—**Original**—

New Technique for Introducing a Surgical Stapler during Robot-Assisted Lobectomy for Lung Cancer

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

Methods: 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 by using a four-arm approach with two assistant ports. For dividing 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.

For RATS lobectomy case 19 and all subsequent cases, we utilized a total port approach that uses three robotic arms and two assistant ports. To resect 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 reduced operation time, blood loss, and robotic arm interference. No patient developed intraoperative complications during RATS lobectomy.

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

(J Nippon Med Sch 2022; 89: 169–175)

Key words: lung cancer, robot-assisted thoracoscopic surgery (RATS), lobectomy, surgical stapler, da Vinci Surgical system

Introduction

Robot-assisted thoracoscopic surgery (RATS) is now widely used for lung cancer. It offers 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 national health insurance[7–9]. Previous reports 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 that provides long-term overall and progression-free survival comparable to that of open thoracotomy[7–12].

Much has been reported on the optimal approach for robotic surgery, including appropriate port placement approach. Approaches range from an incomplete port approach with access via a VATS incision to a total port approach using four robotic arms[1–4,13–15]. Veronesi et al. reported performing four-arm robotic lobectomy for early lung cancer. They used three ports plus one utility incision (3 cm) to isolate the hilar elements and performed

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https://doi.org/10.1272/jnms.JNMS.2022_89-211
Journal Website (https://www.nms.ac.jp/sh/jnms/)

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]; before port placement, they used carbon dioxide (CO_2) for thoracic insufflation, as it 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 by increasing intrathoracic pressure[1–5].

In Japan, the da Vinci Surgical system, including the Si and Xi systems (Intuitive Surgical, Sunnyvale, USA), is approved by the national health insurance system for anatomical pulmonary resection in patients with lung cancer[7–9]. The earlier version of the da Vinci Si robot lacked a vascular stapler that could be controlled by the operating surgeon at the surgical console when dividing pulmonary arteries and veins. These tasks, including dividing the bronchus, are performed by a trained bedside assistant doctor whose role includes placing, manipulating, and firing staplers around major vascular structures, such as pulmonary arteries and pulmonary veins. These are disadvantage of RATS using the da Vinci Si robot. 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 introducing a surgical stapler or energy device during lung resection with the da Vinci Si robotic surgical system, and to describe the management protocol at our center.

Patients and Methods

Patients

We retrospectively investigated clinical data from 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 (Approval Number: 30-10-1010). We analyzed patient characteristics, operation data, intra- and postoperative complications, and the surgical procedures adopted, including 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[1–4,7–9]. 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[3,4,13,15]. We use three 8-mm ports (the 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 through 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 with 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 vessels and bronchi. The assistant port 1 (30 mm Lapprotector™ FF 7070) 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. These were used for retracting the lobes. At assistant port 2, an Air Seal® (Conmed Japan, Tokyo, Japan) access port was inserted for CO_2 insufflation (8-10 mmHg) 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 surgery[8,9,15,16].

For case 19 and subsequent cases 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 **Figure 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, C**). For resecting 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. With 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-

