Use of the Flow-Volume Loop in the Diagnosis of Bronchial Stenosis After Single Lung Transplantation*


Bronchial complications, including stricture, stenosis, and/or anastomotic dehiscence, are a major cause of morbidity following single lung transplantation. This report describes a 19-year-old man with a diagnosis of end-stage pulmonary fibrosis secondary to prior chemotherapy for non-Hodgkin's lymphoma who underwent single lung transplantation. The immunosuppressive regimen included cyclosporine, azathioprine, and methylprednisolone sodium succinate (Solu-Medrol) intravenously for six doses during the first 3 days postoperatively followed by oral prednisone. Sixteen weeks following transplantation, the patient complained of dyspnea. Spirometry revealed a decrease in FEF25-75 and the flow-volume curve demonstrated a biocconcave appearance. The flow-volume loop showed a relatively high initial flow phase occurring over the first 2 to 3 s followed by a low-flow phase. The expiratory phase also showed the same characteristics. Bronchoscopy revealed 75 percent stenosis of the bronchial lumen to the transplanted lung. A transbronchial biopsy specimen obtained at that time was consistent with acute rejection. The patient was treated with a methylprednisolone bolus. A repeated bronchoscopy showed the persistence of stenosis distal to the anastomosis. The patient underwent several bronchoplastic balloon dilatations without complete resolution of the stenosis and a stainless steel mesh stent was placed. Repeated spirometry showed marked improvement of the FEF25-75 and normalization of the flow-volume loop. We conclude that the flow-volume loop curve is a noninvasive procedure that may help monitor the patency of the bronchial anastomoses following single lung transplantation.

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SLT = eq single lung transplant

Unilateral obstruction of the main-stem bronchus is a rare complication that is produced by a neoplasm or severe benign bronchial stenosis. In the past, bronchial complications have been a major cause of morbidity and mortality after lung transplantation. Since the lung graft receives most of the ventilation after transplantation, single lung transplant (SLT) recipients are more likely to develop symptoms due to stenosis than other patients. Bronchial complications have been reported in up to 14 percent of patients following SLT and most of these have been bronchial dehiscence with a resulting stricture or bronchial stenosis.

Stenosis of the trachea or main bronchus produces configurational changes in the flow-volume curve. The exact pattern depends on whether the narrowing affects the intrathoracic or the extrathoracic airway. The pattern produced by narrowing of one main bronchus is well recognized. In a recent study by Gelb et al., patients with unilateral main bronchial obstruction secondary to malignancy demonstrated a biphasic flow-volume curve with a normal early inspiratory curve but with a "straight line" appearance in the late inspiratory and expiratory curves. In one patient, relief of the bronchial stenosis by the insertion of a stent restored normal flow and the flow-volume curves normalized. The flow-volume curve should be even more sensitive to stenosis in SLT recipients since the airway in the graft receives more airflow than the airway in the native diseased lung, as evidenced by quantitative ventilation perfusion lung scanning.

We have recently seen one patient who underwent SLT and developed unilateral main-stem bronchial narrowing. This patient showed a progressive obstructive pattern in his spirometry with a marked decrease in FEV, and FEF25-75 percent. The maximal flow-volume curve demonstrated a biphasic pattern. The relief of the bronchial stenosis by placement of a stent resulted in a marked improvement in his pulmonary function and normalization of the flow-volume curve.

**CASE REPORT**

The patient was a 19-year-old man diagnosed as having non-Hodgkin's lymphoma in 1975 at 4 years of age when he presented with a left-sided jaw mass. His chemotherapy regimen included bleomycin, doxorubicin, and vincristine. He underwent left lung transplantation in October 1981 for end-stage pulmonary fibrosis thought to be due to bleomycin. The operative technique used has been reported previously. graft preservation was achieved by flushing the pulmonary artery bed with prostaglandin El, (PGE1) (500 mg) and Euro-Collins solution at 4 °C. Ischemic time was <180 min. Induction immunosuppression consisted of cyclosporine intravenously followed by maintenance oral treatment. The serum cyclosporine levels were titrated to 200 to 300 ng/ml (radioimmunoassay, specific whole blood monoclonal antibody, Incstar, Stillwater, Minn.). Maintenance azathioprine, 2mg/kg dose, was titrated to maintain WBC >5,000/mm³. Induction methylprednisolone sodium succinate (Solu-Medrol) 500 mg was given intravenously in the operating room followed by 125 mg every 6 h for 6 doses and then changed to maintenance oral prednisone (1 mg/kg/d).

