problem.

The other side continued to heal, but several months later I placed a stent in the bronchus because of stricuring. But as far as dehiscence itself is concerned, as long as there is no massive air leak, we treat it conservatively.

**Dr M.A. Norgaard (Copenhagen, Denmark):** I would like to ask you: There has always been a problem with silicone stents and the mucociliary clearance across the stent, but I would imagine that the problem would probably not be so big with a wire stent since the epithelium will probably overgrow the wires after a while. Have you encountered any problems with the mucociliary clearance? My other question is: How long should it stay there? Do you have the impression that the bronchus wall will stabilize after a while, so that you will be able to remove the wire stents?

**Dr Lonchyna:** Mucus clearing is certainly a major problem with silicone stents, which is one of the reasons that prompted us to go into something different, because even though there is great production of mucus, at least the patients are able to clear it much better with the wire stents. It’s almost impossible to remove a stent once it’s in. I was able to remove a Palmaz Stent when it deformed and buckled once, but when I tried it on a different patient I couldn’t do it. I then ballooned it up against the wall and placed a Wallstent over it. Once it has a fair amount of tissue growing into it, it’s almost impossible to take the wire stents out. So my approach is that I always look first and see if balloon dilation and lasing may open the airway sufficiently enough, and only if I feel there is malacia or buckling or it’s just not opening up well enough, then I’ll put a stent in.

**Dr Haverich:** What is your algorithm now if you are dealing with a stenosis like 4 weeks after the transplant? You would go for a laser first, then balloon, or balloon, then laser, and then stent, or put a stent in every patient? I think you have to make this very clear to the audience.

**Dr Lonchyna:** I always look at the area first, and I will balloon almost everything because that will open up most strictures. If there is sufficient opening with the balloononing, I’ll leave it at that. The YAG laser is used as an auxiliary. If there is loose debris and I can remove it even better, I’ll use the YAG laser. The Wallstent or other wire stent I will use if I feel that it’s collapsing and I’m not accomplishing a patent airway. If I need to come back in a month or so, I’ll do that and put a stent in.