Editorial

Robotic lobectomy: revolution or evolution?

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In their case report "Robotic-assisted thoracoscopic surgery: right inferior lobectomy", Yang *et al.* described their technique for performing a robotic lobectomy (1). They highlight several advantages of a robotic approach and provide good illustrative photos. While robotic surgery provides advantages for the surgeon in terms of dexterity and visualization, the question remains how these advantages affect patient outcomes and whether the robotic approach is a true revolution or an evolution from other minimally invasive approaches.

Thoracoscopic lobectomy

Jacobeus first used thoracoscopy in 1910. Video assisted thoracoscopic surgery (VATS) is a minimally invasive approach and is associated with less pain, shorter recovery time, less tissue trauma, and improved cosmetic results compared to thoracotomy. While there were initial concerns about oncologic outcomes, several studies have shown that outcomes are equivalent to open lobectomy with less pain, decreased postoperative complications, shorter chest tube duration, and decreased length of stay (2-4).

Some studies have even suggested that patients undergoing minimally invasive approaches have improved long-term survival (5). This difference is thought to be due to decreased immunologic and stress responses after minimally invasive surgery. Quicker recovery after thoracoscopic lobectomy may also result in earlier adjuvant chemotherapy. Peterson, *et al.* found fewer delayed or reduced doses of chemotherapy with 61% of VATS patients receiving more than 75% of their chemotherapy doses compared to only 40% after open lobectomy (6). Clinical trials evaluating adjuvant treatment for resected non-small cell lung cancer have shown that approximately half of all patients actually received the planned dose of chemotherapy. For early stage, non-small cell lung cancer, surgery has become the mainstay of treatment, and VATS lobectomy has become the treatment of choice.

Robotic lobectomy

However, there is a learning curve associated with complex thoracoscopic procedures such as lobectomy due to reduced tactile sensation, counterintuitive hand-eye coordination, and loss of degrees of freedom. Robotic surgery was developed to overcome some of these challenges by combining three-dimensional imaging, improved hand-eye coordination, and greater degrees of freedom improving dexterity. Although robotic-assisted thoracic surgery (RATS) may provide advantages over VATS in terms of dexterity and degrees of freedom, a significant increase in cost has been shown in some studies (7,8). In addition, a reduction in tactile sensation, one of the disadvantages of VATS, is increased with RATS due to a lack of haptic feedback, which could lead to tissue damage especially for inexperienced surgeons. Some groups have been working on haptic feedback, and early results are promising. However, the benefits of RATS lobectomy need to be clearly defined especially in light of higher hospital costs and longer operating times (7,8).

Learning curve

Similar to VATS lobectomy, where there is a learning curve of up to 50 cases (9), there is a learning curve associated with transitioning to robotic lobectomy. Fahim *et al.* evaluated 167 RATS lobectomies and found that the total duration of surgery and console time decreased significantly with a steady decline until the 20th case (10). Toker *et al.* reported a learning curve of 14 cases (11) while Meyer *et al.* described a learning curve of 18±3 cases based on operative times, mortality, and surgeon comfort with a trend towards lower morbidity and decreased length of stay with greater experience (12). They concluded that the learning curve may be less for surgeons experienced with VATS. During this learning curve, it is essential to have appropriate mentorship available with a low threshold to convert to either a VATS approach or an open thoracotomy when needed. Case reports and series such as the one by Yang *et al.* as well as videos outlining expert techniques may help to shorten this learning curve (1).

Port placement and positioning

Yang *et al.* describe their port placement with 3 ports in the 8th intercostal space (1). Keeping the ports in the same interspace may help to decrease postoperative pain. The port in the 5th intercostal space may be slightly high. With the introduction of the robotic stapler, keeping the anterior-most port as anterior and inferior as possible gives the robotic stapler more length to fully roticulate. Placing the assistant port more inferiorly may also help prevent interference between the robotic arms and the bedside assistant. Careful patient positioning is important to drop the hip away from the camera. Another important point, which was not specifically stated by Yang *et al.* is the use of carbon dioxide insufflation at 5–8 mmHg to push down the diaphragm and improve exposure. Gauze rolls can also be used to help maintain a bloodless field and also serves as a sponge to tamponade any significant bleeding, which is important when a utility incision is not used and the surgeon is at the robotic console and not at the bedside.

Outcomes

Initial VATS lobectomy studies were difficult to compare due to differences in how VATS was defined in each study. Currently, VATS lobectomy is most often described as defined in the CALGB 39802 trial with a 4–8 cm access incision, a totally thoracoscopic approach without rib spreading, and individual dissection and division of the pulmonary vein, arterial branches, and the bronchus. In order to compare outcomes between robotic studies, it will be important to use standard definitions to define robotic surgery, including the number of robotic arms, the number of ports, and whether a utility incision was used. It will also be important to propensity match VATS, open, and robotic cohorts to ensure that similar comparisons are being made. For example, most minimally-invasive surgeons, may only perform open lobectomies for more advanced, central tumors or after neoadjuvant chemoradiation. There may also be differences in patient selection between robotic and VATS approaches, especially early in a surgeon's experience.

Several studies have shown at least equivalent long-term survival after VATS compared to open lobectomy (3,4). Several studies have shown that RATS lobectomy can be performed safely by experienced thoracic surgeons with no significant differences in morbidity or mortality (8,13,14). Evaluating 8,253 RATS lobectomies in the Healthcare Cost and Utilization Project National Inpatient Sample, Tchouta *et al.* found that high-volume centers had a shorter LOS and decreased mortality (15). Yang *et al.* evaluated 30,040 lobectomies for stage I lung carcinoma (7,824 VATS and 2,025 RATS) in the National Cancer Database and found that MIS approaches were associated with increased 30-day readmission but shorter LOS and improved 2-year survival (16).

