Two-port robotic sleeve lobectomy using Stratafix sutures for central lung tumors

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Abstract

**Objectives:** To explore the feasibility of two-port robotic sleeve lobectomy using Stratafix sutures for central lung tumors, and to summarize the surgical techniques and clinical outcomes.

**Methods:** We retrospectively evaluated 15 consecutive patients who underwent robotic bronchial sleeve lobectomy, performed by a single surgeon between March 2021 and September 2021. A half-continuous suture technique with two Stratafix sutures was used for bronchial anastomosis. The operative techniques and outcomes were analyzed.

**Results:** Complete resection was achieved in all patients undergoing different types of robotic bronchial sleeve lobectomy. There were no conversions to thoracotomy. The mean duration of surgery was 102.35 ± 46.31 min, mean time for bronchial anastomosis was 25.8 ± 15.2 min, mean blood loss was 64.71 ± 38.59 ml, and mean postoperative hospital stay was 4.76 ± 2.54 days. There was no death on follow-up within 90 days after surgery.

**Conclusions:** Two-port robotic bronchial sleeve lobectomy and the novel anastomotic technique are both feasible and safe for selected patients.

**KEYWORDS**

robotic, sleeve lobectomy

**INTRODUCTION**

Robotic surgery is now widely accepted and is being applied to the operative management of patients in various disciplines. In the field of thoracic surgery, robotic surgery is most frequently used for lobectomy in patients with pulmonary lesions such as benign and malignant lung tumors. Given its intrinsic features and advantages there is no doubt that the robotic platform will be used in the future even for extended resection in advanced disease. With the development of a variety of instruments and techniques, thoracic surgeons began to perform video-assisted minimally invasive sleeve lobectomy. Availability of endoscopic technology and artificial intelligence has now facilitated the use of robotic surgery systems for sleeve lobectomies. Most robotic sleeve lobectomies performed thus far have been done by punching three or four ports in the chest wall, thus causing major trauma.

In the present study, we retrospectively analyzed our experience with two-port robotic bronchial sleeve lobectomy using Stratafix sutures in 15 patients with central lung tumors. This report focuses on the technique of two-port robotic bronchial sleeve lobectomy and bronchial anastomosis, and postoperative outcomes.

**PATIENTS AND METHODS**

**Patients**

We reviewed our thoracic surgery database at the Shanghai Pulmonary Hospital of Tongji University (Shanghai, China) for patients with pulmonary tumors. Between March 2021 and September 2021, 15 patients underwent curative two-port robotic bronchial sleeve lobectomy. Bronchial anastomosis was performed using a half-continuous suture
technique with v-loc sutures (Stratafix Spiral PGA-PCL Knotless Tissue Control Device, Ethicon, Inc.) (Table 1). The study protocol was approved by the Institutional Ethics Committee.

The inclusion criteria for robotic bronchial sleeve lobectomy were as follows: tumors were located at the origin of the lobar bronchus, there was direct infiltration from the tumors or metastatic peribronchial lymph nodes, the tumor was growing in the trachea or main bronchus, and a positive bronchial margin was present as determined by pathologic examinations of frozen specimens after standard robotic lobectomy. All surgeries were performed by a single experienced thoracic surgeon who had performed more than 200 uniportal video-assisted thoracic surgery (VATS) sleeve lobectomies and more than 100 standard robotic lobectomies.

Routine preoperative evaluations consisted of thoracic and abdominal contrast-enhanced computed tomography, bronchoscopy, positron-emission tomography, bone scintigraphy, brain magnetic resonance imaging, cardiac evaluation, arterial blood gas analysis, and pulmonary function testing (Table 1). If a metastasis to the mediastinal lymph nodes was suspected, mediastinoscopic biopsy or endobronchial ultrasound-guided transbronchial needle aspiration was performed.

### Surgical technique

#### Body position and anesthesia

After double-lumen endotracheal intubation under general anesthesia, the patient was placed in the lateral jack-knife position (Figure 1).