The patient's hospital course was complicated by hypotension at 48 h postoperatively due to bleeding at the pulmonary venous anastomosis. The anastomosis was repaired and he recovered without any additional complications. A bronchoscopy done at that time showed a patent bronchial anastomosis. The patient was followed with serial spirometry (Fig 1A) and constant workload cycle exercise ergometry performed at weekly intervals, as previously described by our group. At 16 weeks posttransplant, the patient complained of dyspnea and a decrease was noted in his FEF25-75 percent and FEV. The flow-volume curve demonstrated a concave appearance (Fig 1B). The pattern was persistent on several flow-volume maneuvers. A fiberoptic bronchoscopy was performed and stenosis was observed distal to the anastomosis, occluding 75 percent of the bronchial lumen (Fig 2). A transbronchial biopsy specimen obtained at that time was consistent with acute rejection, grade A. The patient was treated with methylprednisolone, 500 mg intravenously, followed by oral prednisone at a dose of 1 mg/kg/d. Two weeks following treatment for acute rejection with bolus corticosteroids, a repeated bronchoscopy revealed a persistent stenosis.
distal to the anastomosis. The patient underwent several bronchoplasty balloon dilations improving the size of the stenosis to 40 to 50 percent of the lumen (Fig 2). The fiberoptic bronchoplastic dilations were performed as described by Keller and Frost. Despite the increase in the diameter of the bronchial lumen, the patient’s FEF25-75 percent and maximum flow-volume curve retained its bioconcave shape. The patient underwent placement of a stainless steel mesh stent (Palmaz vascular stent) by the technique described by Palmaz et al. The repeated spirometry revealed a marked improvement and return to prestenotic values in the FEF25-75 percent as well as the FEV1, and normalization of the inspiratory/expiratory flow-volume curve as shown in Table 1 and Figure 1C.

**DISCUSSION**

The analysis of the flow-volume relationship during forced vital capacity maneuvers provides a mechanism for assessing the dynamic functional capacity of the ventilatory system. Both the rates of airflow and the volume of air inspired or expired over defined time intervals serve as a graphic measure of the flow and resistive properties of the airways. We have described a patient who underwent SLT and subsequently developed bronchial stenosis distal to the bronchial anastomotic suture line. This patient presented with a pattern of worsening obstructive pulmonary function and a biconcave flow-volume loop that normalized after the obstruction was treated. The biconcave abnormality present in the flow-volume loop of this patient (Fig 1) reflects inspiration and expiration of two distinctly different physiologic lung units. The native lung, although diseased, will empty and fill more rapidly than the transplanted lung with the main-stem bronchial stenosis. Therefore, the initial portion of the inspiratory and expiratory flow-volume loop reflects air movements in the native lung, while the latter portions of the flow-volume loop reflect air movement in the transplanted lung with the main-stem bronchial stenosis. In forced expiration or inspiration, the initial half of the vital capacity is expired or inspired normally, while the second half of the vital capacity is expired or inspired at a slower rate due to the bronchial obstruction. This slower constant expiration or inspiration explains the long flat "tail" on the end of both the inspiratory and expiratory curves. Thus, the

**Table 1 — Pulmonary Function Tests**

<table>
<thead>
<tr>
<th></th>
<th>Pretransplant</th>
<th>4-wk Posttransplant</th>
<th>16 wk Posttransplant</th>
<th>Poststent Placement</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC, L (%)</td>
<td>0.7 (13)</td>
<td>1.89 (36)</td>
<td>1.91 (36)</td>
<td>1.89 (36)</td>
</tr>
<tr>
<td>FEV1, L (%)</td>
<td>0.66 (15)</td>
<td>1.64 (38)</td>
<td>1.14 (26)</td>
<td>1.61 (37)</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>0.94</td>
<td>0.87</td>
<td>0.60</td>
<td>0.85</td>
</tr>
<tr>
<td>FEF25-75%,L/min (%)</td>
<td>1.81 (37)</td>
<td>1.8 (37)</td>
<td>0.67 (13)</td>
<td>2.45 (51)</td>
</tr>
</tbody>
</table>

*FVC = forced vital capacity; FEV1 = forced expiratory volume in 1 s; FEF25-75 percent = minute expiratory flow 25-75; % = percent of predicted.
undergone SLT, the flow-volume curve may play a very important role in monitoring for bronchial stenosis, especially because it has been demonstrated that over 70 to 80 percent of the ventilation goes to the transplanted lung. If a fixed obstruction is encountered, a biconeave pattern may result in the flow-volume curve due to the presence of high flows and the fixed obstruction that is present.

These results confirm suggestions by other authors that the forced expiratory flow-volume curve of the biconeave type can reflect main-stem bronchial narrowing in a patient without a transplant in whom a bronchial obstruction is present in a parallel circuit connecting two similar lungs. Furthermore, this finding is more prominent after SLT where the patient who has undergone a transplant will have a diseased lung and a normal lung graft in a parallel circuit making any abnormalities in bronchial air flow more prominent. Expiratory flow-volume curves are noninvasive and are routinely generated during spirometric pulmonary function testing. We have demonstrated in this report that expiratory flow-volume curves can contribute to noninvasive monitoring of the patency of the bronchial anastomosis following SLT.

**References**


**Figure 2.** Top. Bronchoscopic photograph of the stenotic area in the left main bronchus prior to balloon bronchoplasty and stent placement. Bottom. Orifice of the left main bronchus after the stent placement.