Some have reported significant differences in outcomes compared to VATS. Liang *et al.* performed a meta-analysis of 14 studies including 7,438 patients undergoing lobectomy or segmentectomy (17). The 30-day mortality was lower for RATS versus VATS (0.7% *vs.* 1.1%) while conversion to thoracotomy was lower at 10.3% versus 11.9%. There were no significant differences in postoperative complications, OR time, LOS, or chest tube removal. Louie *et al.* evaluated 1,220 robotic and 12,378 VATS lobectomies in the STS General Thoracic Surgery Database and found that operative times were longer for RATS, but complications, hospital stay, 30-day mortality, and nodal upstaging were equivalent (18). Paul *et al.* evaluated 2,498 robotic-assisted and 37,595 thoracoscopic lobectomies in the Nationwide Inpatient Sample and found a higher risk of iatrogenic bleeding complications of 5.0% versus 2.0% with an odds ratio of 2.64 on multivariable analysis (19). Kent *et al.* evaluated multiple State Inpatient Databases including 33,095 patients (20,238 open, 12,427 VATS, and 430 RATS) and found a reduction in mortality (0.2% versus 1.1%), LOS, and complication rates although this was not significant (20).

Lymph node dissection

There were initial concerns that VATS lobectomy could compromise nodal evaluation. However, several studies have found VATS mediastinal lymph node dissection (MLND) to be equivalent to thoracotomy. Some have reported that RATS MLND may have potential benefits in nodal staging (2,7). Wilson *et al.* evaluated 302 patients in the STS Database and found nodal upstaging in 7.4%, 8.8%, and 11.5% after RATS and 5.2%, 7.1%, and 5.7% after VATS for T1a, T1b, and T2a tumors respectively (21). The authors concluded that the rate of nodal upstaging for robotic resection appears to be superior to VATS and is similar to thoracotomy. Disease-free and overall survival were similar to recent VATS series.

On the other hand, Louie *et al.* evaluated 1,220 robotic and 12,378 VATS lobectomies in the STS General Thoracic Surgery Database and found no difference in nodal upstaging (18). Liang *et al.* found no difference in the number of retrieved lymph nodes or lymph node stations (17), and Yang *et al.* evaluated the National Cancer Database for patients undergoing lobectomy for stage I lung carcinomas and found no significant difference in nodal upstaging (16). Rajaram *et al.* evaluated 62,206 patients in the National Cancer Database and found that fewer lymph nodes were obtained, and more than 12 lymph nodes were examined less frequently with RATS (22).

Pain

While RATS offers certain technical advantages for the surgeon, the benefits to the patient in terms of acute and chronic pain outcomes is less clear. Several studies have shown a decrease in postoperative pain after VATS lobectomy including improved perioperative and long-term pain control. Although Nasir *et al.* did not directly compare robotic and VATS lobectomy, they found minimal morbidity, mortality, and pain after RATS with a median pain score of 2/10 at the 3-week postoperative visit, but no acute pain data was provided from the perioperative course, and the only comparison group was 41 patients converted to thoracotomy (23). In terms of chronic pain, Nomori *et al.* found no significant difference in chronic pain between VATS lobectomy, limited thoracotomy for segmentectomy, or open thoracotomy for segmentectomy (24). Thoracotomy was associated with significantly higher acute pain scores.

In a recent study by Kwon *et al.*, there was no significant difference in terms of acute or chronic pain outcomes or morphine equivalents used between VATS and RATS lobectomy (25). Even though there was no difference in pain scores, more RATS patients (69.2%) felt that the robotic approach affected their pain positively, suggesting a difference between reality and perception. This likely reflects patients who feel that they are receiving the latest technology and successful marketing that the latest technology is better. There was a significant increase in acute pain scores and chronic numbness in patients undergoing thoracotomy compared to MIS.

Cost

Paul *et al.* evaluated 2,498 robotic-assisted and 37,595 thoracoscopic lobectomies in the Nationwide Inpatient Sample and found that RATS lobectomy costs significantly more than VATS lobectomy ($22,582 *vs.* $17,874) (19). Swanson *et al.* evaluated 15,503 patients including 14,837 undergoing VATS lobectomy in the Premier database (8). RATS had higher average hospital costs and longer operating times without any differences in adverse events.

Conclusions

Robotic surgery addresses some of the shortcomings of VATS by providing improved dexterity and visualization. Although no randomized comparisons are available and benefits in terms of quality of life and pain need to be further evaluated, a robotic approach appears to have at least equivalent outcomes to VATS in several studies across multiple centers. There is a significant learning curve, but with appropriate mentorship and team training, robotic lobectomy can be performed safely by experienced thoracic surgeons. Cost effectiveness will need to be considered as well but will likely improve with the introduction of new robotic platforms and more widespread adoption of robotic surgery. The technology will continue to improve with new techniques to visualize tumors, the use of energy devices to divide vessels, and haptic feedback as well as the increased use of RATS for more advanced pulmonary resections including segmentectomy, bilobectomy, and sleeve resection in selected cases. With increasing experience, more surgeons performing robotic thoracic surgery, and increasing patient demand, there is a need for further research on outcomes after RATS lobectomy. Lobectomy can be performed thoracoscopically with similar outcomes. Robotic lobectomy may not be truly revolutionary, but RATS provides the next step in the evolution of minimally-invasive thoracic surgery and may provide access to minimally invasive approaches to more patients and surgeons, including those without previous VATS experience.

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Footnote

Conflicts of Interest: The author has no conflicts of interest to declare.

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