Lung Volume Reduction Surgery*
An Analysis of Hospital Costs

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**Objective:** Lung volume reduction surgery (LVRS) represents a potential breakthrough in the management of advanced emphysema, although questions remain about clinical and economic implications of widespread application of LVRS. In this report, we describe hospital costs, excluding physicians’ fees, for LVRS.

**Design:** Hospital charges were obtained from billing records and converted to costs by applying multiple cost-to-charge ratios.

**Setting:** A large, urban academic medical center.

**Patients:** Fifty-two consecutive patients who received bilateral LVRS through a median sternotomy between April 1995 and August 1996.

**Results:** Median hospital stay was 10 days (mean=14.8±12.8 days; range=3 to 48 days), including 2 days (mean=6±9.2 days; range=1 to 35 days) in the ICU. One hospital death occurred. Hospital costs per case ranged from $11,712 to $121,829, with mean costs of $30,976 and median costs of $19,771. Costs were related significantly to duration of ICU stay and length of hospitalization. Patients who accrued the highest costs were significantly older than the remainder of the sample (69.3 years vs 62.4 years).

**Conclusions:** Hospital costs of LVRS vary significantly but are related directly to hospital stay. Identification of factors associated with prolonged stays can be used to assess benefits and risks of LVRS against utilization of health-care dollars. (CHEST 1998; 113:896-99)

**Key words:** costs; economics; lung volume reduction surgery

**Abbreviations:** LVRS=lung volume reduction surgery; OR=operating room

Costs related to disability and treatment of COPD comprise a substantial portion of total health-care expenditures. Lung volume reduction surgery (LVRS) has emerged recently as a treatment modality for patients with advanced emphysema. LVRS has the potential to improve lung function, reduce dyspnea, and improve quality of life in selected individuals with emphysema.1-3 Selection criteria for LVRS are presently evolving and variability among medical centers has been observed.4 Considerable debate has ensued about the proper role of LVRS in the management of emphysema.5,6

If LVRS becomes an established option for the treatment of emphysema, it will be necessary to assess the financial implications to the health-care system. Given the prevalence of COPD in this country, if even a small minority of individuals with COPD were eligible for LVRS, the expenses for hospitals and payers would be large. Basic cost data are necessary for an economic evaluation of LVRS. Costs incurred with LVRS have been reported infrequently. Therefore, we sought to analyze hospital costs for LVRS performed at our institution, including total costs, distribution of costs, and relationship among costs and hospital course.

**MATERIALS AND METHODS**

**Study Population**

Consecutive patients with disabling dyspnea due to advanced emphysema who had LVRS between April 1995 and August 1996 were included in this analysis. All patients had LVRS performed by the same surgeon at a single academic medical center.

**Patient Selection**

Eligibility criteria for LVRS included the following: severe emphysema, disabling dyspnea, nonsmoking for a minimum of 6 months, age ≤75 years, hyperinflation on chest radiograph, heterogeneous disease with target areas for resection as noted by CT of the thorax, FEV1 <40% predicted, PaCO2 of ≤60 mm Hg,
mean pulmonary artery pressure <35 mm Hg or pulmonary artery systolic pressure <50 mm Hg (determined by pulmonary artery catheterization or estimated by echocardiography), ability to participate in preoperative and postoperative pulmonary rehabilitation, and absence of significant cardiac or neurologic disorders. These selection criteria were refined over the study duration and early exceptions occurred as follows: two patients were aged 78 years, one individual had a preoperative PaCO₂ of 71 mm Hg, and six patients did not complete a full course of preoperative pulmonary rehabilitation.

Operative Technique

Bilateral lung resections were performed via median sternotomy incisions. Upper lobe resections were performed in 49 patients and lower lobe resections were performed in 3 individuals. All resections were accomplished with stapling over bovine pericardium.

Postoperative Management

Whenever possible, patients were extubated in the operating room (OR) immediately after surgery. Postoperatively, patients were transferred to the surgical ICU where they remained until such time as they were fully alert, in hemodynamically stable condition, and able to maintain adequate oxygenation and ventilation without mechanical ventilatory support. Pain management was provided by epidural catheters and patient-controlled analgesia systems. Chest tubes were connected to 20 cm H₂O suction. Heimlich valves were used when persistent (>5 days) air leaks were present to allow for discharge from the hospital. Coughing, deep breathing, incentive spirometry, and early ambulation were employed routinely by the nursing staff. Patients were encouraged to resume participation in pulmonary rehabilitation as soon as possible after hospital discharge.

