Review Article

Outcomes of robotic segmentectomies

Robert Herron[1], Awori Hayanga[1], Erkan Kaba[2], Ghulam Abbas[1], Alper Toker[1]

[1]West Virginia University, School of Medicine, Heart and Vascular Institute, Morgantown, WV, USA; [2]Group Florence Nightingale Hospitals, Istanbul Florence Nightingale Hospital, Istanbul, Turkey

Contributions: (I) Conception and design: A Toker, A Hayanga; (II) Administrative support: R Herron, E Kaba; (III) Provision of study materials or patients: A Toker, R Herron; (IV) Collection and assembly of data: A Toker, G Abbas; (V) Data analysis and interpretation: A Toker, A Hayanga; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Alper Toker. 1 Medical Center Dr, Morgantown, 26505 WV, USA. Email: salpertoker@gmail.com; alper.toker@wvumedicine.org.

Abstract: Anatomical segmentectomy of the lung is a rarely performed procedure for lung cancer. For decades, lung segmentectomy has been utilized for the surgical management of disease processes such as bronchiectasis, tuberculosis, and for patients with compromised lung function with carcinoma who are deemed prohibitive risk for a lobar resection. Better surgical techniques, increase in quality of video and instruments used in surgery and introduction of robotic technologies, segmentectomy operations have become the standard for the resection of T1 tumors. Also, the institution and availability of screening programs has increased the detection of early stage lung cancers and have thus made the segmentectomy operation a popular approach. Recently, thoracic surgeons are pursuing the segmentectomy approach in most patients with lung tumours smaller than 2 cm. In this study, we aimed to analyze the outcome data in the literature in regards to robotic segmentectomies.

Keywords: Segmentectomy; robotic surgery; lung cancer; outcomes

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The first segmentectomy was performed by Churchil and Belsey in 1939 (1). Over the next several decades, segmentectomy was known as one of the surgical techniques of choice for lung cancer treatment. In 1995, the Lung Cancer Study Group (LCSG) performed a randomized trial to evaluate the utility of sublobar resections in the treatment of lung cancer. They found that limited resections had an increased local recurrence rate (2).

Following the release of this publication, the segmentectomy operation became reserved for primarily patients who had severely compromised pulmonary function (3).

The LCSG publication was criticized secondary to several factors. For example, the enrollment period for patients in this particular study spanned from 1982 to 1988; some of the resections were wedge resections and therefore not segmentectomies; there was a lack of proper imaging and staging techniques to identify the role of segmentectomies. More importantly, the tumor diameter was greater than 2 cm in 30% of the patients included in the study (2). As VATS techniques matured, more and more segmentectomies were performed in patients with marginal cardiopulmonary function. As thoracoscopic lobectomy and thoracoscopic segmentectomies were demonstrated to have similar outcomes in terms of morbidity, recurrence, and survival (3), additional studies on intentional segmentectomy operations for lung cancer proved the efficacy and safety of the procedure in selected patients.

Lung screening programs have increased the interest for early stage and minimally invasive surgery. In early stage lung cancer, VATS has been the choice for tumor resection and lymph node dissection (LND). Within the past 2 decades, these procedures are typically performed as uniportal, biportal, or triportal techniques (4,5).

As there is no need for an access incision to retrieve the lung, some authors named the procedure as totally thoracoscopic segmentectomy (6,7).

In some major articles, pulmonary segmentectomy has been shown to have similar long-term outcomes when compared to a lobectomy in selected patient populations. These selection criteria include the size, histologic type and nodal (N) status. Surgical complications, length of stay, and readmissions have been shown to be either better or similar to that of lobectomy. In the contemporary practice of lung cancer surgery, segmentectomy and LND is accepted as a modality to treat stage IA non-small cell lung cancers or cancers that are smaller than 2 cm, even considered to be low risk. The aim of this manuscript is to analyze the outcomes in regards to segmentectomy and demonstrate that this procedure demonstrates a potential lung function preserving capacity, and similar long-term prognosis and a lower postoperative complication rate (8-10).

