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Ingenuity of Lobectomy in Reduced Port Robot-assisted Thoracic Surgery Using the Two Ports and One-window Method in Fusion Surgery

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Objective: In 1992, we devised an operation using the two-window method in which ports are created at only two sites in the thoracic wall for malignant lung tumors. However, in robot-assisted thoracic surgery (RATS), five ports are considered necessary for most thoracic approaches, which is in contrast to the concept of minimal invasiveness. This study aimed to determine the outcome of the two ports and one-window method using fusion surgery for RATS.
Methods: Twenty-one RATSs were performed between November 2023 and September 2024. We performed the two ports and one-window method in all patients.
Results: Among 21 planned RATSs for anatomical pulmonary resections, there were no conversions to thoracotomy and no requirement for extra ports. The mean surgery time was 121.0 minutes and the mean console time was 73.1 minutes. The mean intraoperative blood loss volume was 20.7 mL. The mean duration of chest tube drainage and hospital stay were 3.1 and 4.4 days, respectively. There were no postoperative complications or mortalities.
Conclusions: Our early results suggest that the two ports and one-window method is safe, feasible, and provides excellent perioperative outcomes.

Key words: robot-assisted thoracic surgery, reduced port robot-assisted thoracic surgery, two ports and one-window method, fusion surgery

INTRODUCTION

Robotic-assisted thoracoscopic surgery (RATS) for malignant lung tumors, benign mediastinal tumors, and malignant mediastinal tumors has been covered by the national health insurance since 2018 in Japan. Therefore, the number of domestic robotic surgical procedures has been increasing [1]. Although the insurance reimbursement for RATS lobectomy is the same as that for video-assisted thoracoscopic surgery (VATS) lobectomy, which is disadvantageous in terms of cost, it is attracting attention as a third approach following open thoracotomy and VATS.

In the past 20 years, the advent of the da Vinci robotic surgical system has ushered in a new era of minimally invasive surgery. The high-definition imaging technology of this system and the three-dimensional surgical field with scaled movement and tremor reduction ensure the accuracy of the operation and provide convenience and safety [2]. Many studies have shown that RATS is an effective alternative to VATS, and it has the advantages of less intraoperative blood loss, a faster postoperative recovery time, fewer complications, and a less steep learning curve [3-5]. Robotic-assisted surgery is becoming increasingly popular, but this surgical method is relatively reliant on a multi-port pattern. Robotic platforms are designed for four robotic arms. Therefore, five incisions have been considered necessary for most thoracic approaches, which is in contrast to the concept of minimal invasiveness.

In 1992, we devised an operation using the two-window method in which ports are created at only two sites in the thoracic wall malignant lung tumors. We began using this method with benign diseases, and we expanded its application to malignant tumors, and then devised the thoracoscopic two-window method for primary lung tumors [6]. However, in RATS, five ports are considered necessary for most thoracic approaches, which is not minimally invasive. The number of ports in RATS is larger than that in the two-window method. By combining the two ports in front and the assistant port into a single operation hole (window), reduced port RATS was able to be performed with two ports and one window in 2023. Recent studies have described the technique of uniportal robotic-assisted thoracic surgery (URATS) [7-9]. However, before performing URATS, surgeons are recommended to perform biportal RATS, which has one port in addition to the main access port, taking into considering the characteristics of the robotic stapler and the risk of arm-to-arm interference [9]. The implementation of biportal RATS could be beneficial because of the surgical safety of reduced port RATS [10]. Biportal robotic-assisted lobectomy was safe and showed promising efficacy in patients with early stage operable lung tumor compared with multiportal RATS [11].

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Using our experience with the two-window method for VATS and standard robotic techniques, we recently started performing two ports and one-window RATS. This approach facilitates a shared understanding between the surgeon and the assistant and standardizes surgical techniques by aligning the incision sites with those of the conventional two-window method. Furthermore, quick transition to the two-window method for bleeding and mechanical operation problems is possible. In this study, we report our preliminary series of two ports and one-window RATS for early stage lung tumor, focusing on feasibility, safety, the surgical technique, and early postoperative outcomes.

