This study’s objective was to evaluate the hospital cost and perioperative outcomes of pulmonary lobectomies by robotic[-assisted], video-assisted thoracic surgery (VATS), and open approaches performed at The Ohio State University Wexner Medical Center (OSU). Inherent differences in patient selection were overcome by statistical means of a propensity score weighted analysis.

Patients who underwent pulmonary lobectomy between January 1, 2012, and September 1, 2017, were identified from the OSU prospectively maintained Society of Thoracic Surgery (STS) General Thoracic Surgery database. The study design included all patients older than 18 years of age undergoing elective lobectomy for cancer or benign disease and with available financial data. The study excluded patients who underwent sublobar resection, bronchoplastic resection, bilobectomy, or completion pneumonectomy, as well as patients with Pancoast tumors or concomitant chest wall resections.

The group included three high-volume minimally invasive surgeons: one primarily robotics surgeon and two surgeons who transitioned from VATS to robotics as their preferred approach for lobectomy within the study period.

Prior to 2016, manual stapling was used in robotic[-assisted] lobectomies and all VATS and open lobectomies. Since 2016, the surgeons also used the EndoWrist controlled staplers for robotic[-assisted] lobectomies.

The primary financial outcome was total direct hospital cost. Secondary cost outcomes were total indirect cost specific to OSU and charges to the payor. Costs reflect the sum of all expenses to the hospital for the index stay for lobectomy, as provided by the billing department in U.S. dollars.

Total direct costs were defined as cost traceable to specific cost objects in the care of patients, including the price for any item used, facility occupied (operating room, hospital bed, etc), and service provided to conduct the operation and throughout the hospital stay. Total indirect costs are the sum of all additional costs for the hospital that comprised overhead cost and amortization of capital equipment, including the purchase and maintenance of minimally invasive platforms, as previously outlined.1

Selection of surgical approach was at the discretion of the treating surgeon. To account for treatment selection bias, the authors attempted to balance the baseline characteristics and surgical risk factors between the three lobectomy groups using a propensity score methodology with inverse probability of treatment weighing (IPTW).2 A p value ≤0.15 was considered statistically significant.
Variables included age, primary payor, American Society of Anesthesiologists (ASA) score, hypertension, diabetes, coronary artery disease, peripheral vascular disease, preoperative chemotherapy, preoperative thoracic radiation, prior cardiothoracic surgery, history of cerebrovascular accident, chronic obstructive lung disease, preoperative forced expiratory volume in 1 second, diffusion capacity for carbon monoxide, last preoperative hemoglobin and creatinine, presence of cancer, clinical tumor and nodal stage, and lobe resected. Complete data for these variables were available for 87.7% of patients.

**Data**

### Table 1. Perioperative characteristics after IPTW adjustment

<table>
<thead>
<tr>
<th></th>
<th>Robotic-assisted</th>
<th>VATS</th>
<th>Open</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LOS, median [IQR]</strong></td>
<td>3.8 [2.6, 5.9]</td>
<td>3.8 [2.8, 7.0]</td>
<td>5.4 [4.0, 7.6]</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Operating room time, min, mean (SD)/(95% CI)</strong></td>
<td>287.2 (278.2-296.2)</td>
<td>305.8 (288.7-323.0)</td>
<td>278.9 (265.1-292.8)</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>Major complications</strong></td>
<td>12%</td>
<td>12%</td>
<td>15%</td>
<td>0.70</td>
</tr>
<tr>
<td><strong>Pulmonary complications</strong></td>
<td>21%</td>
<td>31%</td>
<td>31%</td>
<td>0.15</td>
</tr>
<tr>
<td><strong>Pneumonia</strong></td>
<td>3%</td>
<td>2%</td>
<td>8%</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

Values in bold indicate statistically significant p values. IPTW: inverse probability treatment weight; Robotic-assisted: robotic-assisted thoracoscopic surgery; VATS: video-assisted thoracoscopic surgery; Open: open thoracotomy approach; LOS: length of stay; IQR: interquartile range; SD: standard deviation; CI: confidence interval.
Table 2. Direct cost analysis

