A new technique for introduction of a surgical stapler in robot-assisted lobectomy for lung cancer

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Abstract

Background:

The da Vinci Si version of robot lacks a vascular stapler that can be controlled by the operating surgeon at the surgical console for dividing the pulmonary vessels. Therefore, in order to initiate and safely perform robotic anatomical lobectomy for lung cancer, it is important to develop a safe method for introducing the surgical stapler.

Method:

We performed a retrospective study of the first 42 consecutive patients who underwent robotic lobectomy for lung cancer at Nippon Medical School Hospital between January 2019 and December 2020.

Results:

Up to case 18, we performed Robot-assisted thoracoscopic surgery (RATS) lobectomy using the four-arm approach with two assistant ports. For dividing the pulmonary vessels, the surgical stapler was introduced through the assist ports. However, since this is not the port position usually used in video-assisted thoracoscopic surgery (VATS), there were many difficult situations.
From case 19 onwards of RATS lobectomy, we began to use a total port approach using three robotic arms and two assistant ports. For resecting the pulmonary vessels or bronchi with endoscopic staplers, the port for the robotic arm was removed and the endoscopic staplers were placed through a 12-mm Xcel bladeless port. This change resulted in a shorter operation time, less blood loss, and less robotic arm interference. There has been no case that developed intraoperative complications during RATS lobectomy.

**Conclusion:**

The new total port approach, with three robotic arms, for introducing surgical staplers during RATS using the da Vinci Si robotic system appears to be feasible.
Introduction

Robot-assisted thoracoscopic surgery (RATS) for lung cancer has come to be widely adopted in recent years. It is reported to offer several advantages over video-assisted thoracoscopic surgery (VATS), such as magnified operative views, three-dimensional visualization, enhanced surgical instrument maneuverability, and better precision\(^1\)\(^-\)\(^6\). In Japan, robotic anatomical lobectomy and segmentectomy for lung cancer are covered by the Japanese national health insurance \(^7\)\(^-\)\(^9\). Previous reports have confirmed acceptable morbidity and mortality of robotic surgery for appropriately selected lung cancer patients\(^5\)\(^-\)\(^9\). RATS has also been reported to be a safe and feasible technique, providing comparable long-term overall and progression-free survival to open thoracotomy\(^7\)\(^-\)\(^12\).

Much has been reported on the optimal approach for robotic surgery, including the appropriate port placement approach, ranging from an incomplete port approach with access via a VATS incision, to a total port approach with the use of four robotic arms\(^1\)\(^-\)\(^4\), \(^13\)\(^-\)\(^15\).

Veronesi et al. reported performing four-arm robotic lobectomy for early lung cancer using three ports plus one utility incision (3 cm) to isolate the hilar
elements, and performed vascular resection using endoscopic staplers\(^1\). Ramadam et al. reported using a total port approach with four robotic arms, in a completely closed environment\(^{15}\); prior to port placement, they used carbon dioxide (CO2) for thoracic insufflation, which provides many benefits, such as expanding the thoracic cavity by decreasing the lung volume and pushing the diaphragm downward and decreasing the risk of bleeding via increasing the intrathoracic pressure\(^{1-5}\).

In Japan, the da Vinci Surgical system, including the Si system and Xi system (Intuitive Surgical, Sunnyvale, Sunnyvale, USA), is approved by national health insurance as the robotic system for anatomical pulmonary resection in patients with lung cancer\(^{7-9}\). The earlier version of the da Vinci Si robot lacks a vascular stapler that can be controlled by the operating surgeon at the surgical console for dividing the pulmonary artery and pulmonary vein. These tasks, including dividing the bronchus, are performed by a trained bedside assistant doctor whose role includes placing, manipulating, and firing the staplers around major vascular structures, such as pulmonary arteries and pulmonary veins. These are the disadvantage of RATS using da Vinci Si robot. In order to initiate and safely perform robotic anatomical
lobectomy or segmentectomy for lung cancer, it is important to develop a safe method to introduce the surgical stapler for dividing the pulmonary arteries and veins, and to standardize the technique. Therefore, this study was aimed at introducing a new procedure for the introduction of a surgical stapler or energy device during lung resection using the da Vinci Si robotic surgical system, and to present the management protocol at our institute.


**Patients and methods**

**Patients**

We retrospectively investigated the clinical data of the first 42 consecutive patients who underwent RATS for lung cancer from January 2019 to December 2020 at Nippon Medical School Hospital. This study was conducted with the approval of the institutional ethics committee of Nippon Medical School Hospital. We analyzed the patient characteristics, the operation data, the intra- and postoperative complications, and the surgical procedures adopted, including the port placement pattern.