### Table 1 General patient status (n = 15)

| Variable                              | Data                |
|---------------------------------------|---------------------|
| Age (y)                               | 58.82 ± 11.81       |
| Gender (male/female)                  | 13/2                |
| Smoking (%)                           | 11 (73.33)          |
| Height (cm)                           | 168.24 ± 7.09       |
| Weight (kg)                           | 67.24 ± 6.58        |
| Lesion diameter (mm)                  | 3.47 ± 1.73         |
| FEV1 (% predicted)                    | 86.90 ± 18.48       |
| MVV (% predicted)                     | 64.38 ± 23.85       |
| PaO2 (mm Hg)                          | 87.59 ± 8.82        |
| PaCO2 (mm Hg)                         | 40.79 ± 2.74        |
| SaO2 (%)                              | 97.55 ± 1.06        |
| Blood albumin level (g/L)             | 37.65 ± 3.33        |
| Hemoglobin level (g/L)                | 131.53 ± 19.21      |
| Average length of hospital stay (d)   | 8.12 ± 3.13         |

*Abbreviations: FEV1 (% predicted), forced expiratory volume percentage in first second; MVV (% predicted), percentage of maximum ventilation per minute.*

#### Incisions and port positions

The da Vinci Xi Robotic system was docked from the head of the patient. We made a 4-cm utility incision extending from anteriorly to the midline in the fourth or fifth intercostal space with the use of a silicon rubber wound protector. The first port was used primarily for the robotic camera (the no. 2 arm and the no. 4 arm). The second port, which was situated on the posterior axillary line in the seventh intercostal space, was used primarily for the no. 1 arm (Figure 2). The no. 3 arm was not used. The no. 2 and no. 4 arms were far apart, which reduced the interference between the robotic arms in the same port. At the same time, the joints of the robotic arm could be stretched out. Traction on the lung was achieved by the second assistant pulling the oval forceps on the dorsal side of the patient through the first port. The points where the three mechanical arms entered the chest wall were arranged in a triangle. The position of
the camera was at the vertex of the triangle. The port placement and the distribution of the incisions are shown in Table 2.

The instruments and equipment used in the robotic sleeve surgery were the same as those used for conventional robotic lobectomy. The two ports were also used for the suction instrument, sutures, and endo-stapler.

Pulmonary resection and bronchial anastomosis

Dissection of the hilar, subcarinal, and other mediastinal lymph nodes was performed at the beginning of the procedure. The pulmonary vessels were then divided and transected.

Depending on the findings of the pre-operative bronchoscopy and the intraoperative findings, the proximal main bronchus and the distal lobar bronchus were transected with scissors. We determined whether the margins of the proximal and distal bronchi were negative, i.e. had at least a 1-cm tumor-free margin on examination of the frozen sections obtained from these sites. If the frozen section showed tumor, the resection was extended to include another one or two bronchial rings.

The bronchial anastomosis between the proximal main bronchus and the distal lobar bronchus was performed by using a half-continuous suture technique with two tensile strength size 3-0 v-loc sutures (Stratafix Spiral PGA-PCL Knotless Tissue Control Device, Ethicon Inc.) (Figure 3a). The anastomosis was sewn in an anticlockwise direction (posterior wall first) until almost half of the circumference of the airway was reconstructed (Figure 3b). The anastomosis was then completed with the other needle running clockwise until both sutures met and were tied together at the medial portion of the anterior wall (Video 1). After the bronchial anastomosis was completed, a sealing test was performed to confirm that there was no leakage at the site of the anastomosis. The bronchial anastomosis was not routinely covered by a fatty pad.