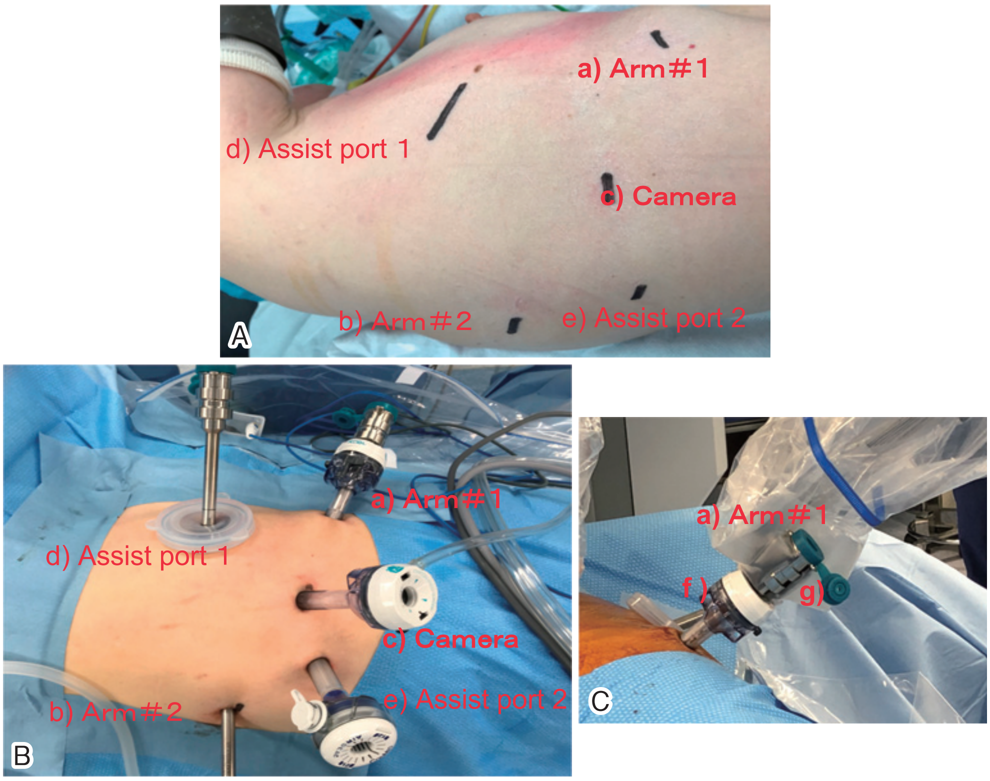

Fig. 1 A, B: Images of port placement. The total port approach with three-port placement for right-sided lobectomy with da Vinci Si robotic arms 1 and 2, camera, and access ports. a) Port placed in the 7th intercostal space (ICS) on the anterior axillary line. ENDOPATH® Xcel bladeless and the instrument cannula are used. For the 1st arm, a permanent cautery spatula (monopolar) is inserted through the port. b) A port placed in the 7th–8th ICS on the posterior axillary line is used for the 2nd arm with Fenestrated bipolar forceps. c) Port placed in the 7th–8th ICS on the mid-axillary line is used for the ENDOPATH® Xcel bladeless port as a camera port. d) A port placed in the 4th–5th ICS on the anterior axillary line is 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 CO_2 insufflation and retraction of the lung using Thoraco cotton®.
C: 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.

axillary line. All the above procedures are performed in a completely closed environment, and CO_2 insufflation (8-10 mm Hg) is used to expand the thoracic cavity and push the diaphragm down.

Statistical Analysis

Data from patients who underwent RATS with four robot arms were compared with those of patients who underwent RATS with three robot arms. The Student T test for continuous data was used for univariate analyses, and *P* values of less than 0.05 were considered to indicate statistical significance.

Results

Up to case 18, we performed RATS lobectomy by using a 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, as shown in **Table 1**. The average operation time was 249.1 min, average console time was 192.7 min, and 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 **Figure 2**. There were three patients who underwent lobectomy with a four-arm approach, in whom the blood loss was more than 100 mL; in contrast, no patient who underwent surgery by the three-arm approach had excessive blood loss, as shown in **Table 1**. One patient in the former group

Table 1 Clinicopathological data of patients who underwent robotic lobectomy

Case	1 ~ 18	19 ~ 42	p-value
procedure	Four robot arms	Three robot arms	
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 (> 100 mL)	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	