**Surgical procedure**

The patients are placed in the lateral decubitus position with their hips flexed. The da Vinci Surgical system Si, the robotic surgical system used, is rolled in from the head side of the patients, as described in previous reports. For the da Vinci Si arms ports, we use 8-mm reusable metal da Vinci trocars. The placement of the port is optimized for robotic arm maneuverability, as reported by Cerfolio et al. We use three 8-mm ports (1st, 2nd and 3rd robotic arms), one 12-mm port (camera), and two assistant ports, as the total port approach with four robotic arms. For cases 1-18, we placed the three...
ports for the robotic arms in the 7th or 8th intercostal space (ICS), and a port for the 3rd robotic arm, which was mainly used for retraction of the lungs using the Cadiere grasper. The port for the 2nd robotic arm was placed 8 cm away from the 3rd port, and was used for the bipolar Fenestrate. The port for the 1st robotic arm, which was used for the monopolar-Spatula, was placed 8 cm away from the port for the camera, which was placed in the mid-axillary line. The assistant ports were a 12-mm port for a 30-mm Lapprotector™ FF7070 (Hakko Co., Ltd., Tokyo, Japan) and an 8-mm port for an instrument cannula (Intuitive Surgical, Sunnyvale, USA), which were used for stapling of the vessels and bronchi. The assistant port 1 (30 mm Lapprotector™ FF7070) was placed in the 4th or 5th ICS on the anterior axillary line, and the other assistant port, assistant port 2 (8 mm) was placed in the 8th or 9th ICS on the posterior axillary line, and they were used for retracting the lobes. At assistant port 2, an Air Seal® (Conmed Japan, Tokyo, Japan) access port was inserted for CO2 insufflation (8-10 mm Hg) of the thoracic cavity. These assistant ports, placed in preparation for an unexpected or critical bleeding event, were especially important for surgeons beginning to gain experience in robotic surgery8-9, 15, 16.
From case 19 onward of RATS lobectomy, we have used one 8-mm port (2nd robotic arm), two 12-mm ports (1st robotic arm, camera) and two assistant ports, as the total port approach with three robotic arms, as shown in Fig. 1A, B. The 1st robotic port is placed in the 7th ICS on the anterior axillary line, as described above. Via this port, a 12-mm Endopath Xcel bladeless port (Johnson & Johnson K.K., Tokyo, Japan) is inserted, through which an 8-mm instrument cannula for the robotic arm is inserted (Fig. 1B, 1C). For resecting the pulmonary arteries, veins, or bronchi with endoscopic staplers, the port for the robotic arm is removed and the endoscopic stapler is placed through the 12-mm Xcel bladeless port. In this approach, the 3rd robotic arm is not used, so that the port placement for the 2nd arm is shifted slightly behind, and the 2nd port is set in a position that does not interfere with the robotic camera, which is inserted through the port in the 6th or 7th ICS on the mid-axillary line. All of the above procedures are performed in a completely closed environment, and CO2 insufflation (8-10 mm Hg) is used to expand the thoracic cavity and push the diaphragm down.

**Statistical analysis**

Comparative analyses were performed for patients who received RATS with
four robot arms versus three robot arms. Student’s T test for continuous data were used for univariate analyses about $P$ values of less than 0.05 were considered to indicate a statistically significant.
Results

Up to case 18, we performed RATS lobectomy by the four-arm approach with two assistant ports, as described in previous reports\(^3\), \(^4\), \(^13\), \(^15\); there were no cases of major complications or bleeding that required urgent conversion to open thoracotomy in shown in table 1. The average operation time was 249.1 min, average console time was 192.7 min, and the median duration of chest tube drainage was 4.1 days (range, 2-12). Three patients needed pleurodesis because of prolonged air leakage. However, we frequently encountered interferences among the robot arms, especially the 2nd and 3rd arms, which resulted in bleeding from the chest wall, as shown Fig 2. There were 3 patients who underwent lobectomy by the four-arm approach, in whom the blood loss was more than 100 mL; on the other hand, none of the patients who underwent surgery by the three-arm approach had excessive blood loss, as shown in Table 1. One of the patients of the former group had postoperative chest pain which necessitated visits to a pain clinic. Thus, the insertion and removal of the robotic arms were causing interference. The bleeding was not from the pulmonary artery or other large vessels in any of the three cases.