For tumors that invaded the pulmonary artery (PA), arterioplasty or PA reconstruction was performed. First, the proximal and distal PA were divided and blocked by a Romeo occluder (an intrathoracic vascular occluder). The distal arterial wall was cut open and the portion of the PA invaded by tumor was removed by robotic scissors. Once negative arterial margins were achieved, the proximal and distal margins were trimmed by scissors to match each other. We then used heparin to rinse the lumen of the arterial stumps. The vessel anastomosis between the proximal main vessel and the distal lobar vessel was performed by using a half-continuous suture technique with two 4-0 prolene sutures (Ethicon Inc.) (Figure 4a). The half-continuous suture was specially made. Each suture was 15 cm long. The end was sutured on a blood vessel gasket to prevent the suture from falling off when the blood vessel was sutured. Two such sutures were required for each anastomosis. When the anastomosis of the pulmonary artery was about 50% completed, the first prolene suture was held by a bull-dog clamp in the thoracic cavity and the second step suturing started immediately. The technical details of the PA arterioplasty are described in Video 2 (Figure 4b).

Postoperative care

All patients were awakened in the operating room soon after the surgery and transferred to the intensive care unit. Mobilization and pulmonary rehabilitation were started on postoperative day 1. Routine fiberoptic bronchoscopy was performed to evaluate the anastomosis site on postoperative day 1 and 30 days after discharge.

Statistical analysis

Continuous variables were summarized as mean ± standard deviation and compared using the two-sample Student’s t-test. Categorical data were presented as frequencies and
percentages. The chi-square (χ²) test or the Fisher’s exact test was used to compare the distribution of categorical variables between groups. A two-sided $p < 0.05$ was considered statistically significant. All statistical analyses were performed using the IBM SPSS Statistics for Windows, version 25.0 (IBM Corporation).

**RESULTS**

**Baseline characteristics**

The baseline characteristics of the 15 patients who underwent robotic bronchial sleeve lobectomy are summarized in Table 1. Most patients were men (86.7%, 13/15) and had a history of smoking (73.3%, 11/15).

**Intraoperative characteristics**

The various operations done are listed in Table 3. One case of left upper double-sleeve lobectomy and one case of left upper sleeve lobectomy with PA arterioplasty were also included. All 15 patients underwent radical resection and successful bronchial anastomosis using the da Vinci Xi robotic system with no conversions to thoracotomy. The mean total surgical duration was 102.35 min and total bronchial anastomosis time was 25.8 min. All patients were extubated at the end of the surgery. Mechanical ventilation was not required in any patient.

**Histologic type and pathologic stage**

Squamous cell carcinoma of the lung was the most common histologic type (10/15), followed by adenocarcinoma of the lung (Table 3).

All resections were classified as RO, i.e. no residual tumor. There were 13 cases of non-small-cell lung cancer in total (13/15). The other two cases, a carcinoid and an adenoid cystadenocarcinoma, were not staged. Nine of the 13 cases of non-small-cell lung cancer were

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**Figure 4** The vessel anastomosis between the proximal main vessel and the distal lobar vessel was performed by using a half-continuous suture technique with two 4-0 Prolene sutures. (a) The half-continuous suture was specially made. Each suture was 15 cm long. The end was sutured on a blood vessel gasket to prevent the suture from falling off when the blood vessel was sutured. (b) Pulmonary artery arterioplasty

**Table 3** Intraoperative and postoperative characteristics of 15 patients undergoing robotic bronchial sleeve lobectomy

| Variable                                      | Value                  |
|-----------------------------------------------|------------------------|
| Type of robotic bronchial sleeve lobectomy    |                        |
| Right                                         |                        |
| Upper                                         | 4 (26.7)               |
| Middle                                        | 1 (6.7)                |
| Lower                                         | 3 (20.0)               |
| Left                                          |                        |
| Upper                                         | 3 (20.0)               |
| Lower                                         | 4 (26.7)               |
| Intraoperative characteristics                |                        |
| Operation time (min)                          | 102.35 ± 46.31         |
| Intraoperative blood loss (ml)                 | 64.71 ± 38.59          |
| Number of lymph node stations removed         | 5.29 ± 1.86            |
| Number of lymph nodes removed                 | 14.86 ± 9.05           |
| Thoracic drainage on the first day after surgery (ml) | 288.82 ± 240.49       |
| Postoperative hospital stay (d)                | 4.76 ± 2.54            |
| Pathologic type                               |                        |
| Squamous cell carcinoma                       | 10 (66.7)              |
| Adenocarcinoma                                | 3 (20.0)               |
| Other                                         | 2 (13.3)               |
| Pathologic TNM stage*                         | 13 (86.6)              |
| IB                                            | 2                      |
| IIA                                           | 6                      |
| IIB                                           | 3                      |
| 90-day mortality                              | 0                      |
| Postoperative complications                   |                        |
| Prolonged air leak >7 days                    | 1                      |
| Pneumonia                                     | 1                      |
| Bronchopleural fistula                        | 1                      |