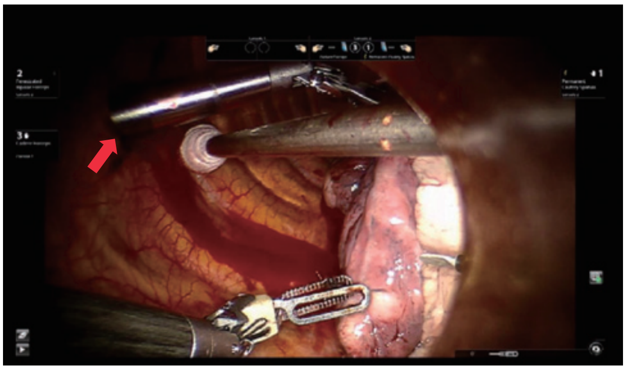

Fig. 2 Bleeding from the chest wall. The red star shows the 3rd port.

had postoperative chest pain that required visits to a pain clinic. Thus, 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 a Cadiere grasper to retract the lung lobes. Because 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, which prolongs operation time. To divide the pulmonary artery, pulmonary vein, and bronchus, a surgical stapler is used through the assist ports. However, since this is not the port position usually used in VATS, the procedure was lengthy and difficult, especially for bedside assistant doctors[6,17].

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. Staplers for dividing the pulmonary arteries or veins through a port in the 7th ICS are commonly introduced in VATS, and surgical assistants are familiar with the procedure. When performing lower lobectomy for right lower lobe lung cancer, all introductions

Table 2 Placing the port for dividing the vessels, bronchus and lung fissures

RUL, RML		
	1st Arm: 7th ICS	
		PA, PV, bronchus
		medial and lateral portion of posterior fissure
	2nd Arm: 6th ICS	
		the anterior fissure
RLL		
	1st Arm: 7th ICS	
		PA, PV, bronchus
		medial and lateral portion of posterior fissure
LLL		
	2nd Arm: 7th ICS	
		PA, PV, bronchus
		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

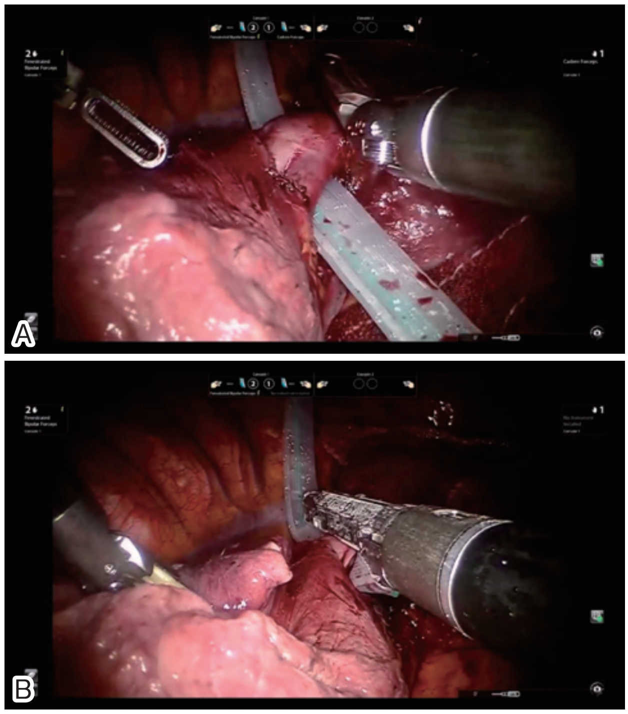

Fig. 3 Insertion of the Penrose drain and division of the pulmonary arteries (A7-10). A) Exposing the pulmonary arteries (A7-10) and introducing the Penrose drain as a guide for the surgical stapler during lobectomy through the 1st robotic port placed in the 7th ICS on the anterior axillary line, through the 12-mm Endopath Xcel bladeless port.
B) Removing the robotic port, inserting the stapler via the Xcel port, and advancing the stapler across the PA.

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 **Figure 3A**, the Cadiere grasper introduced through the 12-mm Endopath Xcel bladeless port is used to expose the pulmonary artery A7-A10. After removal of the Cadiere grasper, 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 and anterior fissures are divided by placing the staplers. For performing upper or middle lobectomy on the right side, the port that 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.