Although published articles advocate for segmentectomy operations, some surgeons have expressed concerns: "*Is this a sufficient oncologic operation for a lung cancer patient? Does this operation increase the rate of local recurrence? Does the segmentectomy operation lead to more instances of prolonged post-operative air leak? Is it ethical to perform this operation in a completely healthy patient who could otherwise tolerate a lobectomy? If I do this operation utilizing a minimally-invasive technique, will it be still a sufficient operation? What is the data for a robotic segmentectomy operation?* More importantly, in some instances, the question is "*is it worthwhile to even keep the superior segment of the lower lobes or anterior segment of the right upper lobes, when the rest of the lobe is resected? Does hemorrhage and infection in the residual lobe cause a major post-operative problem?*"

The aim of this study is to share our recent robotic segmentectomy results, thus including our experience at West Virginia University, WV, USA and Florence Nightingale Hospitals in Istanbul, Turkey.

Early contributions between 2011 to 2014

Several years ago, data regarding robotic segmentectomies were limited. Experiences in regards to robotic segmentectomy performance were mainly published to assess the technical feasibility of this operation in conjunction with LND (11-13).

Dylewski (12) reported 35 segmentectomy operations in his large experience. This manuscript did not provide detailed information about segmentectomy cases. Pardolesi and colleagues (11) reported 17 segmentectomies. In their study, no open conversion was reported with 189 minutes median surgical duration (11). In our earliest experience (13), which was published in 2014, we operated on 15 patients for primary or metastatic lung cancer without any conversion to open surgery (13). Complications related to surgery were rare only, in 4 out of 21 patients undergoing segmentectomy operations, including patients undergoing segmentectomy for benign disease (13).

VATS *vs.* Open segmentectomy: what does minimally invasive segmentectomy bring to the table?

In a study published by Leshnower and colleagues in 2010, the postoperative morbidity rate of VATS segmentectomy operations was demonstrated to be 17.6% (14). When compared to an open approach, the VATS segmentectomy could be considered as safe operation with less complications and short postoperative stay. In some studies, it has been demonstrated that the duration of operation, bleeding, duration and amount of tube drainage and duration of postoperative stay, have shown to be similar (15). Thoracoscopic segmentectomy has been shown to have similar postoperative and oncologic results in T1a and T1b patients who were carefully selected (15).

In tumors smaller than 2 cm and peripherally located, stage IA, NSCLC thoracoscopic segmentectomy and thoracoscopic lobectomy were compared (16). Local recurrence rates were similar (5.1% *vs*. 4.9%) with no differences in 5-year overall or disease-free survival (16). Uniportal and total thoracoscopic segmentectomies are gaining ground in segmentectomy operations. These techniques encourage surgeons to do more minimally invasive segmentectomies (4,17).

In a study by Koike *et al.*, which includes 328 patients, clinical stage IA NSCLC patients who had a wedge or a segmentectomy operation were compared with the aim of analyzing factors contributing to locoregional recurrence (18). They also aimed to study poor prognostic factors for disease-specific survival (18).

The survival without local recurrence after segmentectomy operations were demonstrated to be 84.8% at 5 years and 83.6% at 10 years. The 5- and 10-year disease-specific survivals were 83.6% and 73.6%, respectively. Four independent factors of local recurrence were as follows: (I) wedge resections, (II) R1 positivity at the margins, (III) invasion of the visceral pleura, and (IV) invasion of lymphatics. Cigarette smoking has been shown to be an independent predictor of poor survival. Secondary to the discussion in this manuscript, segmentectomy operation has been recommended as a suitable option in clinical stage IA patients with (18).

Robotic surgery and segmentectomy

Although VATS has been shown to possess several advantages over open surgery, it is not without its limitations. Limitations of VATS include the restricted ability of instrument maneuvering, two-dimensional visualization, and loss the of eye-hand-target axis. As a result of these limitations, VATS has been claimed to be reserved for experienced surgeons for pulmonary segmentectomy (19). The demonstrated advantages of robotic surgery include magnified three-dimensional visualization, dexterity with angulation of the robot arm, and tremor filtration. With these qualifications, robotic surgery does potentially allow for a faster operation in regards to segmentectomy when compared to VATS (19). Robotic surgery increases dissection capabilities in sublobar vessels. With robotic surgery, branches of basilar pulmonary vessels and bronchi lying deep in the parenchyma can be identified easier than VATS. The performance of the LND is another additional advantage of robotic surgery. Also, robotic bisegmentectomy for lower lobe resection have been proven to be safe and feasible (20).

What is the major difficulty in the robotic segmentectomy operation?