In the four-arm approach, we used the Cadiere grasper as a surgical
instrument for retracting the lung lobes. Given that retraction is critical for properly exposing the hilar structures that need to be divided, it was very useful. However, robotic arms such as the Cadiere grasper cause injury to the lung and air leakages, which need to be repaired. Such repair of air leakages contributes to prolongation of the operation time. For dividing the pulmonary artery, the pulmonary vein, and the bronchus, a surgical stapler is used through the assist ports. However, since this is not the port position usually used in VATS, the procedure took a long time and there were many difficult situations, especially for the bedside assistant doctors.

The aforementioned factors prompted us to change our approach for robotic lobectomy from the four-arm (1st, 2nd, and 3rd arms and a camera) approach to the total port approach using three arms (1st and 2nd arms and a camera).

For the 1st arm, the port is placed in the 7th ICS on the anterior axillary line, and is used for staplers or energy devices. Such introduction of staplers for dividing the pulmonary arteries or veins through a port in the 7th ICS is commonly adopted in VATS and the surgical assistants are familiar with the procedure. When performing lower lobectomy for right lower lobe lung cancer, all introductions of staplers are made from the port via the 12-mm Endopath
Xcel bladeless port in the 7th ICS on the anterior axillary line (Table 2). As shown in Fig. 3A, the Cadiere grasp introduced through the 12-mm Endopath Xcel bladeless port is used to expose the pulmonary artery A7-A10. After removal of the Cadiere grasp, the vascular stapler to divide the pulmonary arteries is introduced through the same port (Fig. 3B).

As shown in Table 2, from the Xcel port, the posterior fissure and the anterior fissure are divided by placing the staplers. For performing upper or middle lobectomy on the right side, the port which is placed for the 2nd arm in the 8th ICS on the posterior axillary line is used for dividing the anterior fissure between the upper and middle lobe.

In the case of left lung cancer, the 2nd arm is also placed in the 7th ICS on the anterior axillary line, and is used for introducing staplers or energy devices. As shown Table 2, we began to adopt this new procedure for introducing surgical staplers from case 19 onwards. The average operation time was 192.7 min, average console time was 144.8 min, and the median duration of chest tube drainage was 3.3 days (range, 2-12). This change in surgical approach resulted in a shorter operation time, and less robotic arm interference (Table 1). The blood loss was 24.3ml and lower than the four port
approach. There were no significant differences in the postoperative outcomes, such as the duration of drainage, hospital stay, or frequency of complications between cases 1-18 and cases 19-42.
Discussion

Kernstine et al. performed completely robotic lobectomies with three arms, but enlarged the axillary port to a variable size, depending on the lobe to be resected and size of the tumor\textsuperscript{17}; such an approach is the so-called robotic-assisted approach. Park et al. used a three-arm technique, but made a utility incision to extract the resected lobe\textsuperscript{19}. These techniques are feasible and safe, but are conducted in a partially open environment, which precludes the use of CO2 insufflation. Insufflation of CO2 into the chest cavity caused the gas to enter the vascular sheath and mediastinal pleura, pushing the mediastinum and diaphragm, which resulted in a sufficient field of view, reducing the risk of bleeding and enabling sharp dissection of the hilar lymph nodes. The accuracy of lymph node dissection and the sharp and fine vascular dissection in robotic surgery already seems to be far superior to the procedures used in VATS or open thoracotomy.

On the other hand, our 3-arm technique using the Lapprotector\textsuperscript{TM} allows CO2 insufflation, which can expand the thoracic cavity and decrease the volume of the lung and push the diaphragm down. Ramadan et al. previously reported that their method of CO2 insufflation for the total port
approach with four robotic arms was more useful than other robotic approaches, such as the robotic-assisted approach\textsuperscript{15}.

After the first 18 RATS lobectomies at our institute, we changed our approach from a total port approach using four robotic arms to a total port approach using three robotic arms (1st and 2nd arms and a camera), while also changing the procedure for introducing a surgical stapler.

Since it was a learning phase up to case 18, the surgeries took much longer and there were various problems, as reported previously\textsuperscript{1-6, 20}.

In the da Vinci Si robotic surgical system, unlike in the Xi system, the surgical stapler is usually inserted through an assistant port, because it is not possible to use a robot-controlled surgical stapler for dividing the PA, PV, and bronchus\textsuperscript{7-10, 21, 22}. Up to case 18 among the patients enrolled in this study, there was no option but to introduce the surgical stapler through the assistant port. Velonesi et al. reported that they used three ports, along with one utility incision (3 cm) to isolate the hilar elements and perform vascular resection using endoscopic staplers\textsuperscript{1}. Kagimoto et al. also reported using the same approach with the utility incision made in the axillary line\textsuperscript{7}. The assistant port is also important in case of sudden or catastrophic bleeding.
However, the positions of these assistant ports are not always conducive to the introduction of surgical staplers to divide the PA and PV\textsuperscript{8,9}. In fact, until case 18, insertion of the surgical stapler from the unfamiliar positions was a difficult and uncomfortable operation. The direction of the staplers was sometimes limited by the location of the assistant ports, resulting in difficulties in positioning the staplers as previous reports\textsuperscript{13-15, 23}.