<table>
<thead>
<tr>
<th>% of total direct cost, mean (SD)</th>
<th>Robotic-assisted (N=69)</th>
<th>VATS (N=76)</th>
<th>Open (N=33)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR/ASU/PACU cost</td>
<td>48.5 (14.9)</td>
<td>47.5 (9.6)</td>
<td>42.2 (12.3)</td>
<td>0.05</td>
</tr>
<tr>
<td>Anesthesia cost</td>
<td>3.2 (1.0)</td>
<td>4.2 (1.0)</td>
<td>3.9 (1.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ICU cost</td>
<td>1.2 (4.9)</td>
<td>0.0 (0.0)</td>
<td>1.5 (8.9)</td>
<td>0.78</td>
</tr>
<tr>
<td>Ward/nursing cost</td>
<td>15.2 (6.8)</td>
<td>19.5 (8.6)</td>
<td>22.7 (9.6)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Values in bold indicate statistically significant p values. Robotic-assisted: robotic-assisted thoracoscopic surgery; VATS: video-assisted thoracoscopic surgery; Open: open thoracotomy approach; SD: standard deviation; ICU: intensive care unit.

Results

A total of 697 patients who fulfilled the selection criteria underwent lobectomy completed by a robotic-assisted (n=296) and VATS (n=161) or an open thoracotomy (n=240) approach. Although risk factors were similar between robotic-assisted and open thoracotomy patients, patients who underwent VATS on average were younger and had lower ASA scores, fewer cardiovascular comorbidities, and greater preoperative forced expiratory volume in 1 second and diffusion capacity for carbon monoxide.

The IPTW-adjusted mean operative times were lowest for open thoracotomy and longest for a VATS lobectomy (robotic-assisted 287 minutes vs VATS 306 minutes vs open 279 minutes, p=0.05). See Table 1.

Median length of hospital stay was similar between the patients undergoing robotic-assisted and VATS and significantly longer following open lobectomy (robotic-assisted 3.8 days vs VATS 3.8 days vs open 5.4 days, p<0.001; Table 1).

The IPTW-adjusted mean total direct hospital cost for robotic-assisted lobectomy was $17,223 (95% confidence interval [CI], $16,405-$18,081) and was not significantly different as compared with VATS lobectomy ($17,259 [95% CI: $15,983-$18,639]; p>0.99), or open lobectomy ($18,075 [95% CI: 16,920-19,308; p=0.48).

Operating room cost of robotic-assisted lobectomy was significantly greater than the cost for open but similar to the cost for VATS lobectomy. The study found an inverse relationship between operating room cost and the cost for the hospital room and nursing among the three groups (Table 2).
Key takeaways
This retrospective study of a large single-institution experience demonstrated that there were no significant differences in hospital cost or charges to the payor among robotic-assisted, VATS, and open lobectomies in a propensity weight-adjusted analysis.

It is evident that the choice of surgical approach may have a broader impact on health economics and the surgical community; however, these results indicate that the primary criterion of selection of the lobectomy approach should be driven by the surgeon’s experience and comfort level. Although cost should remain a consideration, it should not dictate the surgical approach.

Robotic-assisted lobectomy can be performed with similar cost and outcomes as VATS at a high-volume center. Increased procedural cost of minimally invasive lobectomy can be recovered in the postoperative period, associated with improved postoperative outcomes and shorter hospital stay.

Study limitations
As a result of the observational study design, unmeasured confounders cannot be completely excluded and may have influenced the comparison between groups.

With regard to outcomes and cost, every effort was made to control for differences in patient factors and known STS risk factors. However, there may be other salient patient or disease factors that were not accounted for and could have influenced the selection of the operative approach.

The groups are not randomized, and therefore the biases and experiences of individual surgeons, as well as the degree of trainee involvement, could have influenced the study results.

Cost of post discharge health care use, including readmissions and rehabilitation services were not considered and may have additional implications from a health economic standpoint.

Financial analysis may not be directly comparable with other institutions, because cost factors may vary significantly between hospital systems. Comparability of absolute hospital cost between studies is further challenged by different cost definitions and time periods between studies. As such, the absolute cost figures presented may appear higher or lower in this study as compared with some previous reports.

This study is limited to comparison of hospital outcome measures and does not account for differences in patient reported outcomes and oncologic endpoints.
References


Important Safety Information

Dr. Merritt has received compensation from Intuitive for consulting and/or educational services. For Important Safety Information, indications for use, risks, full cautions and warnings regarding the use of da Vinci® surgery, please refer to www.intuitive.com/safety.

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