The major difficulty is lack of palpation/loss of tactile feedback. We overcome this problem by palpating and tattooing the lesion and choosing the VATS platform for docking. In order to accomplish this, at least one of the ports should be at the level of lesion. Three-dimensional images can be constructed to define the lesion and its relationships with the segmental arteries and veins and bronchi. Robotic surgery performance for a segmentectomy operation requires an excellent anatomy orientation with the patient and the lesion. The foreknowledge of the lesion and host's anatomy will increase the safety and accuracy of the operation (21). Presurgical planning utilizing the patient's actual 3D pulmonary model in stage IA NSCLC ≤2 cm in diameter could in fact aid in the identification of patients suitable for the VATS approach (22). This technique may be required in the patient being considered for robotic segmentectomy as well. In our experience, axial, coronal, and sagittal tomographies are used and discussed in detail with an experienced radiologist before each operation (6).

Management of the intersegmental plane remains another controversial issue. The intersegmental veins are preserved and are therefore considered the landmark for the intersegmental plane dissection. Sacrificing the intersegmental vein, especially at the hilum, could impair gas exchange and may lead to the loss of significant pulmonary function. However, this mainly depends on the margin from the tumor. If the margin is found to be insufficient, a portion from the neighbouring segment can be resected as a wedge to include the intersegmental vein within the specimen (23,24).

To separate a segment from neighbouring segments, stapling, electrocautery, or a combination of these techniques is utilized. Stapling is considered easy from a technical standpoint. It reduces the amount of postoperative air leak; however, it may increase the cost and may cause negative effects on postoperative pulmonary functions secondary to the resultant shrinkage of the residual segment (25,26).

The other issue requiring discussion is that of the common basilar segmentectomy. It is commonly questioned on whether or not it is worth it to save the superior segment alone at the cost of possible edema, hematoma, and lack of a good/effective ventilation in this remaining segment. On the other hand, for lower lobe superior segmentectomies, it is largely agreed that is definitely worth it to leave basal segments. Thus, each surgeon must always think of the resection margins and the nature of the remaining segments.

Outcomes

Early postoperative outcomes: conversion to open, morbidity, mortality, and median stay were considered.

In one of the earliest experiences, 100 patients were operated on for a planned pulmonary segmentectomy (27). Seven patients were converted to robotic lobectomy. Ninety-three patients had segmentectomy without conversion to open (26). Lung cancer was the indication in 79 patients. Blood loss was negligible, 19 lymph nodes were removed, the median duration of surgery was 88 minutes, and the duration of stay was 3 days. There were 2 major morbidities in 2 patients (27). No 30- or 90-day mortalities were reported.

In another study that included 71 patients, with stage I NSCLC underwent segmental resection. All resections were R0. The average duration of surgery was 134 min.

With the pathology report, 10 (8 with T criteria and 2 with N criteria) of 71 (14%) patients were upstaged. Hospital stay was Almost 1/3 of the patients had some degree of complications with no particular attribution to the surgical robot. No mortality reported within 90 days (28).

In our earliest study (13), no conversion to open was reported. Four patients out of 21 had surgery for benign disease. The mean console time, chest tube duration time and postoperative hospital stay were respectively 84±26 minutes (range, 40–150 minutes), 3±2.1 days (range, 1–10 days) and 4±1.4 days (range, 2–7 days). Mediastinal nodal stations dissected was 4.2, the number of dissected lymph nodes was 14.3 nodes (range, 2–21 nodes) from mediastinum and 8.1 nodes (range, 2–19 nodes) from hilum respectively (13).

In our further experience (29), we compared the VATS and robotic segmentectomy (RATS) operations. RATS and VATS exhibited similar major morbidity and mortality rates (24–23% and 0–1.5%) respectively. They also showed similar duration of surgery and drainage. The duration of postoperative stay for RATS showed a tendency toward being shorter 4.65±1.94 days (range, 2–10 days) *vs*. 6.16±4.7 days (range, 2–24 days) (29).