Because the console surgeon does not have the ability to control the surgical staplers used for dividing the major vessels in da Vinci Si system, unlike in the Xi system, which has a robotic stapler, it is very important to establish a safe procedure to insert the stapler. Therefore, in order to overcome these problems, we introduced and began to practice a new approach from case 19. As shown Fig. 3A, we exposed the pulmonary artery and introduced the penrose drain as a guide using the Cadiere grasper via an 8-mm instrument cannula for the robotic arm through the 12-mm Endopath Xcel bladeless port. We then removed the instrument cannula, and inserted the surgical stapler through the Xcel port (Fig. 3B). Since the angle of insertion of the stapler was the same as in VATS lobectomy, the assistant doctor was in a familiar position and was able to complete the lobectomy without any problems\textsuperscript{4, 6, 24}. 
In fact, after case 19, we became more skilled, the operation time decreased with the use of the new approach, and we were able to perform the surgery smoothly and safely. For right upper lobectomy or middle lobectomy, the stapler for dividing the anterior fissure is inserted via an 8-mm instrument cannula for the robotic 2nd arm through the 12-mm Endopath Xcel bladeless port on the mid-axillary line, as shown in Table 2. For right or left lower lobectomy, the stapler for dividing the PA, PV, bronchus and fissure is inserted via an 8-mm instrument cannula for the robotic arm through the 12-mm Endopath Xcel bladeless port on the anterior axillary line, as shown in Fig. 2. All vessels were divided with surgical staplers inserted through the Xcel port in the 7th ICS, as shown in Table 2.

An important aspect of RATS for lung cancer is to ensure safety, and catastrophic complications such as pulmonary artery injury could not occur\textsuperscript{5-9, 13, 24}. Cao et al. reported the occurrence of an intraoperative catastrophe in 1.9% of cases, a similar frequency to that reported for conventional VATS lobectomy\textsuperscript{24}. Recently, Ueno reported that three of the 156 cases of RATS lobectomy in their series required conversion to open thoracotomy\textsuperscript{8}. In two of these patients, the reason for the conversion was bleeding from the
pulmonary artery. Sato et al. also reported that they needed conversion to open thoracotomy in five of the first consecutive 65 patients at their institution who underwent RATS lobectomy: the reason for the conversion was uncontrolled bleeding from the pulmonary artery in two cases, and from the pulmonary vein in one case\textsuperscript{9}. In our study, none of the 42 consecutive patients who underwent RATS required conversion to open thoracotomy. As shown in Table 1, there were no intraoperative complications, and no significant problems were encountered during the RATS lobectomy. We believe that these favorable surgical outcomes of a surgery that appears to be safe, may be due, in large part, to our adoption of the new procedure for introducing the surgical stapler.

This was a retrospective study of the initial 42 cases of RATS lobectomy at our institution, to determine the validity of a new procedure to introduce a surgical stapler, namely, the total port approach with three robotic arms using the da Vinci Si robotic surgical system and a new procedure for introducing surgical staplers. Recently, the da Vinci Xi system has been equipped with a robotic stapler (EndoWrist Stapler), which seems to be safe and effective\textsuperscript{13, 21, 22}. However, the arc of motion of a robotic stapler is large and different
from that of other robotic instruments, and it needs some getting used to, for dividing the hilar structures. From a medical economic point of view, a robotic stapler is expensive and not economical to use\textsuperscript{13,22}. We were able to perform RATS lobectomy safely using the da Vinci Si system. Our team has only just started to perform robotic surgery for lung cancer, and we are accumulating more cases for further validation.