For 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 in **Table 2**, we began to adopt this new procedure for introducing surgical staplers at case 19. Average operation time was 192.7 min, average console time was 144.8 min, and median duration of chest tube drainage was 3.3 days (range, 2-12). This change in surgical approach reduced operation time and robotic arm interference (**Table 1**). Blood loss was 24.3 mL, lower than for the four-port approach. There were no significant differences in postoperative outcomes, such as 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 that depended on the lobe to be resected and the size of the tumor[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[18]. These techniques are feasible and safe but are conducted in a partially open environment, which precludes the use of CO_2 insufflation. Insufflation of CO_2 into the chest cavity causes the gas to enter the vascular sheath and mediastinal pleura, pushing the mediastinum and diaphragm, which results in a sufficient field of view, thereby 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 seem to be far superior to the procedures used in VATS or open thoracotomy.

Our 3-arm technique using the Lapprotector™ allows CO_2 insufflation, which can expand the thoracic cavity, decrease the volume of the lung, and push the diaphragm down. Ramadan et al. previously reported that their method of CO_2 insufflation for the total port approach with four robotic arms was more useful than other robotic approaches, such as the robotic-assisted approach[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. Because it was a learning phase up to case 18, the surgeries took much longer and various problems were encountered, as reported previously[1–6,19].

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[7–10,20,21]. Up to the present case 18, 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[1]. Kagimoto et al. also reported using the same approach, with the utility incision made in the axillary line[7]. The assistant port is also important in cases 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[8,9]. In fact, until case 18, insertion of the surgical stapler from unfamiliar positions was difficult and uncomfortable. The direction of the staplers was sometimes limited by the location of the assistant ports, thereby resulting in difficulties in positioning the staplers, as previously reported[13–15,22].

Because the console surgeon does not have the ability to control the surgical staplers used for dividing the major vessels in the 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, to overcome these problems we introduced and began to practice a new approach from case 19. As shown in **Figure 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**). Because the angle of insertion of the stapler was the same as that in VATS lobectomy, the assistant doctor was in a familiar position and could complete the lobectomy without problems[4,6,23]. In fact, after case 19, we became more skilled; 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 **Figure 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; catastrophic complications such as pulmonary artery injury must be avoided[5–9,13,23]. Cao et al. reported an incidence of intraoperative catastrophe of 1.9%, similar to that reported for conventional VATS lobectomy[23]. Recently, Ueno reported that three of 156 cases of RATS lobectomy in their series required conversion to open thoracotomy[8]. In two of these patients, the reason for conversion was bleeding from the pulmonary artery. Sato et al. reported that they needed conversion to open thoracotomy in five of the first consecutive 65 patients at their center 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[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 RATS lobectomy. We believe that these favorable surgical outcomes for a surgery that appears to be safe are mostly attributable to our adoption of the new procedure for introducing the surgical stapler.

This retrospective study of the first 42 cases of RATS lobectomy at our center investigated the validity of a new procedure for introducing a surgical stapler, namely, the total port approach with three robotic arms using the da Vinci Si robotic surgical system. Recently, the da Vinci Xi system was equipped with a robotic stapler (EndoWrist Stapler), which seems to be safe and effective[13,20,21]. However, because the arc of motion of a robotic stapler is large and differs from that of other robotic instruments, it requires considerable experience to divide the hilar structures. In addition, robotic staplers are expensive and uneconomical[13,21,]. We were able to perform RATS lobectomy safely by 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 centers planning to perform robotic lobectomy, especially those planning to use the Si system, our recommended approach for introducing surgical staplers appears safer and easier to adopt.

Conflict of Interest: The authors declare no conflicts of interest.

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(Received, April 24, 2021)
(Accepted, May 31, 2021)
(J-STAGE Advance Publication, September 14, 2021)