Hospital Costs

Costs were defined as the dollar amount of resources utilized to provide all aspects of the inpatient stay, including direct and indirect costs. Hospital costs excluded physicians’ fees and outpatient evaluations. Costs were calculated by applying multiple cost-to-charge ratios to inpatient charges. In our institution, 138 ratios are used that are updated annually. A step-down method was used to allocate indirect costs to cost centers. In this method, the indirect department that receives the least amount of services from other indirect departments and provides the most service to other departments allocates its costs first. A similar analysis follows to determine the order of cost allocation for each remaining indirect department. Overhead costs such as housekeeping costs were allocated to cost centers based on square feet, while billing department costs were allocated based on revenue.

Costs were divided into seven categories designated as routine, OR, ICU, respiratory therapy, pharmacy, laboratory, and radiology. Routine costs included room and board costs for a non-ICU bed, associated nursing care, supplies, and overhead. ICU costs included ICU room, board, nursing care, supplies, and overhead.

Data Analysis

Data were summarized as proportions, means, medians, or ranges. Associations between costs and other variables were determined by calculation of correlation coefficients (Pearson r). χ² and unpaired t tests were used to compare differences in costs between patient groups. Statistical significance was considered at p<0.05.

Results

Patient Population

The study group included 52 patients: 27 men and 25 women. The ages of the patients ranged from 48 to 78 years, with a mean of 63.5 years. Mean preoperative pulmonary functions test results and arterial blood gas values for the group are found in Table 1. The mean FEV₁ was 23% of predicted. Thirteen patients had preoperative PaCO₂ values >50 mm Hg. The primary insurer of this group was Medicare (71%). Other sponsors included commercial insurers (17%), health maintenance organizations or preferred provider organizations (8%), and public aid (4%).

Hospital Course

Postoperative hospital stays ranged from 3 to 48 days, with a mean of 14.8 days and a median of 10 days. ICU stays ranged from 1 to 35 days, with a median stay of 2 days and a mean ICU stay of 6 days. The most frequent postoperative complication was prolonged (>7 days) air leak, experienced by 50% of patients (Table 2). Although most patients were able to be extubated immediately postoperatively, 10 subjects required ≥5 days of mechanical ventilation. Ten patients developed arrhythmias, none of which were life threatening or required cardioversion. One patient died during hospitalization on the fourth postoperative day. Death followed the development of ARDS.

Costs

Total hospital costs for the entire sample were $1,608,697. A frequency distribution of costs shown in Figure 1 demonstrated that costs in this sample were not normally distributed. Hospital costs per

Table 1—Profiles of 52 Patients Selected for LVRS*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean Value±SD (% Predicted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>63.5±7.3; range: 48-78</td>
</tr>
<tr>
<td>Gender, male/female</td>
<td>27/25</td>
</tr>
<tr>
<td>FVC, L</td>
<td>1.86±0.65 (51)</td>
</tr>
<tr>
<td>FEV₁, L</td>
<td>0.65±0.23 (23)</td>
</tr>
<tr>
<td>TLC, L</td>
<td>6.6±2.1 (112)</td>
</tr>
<tr>
<td>RV, L</td>
<td>4.6±1.7 (182)</td>
</tr>
<tr>
<td>Dco, mL/mm Hg/min</td>
<td>5.86±4.0 (27)</td>
</tr>
<tr>
<td>6-min walk, feet</td>
<td>798±331</td>
</tr>
<tr>
<td>pH</td>
<td>7.41±0.03</td>
</tr>
<tr>
<td>PaO₂, mm Hg</td>
<td>61±18.2</td>
</tr>
<tr>
<td>PaCO₂, mm Hg</td>
<td>45.2±5.6</td>
</tr>
<tr>
<td>HCO₃⁻, mEq/L</td>
<td>28.5±4.6</td>
</tr>
</tbody>
</table>

*TLc=total lung capacity; RV=residual volume; Dco=diffusing capacity of the lung; HCO₃⁻=bicarbonate.
case ranged from $11,712 to $121,829 with a mean of $30,976 and a median of $19,771. Costs were related significantly to length of hospital stay (r=0.88; p<0.01) and length of ICU stay (r=0.95; p<0.01). A breakdown of costs according to specific cost categories is depicted in Figure 2. ICU and OR costs accounted for more than half (57%) of total hospital costs.

Cost comparisons were made of patients grouped according to age, gender, and the presence or absence of the following complications during hospitalization: air leak >7 days, mechanical ventilation >5 days, pneumonia, and arrhythmias. No significant differences in costs were associated with differences in age, gender, or air leak >7 days. Significant cost increases were associated with mechanical ventilation >5 days (p<0.001), arrhythmias (p<0.001), and pneumonia (p<0.001).

Patients were divided into two groups according to hospital costs: those whose costs were <$20,000 and those whose costs were >$20,000. No significant differences were noted between groups for age, sex, forced expiratory volume, FEV₁, PaCO₂, tension or 6-minute walk distance. Patients with costs <$20,000 had an average FEV₁ of 0.71 L, compared with a mean value of 0.59 L for patients with costs of ≥$20,000, a difference that approached statistical significance (p=0.06).