In conclusion, for facilities that are planning to perform robotic lobectomy in the future, especially those planning to use the Si system, it would be safer and easier to adopt our recommended approach for introducing surgical staplers.
Conflict of Interest

The authors declare no conflicts of interest.
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Conflict of Interest

The authors declare no conflicts of interest.
Figure legends

Figure 1A, B: Images of port placement. The total port approach with three-port placement for right-sided lobectomy with da Vinci Si robotic arms 1 and 2, camera, and access ports. a) Port placed in the 7th intercostal space (ICS) on the anterior axillary line. ENDOPATH® Xcel bladeless and the instrument cannula are used. For the 1st arm, a permanent cautery Spatula (monopolar) is inserted through the port. b) Port placed in the 7th-8th ICS on the posterior axillary line, used for the 2nd arm with Fenestrated bipolar forceps. c) Port placed in the 7th-8th ICS on the mid-axillary line, used for the ENDOPATH® Xcel bladeless port as a camera port. d) Port placed in the 4th-5th ICS on the anterior axillary line, used for a 30-mm Lapprotector™ FF7070 and an 8-mm instrument used for retraction of the lung using Thoraco cotton®. The lung is removed via this port. e) A port made in the 8th-9th ICS, used for CO2 insufflation and retraction of the lung using Thoraco cotton®.

Figure 1C: A 12-mm Endopath Xcel bladeless port (f) is inserted, through which an 8-mm instrument cannula (g) for the robotic arm is inserted for robotic arm #1.
Figure 2: Bleeding from the chest wall. The red star shows the 3rd port.

Figure 3: Insertion of the penrose drain and division of the pulmonary arteries (A7-10). A) Expose the pulmonary arteries (A7-10) and introduce the penrose drain as a guide for the surgical stapler during lobectomy through the 1st robotic port placed in the 7th ICS on the anterior axillary line, through the 12-mm Endopath Xcel bladeless port.

B) Remove the robotic port, insert the stapler via the Xcel port and advance the stapler across the PA.
Figure 1

A

a) Arm #1
b) Arm #2
c) Camera
d) Assist port 1
e) Assist port 2

B

d) Assist port 1
b) Arm #2
c) Camera
d) Assist port 1

C

a) Arm #1
f) 
g)
Table 1

Clinico-pathological data of the patients who underwent robotic lobectomy.

| Case procedure | 1st ~18th | 19th~42th | p-value |
|----------------|-----------|-----------|---------|
| No. of operations | 18        | 24        |         |
| Age (range) | 69.5(46-79) | 71.2(38-84) |         |
| Sex | | | |
| Male | 10 | 13 | |
| Female | 8 | 11 | |
| Height (cm) | 161.0 (142-173) | 168.8(149-183) | |
| Clinical stage | | | |
| IA1 | 0 | 2 | |
| IA2 | 3 | 6 | |
| IA3 | 10 | 8 | |
| IB | 3 | 6 | |
| IIA | 1 | 0 | |
| IIB | 1 | 2 | |
| Surgical procedure | | | |
| upper lobectomy | 8 | 9 | |
| middle lobectomy | 1 | 1 | |
| lower lobectomy | 9 | 13 | |
| Middle and lower lobectomy | 0 | 1 | |
| No. of Conversions to Thoracotomy | 0 | 0 | |
| Operation time (min)(range) | 249.1 ± 57(151-361) | 196.5 ± 35.6(165-272) | 0.002 |
| Console time (min)(range) | 192.7 ± 50.1(107-301) | 144.8 ± 30.2(125-220) | 0.001 |
| Blood loss (ml)(range) | 48.9 ± 83.6(0-310) | 24.3 ± 35.0(0-130) | 0.253 |
| Blood loss (> 100ml) | 3 | 1 | |
| bleeding from chest walls | 3 | 0 | |
| Chest tube duration (days)(range) | 4.1 ± 2.6 (2-12) | 3.3 ± 1.6(2-7) | 0.235 |
| No. of Complications | | | |
| prolonged air leakage (> 7 days) | 3 | 3 | |
| Chest pain (pain clinic) | 1 | 0 | |
|       | Placing the port for diving the vessels, bronchus and lung fissures |
|-------|------------------------------------------------------------------|
| **RUL, RML** |                                                              |
| 1<sup>st</sup> Arm: 7<sup>th</sup> ICS | PA, PV, bronchus the medial and lateral portion of posterior fissure |
| 2<sup>nd</sup> Arm: 6<sup>th</sup> ICS | the anterior fissure |
| **RLL** |                                                                 |
| 1<sup>st</sup> Arm: 7<sup>th</sup> ICS | PA, PV, bronchus the medial and lateral portion of posterior fissure |
| **LLL** |                                                              |
| 2<sup>nd</sup> Arm: 7<sup>th</sup> ICS | PA, PV, bronchus the anterior and posterior fissure |

*RUL*: right upper lobectomy, *RML*: right middle lobectomy, *RLL*: right lower lobectomy, *LLL*: left lower lobectomy, *PA*: pulmonary artery, *PV*: pulmonary vein