Note: Continuous data are mean ± SD; categorical data are n (%).

Abbreviation: IASLC, International Association for the Study of Lung Cancer.

*The IASLC 8th edition of the TNM classification was used for non-small-cell lung cancer.
found to have early-stage disease (TNM I–II), while four cases had advanced-stage disease (TNM III). Table 3 shows the distribution of the various disease stages in the patients.

**Postoperative outcomes**

The mean postoperative hospital stay was 4.76 ± 2.54 days. The overall operative mortality and morbidity rates were 0% and 20.0%, respectively (Table 3). One patient (6%) developed a bronchopleural fistula which closed spontaneously after drainage. Postoperative recovery at 3 months was uneventful in all patients.

**DISCUSSION**

There are several intrinsic features to robotic surgery, such as three-dimensional vision, seven-freedom maneuverability of the instruments, and tremor filtering. These features confer several advantages during robotic lobectomy as compared with lobectomy done by thoracotomy. These are less blood loss, shorter length of hospital stay, decreased postoperative pain, and more effective lymph node dissection. We sought to use the advantages of robotic surgery while further reducing the trauma of surgical incisions by using only two ports for robotic sleeve lung surgery.

The concept of two-port robotic sleeve lung surgery is similar to that of uniportal thoracoscopic sleeve resection. In robotic sleeve lung surgery, there is no visual blind spot during sleeve anastomosis. Both arms are involved in the anastomosis in the thoracic cavity, which is more convenient than the sleeve anastomosis possible under uniporal thoracoscopy. The three mechanical arms are distributed in a triangle in the two-port robotic sleeve lung surgery, which reduces the interference between the mechanical arms. Surgical incisions are smaller and trauma is less. Also, surgery is safer and more convenient.

In robotic sleeve surgery, choosing the right suture is key to its success. In two-port robotic sleeve surgery, there is no assistant to tighten the sutures. In bronchial or tracheal sleeve anastomosis, we used barbed sutures. In the pulmonary artery sleeve anastomosis, we used specially made prolene sutures and bull-dog clamps to tighten the sutures. However, barbed sutures have the risk of scratching the surrounding blood vessels after degradation, so it is recommended that they should be covered with the surrounding tissues if the anastomosis is adjacent to a vessel.

Besides the surgical and survival outcomes, the learning curve of robotic sleeve lobectomy is another concern for thoracic surgeons. Our team has accumulated a lot of experience in sleeve lung resection under uniportal thoracoscopy and two-port robot-assisted lobectomy. This has greatly shortened the learning curve for performing two-port robotic sleeve lobectomy. However, the lack of force feedback in robotic surgery may cause unexpected damage to the patient. This is a limitation as compared with uniportal thoracoscopic sleeve lobectomy.

The primary limitation of this study is the small number of patients in the series. All operations were performed by a single surgeon in an institution which has a high volume of robotic pulmonary resections. Our follow-up period was short and we evaluated only postoperative outcomes. Therefore, the efficacy of the procedure on the oncological prognosis and survival of the patient is not known.

**CONCLUSION**

Two-port robotic sleeve lobectomy using Stratafix sutures is a feasible, safe, and effective procedure for the surgical treatment of central lung tumors. We suggest that the two-port robotic system is an effective option for a minimally invasive surgical approach in selected patients.

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**COMPETING INTERESTS**

All authors have no competing interest to declare.

**DATA AVAILABILITY STATEMENT**

All data included in this study are available upon request by contact with the corresponding author.

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