The eight patients whose hospital costs were >$50,000 were compared with the remaining patients in the sample. As expected, the highest cost group had significantly longer ICU stays (26.5 days vs 2.7 days), total hospital days (39 days vs 11.1 days), postoperative arrhythmias (p=0.02), postoperative pneumonias (p=0.004), and prolonged ventilator dependence (p=0.022). Patients with the highest total hospital costs were significantly older than others in the sample (69.2±5.1 years vs 62.4±7.2 years) (p=0.01). No other significant differences were found among demographic variables or preoperative indexes.

**Table 2—Hospital Course for 52 Patients Receiving LVRS**

<table>
<thead>
<tr>
<th>Postoperative Complications</th>
<th>No. (%) of Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air leak &gt;7 d</td>
<td>26 (50)</td>
</tr>
<tr>
<td>Ventilator &gt;5</td>
<td>10 (19)</td>
</tr>
<tr>
<td>Arrhythmias</td>
<td>10 (19)</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>5 (10)</td>
</tr>
<tr>
<td>Hospital death</td>
<td>1 (4)</td>
</tr>
</tbody>
</table>

*Median hospital days, 10 (range, 3 to 48 days); median ICU days, 2 (range, 1 to 35).

**Figure 2. Breakdown of hospital costs for LVRS.**

**Figure 1. Frequency distribution of total hospital costs for LVRS.**

**Discussion**

We have assessed hospital expenses for LVRS performed at an urban academic medical center. We have reported costs rather than charges because costs better reflect resources used than do charges, which are prices set by the institution. Hospital costs per case were variable but substantial, ranging from $11,712 to $121,829 with a median of $19,771. Longer hospitalizations, particularly longer ICU stays, were associated with the highest hospital costs. This suggests that actions resulting in fewer postoperative complications, especially those requiring continued ICU care, would reduce costs significantly.

Although the population sample size in this study was relatively small, we sought to uncover variables associated with patients most likely to accrue high hospital costs. Our findings and other preliminary data suggest that advanced age should be explored as a possible contributor to longer hospitalizations and higher hospital costs.

Few reported experiences with LVRS have included expense data. When mentioned, references to expenses are anecdotal with little, if any, descrip-
tion of patients, techniques, and methods used to estimate expenses. Charges are reported more often than costs, although definitions of these terms are rarely provided. Charges for LVRS via median sternotomy are estimated to be $30,000 to $45,000.5,9 Hospital charges of $17,513 have been reported for LVRS via laser thoracoscopy requiring a 10-day hospital stay.10

A detailed financial breakdown of costs of LVRS was described by Albert and colleagues.11 Financial data from 23 patients treated with LVRS at the University of Washington Medical Center were reviewed. The type of operative procedure performed was not specified. Patients spent an average of 8 days in the hospital and 1 day in the ICU. Median costs of LVRS, including preoperative evaluation and hospitalization, and excluding professional fees, were estimated to be $16,065. This compares with median costs for our sample, excluding physicians' fees, of $19,771 for a 10-day hospital stay with 2 ICU days. In both reports, most hospital expenses were attributable to room costs (ICU, general unit) and OR costs. Total charges were related directly to length of hospitalization.

Generalization of our results should be undertaken cautiously. Numerous factors can potentially influence expenses reported for LVRS, including definitions of expenses (costs, charges), methods for calculating expenses, the hospital setting (academic, community), patient selection criteria, experience and proficiency of the clinical team, operative technique, and clinical management protocols. Nevertheless, our sample of patients is similar to other reported series of patients undergoing LVRS by median sternotomy12,13 with respect to preoperative physiologic profiles, operative technique, and occurrences of postoperative complications. In addition, our method for estimating costs by applying cost-to-charge ratios to observed charges is used commonly to estimate hospital costs. Therefore, our hospital costs for the surgical admission are likely similar to those other centers might anticipate, employing similar cost accounting methods, selection criteria, and operative technique.

The description of costs noted in this and other reports is perhaps best viewed as a preliminary step to future studies in which cost consequences of LVRS are considered. Cook and Ellrodt14 recently described economic evaluations that compare costs and consequences among alternate courses of action. Examples of potential economic evaluations of LVRS include comparing hospital length of stay and costs of LVRS performed via thoracoscopy vs median sternotomy (cost effectiveness); determining the effect of LVRS on patients' annual health-care expenditures (cost benefit); and determining the impact of LVRS on length of survival and quality of life (cost utility). Given the prevalence of chronic obstructive lung disease in this country, continued reports are necessary to determine whether sufficient benefit is provided to justify expenditures.

REFERENCES


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