Oncological outcome: long term survival, lymph node removal, recurrence, completeness of the resection could be considered as oncological outcomes after segmentectomy operation

Some authors refer to the number of lymph nodes removed. They believe that this is an indirect indicator of oncological radicality (30). This is a common practice in VATS surgery. For example, in VATS segmentectomy operations, Bédat *et al*. found the number of dissected nodes from mediastinum as 11.8 (31), Song *et al*. dissected a mean of 13.7 lymph nodes from mediastinum (32). We have published the mean number of dissected lymph nodes from mediastinum as 14.3 in primary lung cancer segmentectomy operations with Surgical Robot (13). In Cerfolio's study, 3 developed recurrence in the residual lobe out of 79 lung cancer patients, with a median follow-up of 30 months. Overall, 5-year survival in this study was 95% at 30 months (27). In a most recently published series, 71 patients were followed up for 54 months (2 months to 9 years) (28). The overall 5-year survival and lung cancer-specific 5-year survival was reported to 55% and 43% respectively. In another study 5-year disease free survival in pathological stage I disease was 73%. In 4 out of 71 (5%) patients Local or mediastinal recurrence occurred. In patients with pathological upstaging, or a recurrence in the residual lung, there were no 5-year survivors. Pathological upstaging was reported to be a risk factor for lung cancer specific death. The authors claimed that advanced age is also another factor too. The authors did not attribute this outcome to the robotic segmentectomy operation, and reported that a proper staging in the preoperative era is the most important prognostic factor for long-term survival (28).

A meta-analysis that published recently by Liang and colleagues, compared robotic assisted lobectomies and segmentectomies (RAL/S) to video-assisted thoracoscopic surgery. This study demonstrated a lower 30-day mortality rate for robotic surgery (0.7%) when compared to VATS approaches (1.1%; P=0.045) and a lower conversion rate to open surgery with RAL/S (10.3%) compared to VATS (11.9%; P<0.001). The postoperative complication rate, duration of surgery, length of stay, chest tube removal time, dissected lymph nodes, and nodal stations were all similar between the two groups (33).

Phase III randomized clinical trials in early stage NSCLC patients are almost completed. The National Cancer Institute Cancer and Leukemia Group B 140503 study (CALGB/Alliance 140503) randomized patients to either lobectomy or sublobar resection (wedge or segmentectomy) with N0 status confirmed via intra-operative frozen section analysis (34). The statistics in regards to morbidity and mortality were published in 2018, and demonstrated no significant difference between lobectomy and sublobar resections with regard to mortality at 30 and 90 days, overall adverse events, and severe adverse events. Cardiac and/or pulmonary complications were reported to be similar (35). Oncological and long-term outcomes such as disease-free survival, overall survival, loco-regional and systemic recurrence, and pulmonary function at 6 months are expected to be reported in 2021 (34). The Japan Clinical Oncology Group (JCOG) and the West Japan Oncology Group (WJOG) study JCOG0802/WJOG4607L have also completed enrollment of patients to randomize lobectomy *vs*. segmentectomy (36). Suzuki *et al*. published perioperative outcomes in 2019. In their study, no mortalities were reported, and complications were found to be similar in both arms (37). However, prolonged air leaks were more common in segmentectomy patients (37).

In Group Florence Nightingale Hospitals, last Author of this manuscript performed 52 segmentectomy operations for lung cancer. Twenty-eight (53.8%) of the operations were performed for Adeno cancer. Mean age was 65.1, mean number of lymph node dissected was found to be 15.9 nodes/patient. Duration of hospital stay was 7 days, because patients were not discharged with a chest tube on them before 10 days. There were 5 readmissions due to non-surgical problems. There were 11 patients with longer than 8 days of postoperative stay. There were no mortalities and the most common complication was prolonged airleak in 10 patients (19.2%). The data of segmentectomy operations performed at WVU will be presented elsewhere.

Operation time, cost and hospital stay

VATS and RATS lobectomy or segmentectomy operations were studied for cost analysis (38). The robotic surgery was shown to be more expensive than that of VATS. Duration of operation was shorter with VATS which decreases utilization time of the operation room. But the same length of hospital stay was similar to that of robotic surgery (38). The data from 87 patients with VATS and robotic lobectomy also showed that the duration of operation was significantly longer than VATS. The length of hospital stays was similar (39).

Conclusions

The segmentectomy operation for early stage lung cancer has not been demonstrated to be a gold standard until now. However, studies are on the way. For a large group of patients, perioperative and early postoperative outcomes show similar results when compared to lobectomy. Prolonged air leak and the complications in the residual lobe are important drawbacks. For compromised situations, certainly the value of the segmentectomy operation is not questionable. Robotic surgery is undeniably the future in regards to the surgical management of patients with lung carcinoma, and would certainly bring the best outcome as surgeons become more familiar with the robotic technique.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/vats.2020.03.04). AT serves as an unpaid editorial board member of *Video-Assisted Thoracic Surgery* from Jun 2019 to May 2021. The other authors have no conflicts of interest to declare.

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