METHODS

Study design and participants

Twenty-one RATSs were performed between November 2023 and September 2024. We performed the two ports and one-window method in all 21 patients. To be eligible for inclusion in this study, patients had to meet the following inclusion criteria: (I) a tumor with a maximum diameter < 50 mm as shown on a chest computed tomography (CT) scan; (II) no mediastinal lymph nodes with a maximum diameter > 1 cm or no standardized uptake value uptake as shown in a positron emission tomography-computed tomography (PET-CT) scan; and (III) no abnormality detected in preoperative examinations.

The patients were strictly required to quit smoking for 4 weeks, and preoperative examinations were finished and evaluated before surgery. These examinations included pulmonary function testing, coronary computed tomography (CT) angiography, ultrasound cardiograms, brain magnetic resonance imaging, and abdominal ultrasound. Bone scintigraphy or positron emission tomography-CT was performed to rule out metastasis. Surgery was arranged after strict evaluation of the results of the above-mentioned tests. The patients were followed up until they were discharged from the hospital. Data were retrospectively collected from the surgical and medical records. The assessed outcomes were the surgery time, console time, intraoperative blood loss volume, requirement for blood transfusion, number of harvested lymph nodes, postoperative blood test results, lung expansion on radiographs, duration of chest tube drainage, length of hospital stay, early postoperative complications, and death. There was no loss to follow-up because the patients were only followed up until they were discharged from hospital.

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics board of Tokai University Hospital (No. 24R126), and informed consent was obtained from all of the patients. The data of the patients were retrospectively evaluated in the present study.

Surgical procedure for the two ports and one-window method

Typical images of the body surface during the two ports and one-window RATS are shown in Fig. 1. Under general anesthesia with single-lung ventilation, the patients were placed in the lateral decubitus position with a low pelvis. The da Vinci Xi Surgical System® (Intuitive Inc., Sunnyvale, CA, USA) was positioned at the patient's anterior side, and the boom of the patient cart was rotated 90° toward the patient's head. To avoid collisions, we did not use all four arms for lung deployment. Arm 1 was canceled when operating on the right side (arm 2 was used for the left hand, arm 3 for the camera, and arm 4 for the right hand) (Fig. 1b). Arm 4 was canceled when operating on the left side (arm 1 was used for the left hand, arm 2 for the camera, and arm 3 for the right hand). These techniques were identical to those used in DRATS and URATS [7, 10].

In our approach, a single 3–4-cm working port window was created in the sixth intercostal space (ICS) for upper lobe resection. The seventh ICS was used for middle and lower lobe resection along the anterior axillary line as the main port. Second and third ports for two 8-mm trocars were created on the same ICS line as the single window (Fig. 1a). However, the working port was adjusted in accordance with the patient's body shape. One window was created using two cotton swabs with the help of the bedside assistant. This method removes the need for CO_2 insufflation. These additional devices were inserted anterior to the trocar used for the camera to minimize interference with the robotic instruments (Fig. 1b). There was no port for the assistant. However, during the surgery, the stapler, suction, and clamps were held by the bedside assistant through the assistant port (Fig. 2).

The detailed pathological analysis results were available within 4 weeks. The duration of surgery and blood loss were immediately documented. The volume and duration of the postoperative chest tube drainage and complications were recorded during the patients' stay in the hospital.

Statistical analysis

The surgical and postoperative outcomes were assessed using descriptive statistics. Continuous data are presented as the mean ± standard deviation [range], and categorical data are presented as the number and percentage. All collected were tabulated using Microsoft Excel for further analysis.

RESULTS

The patients' characteristics are shown in Table 1. The surgical details are shown in Table 2. All procedures were completed with the two ports and one-window approach. All procedures of anatomical resection were lobectomy (21/21; 100%). The mean surgery time was 121.0 ± 21.3 minutes (range, 70–162 minutes) and the mean console time was 73.1 ± 17.6 minutes (range, 35–97 minutes). The mean intraoperative blood loss volume was 20.7 ± 21.1 mL (range, 1–76 mL). No patient required blood transfusion. The mean duration of chest tube drainage was 3.1 ± 2.2 days (range, 1–9 days). The mean length of hospital stay (i.e., follow-up time) was 4.4 ± 2.2 days (range, 3–10 days). There were no complications or perioperative deaths.

DISCUSSION

The da Vinci Xi surgical system is a fourth-generation robotic-assisted surgical platform that enables a multiport approach in minimally invasive thoracic surgery. This system is characterized by its superior maneuverability, high-definition three-dimensional visualization, and flexible port placement, and it has

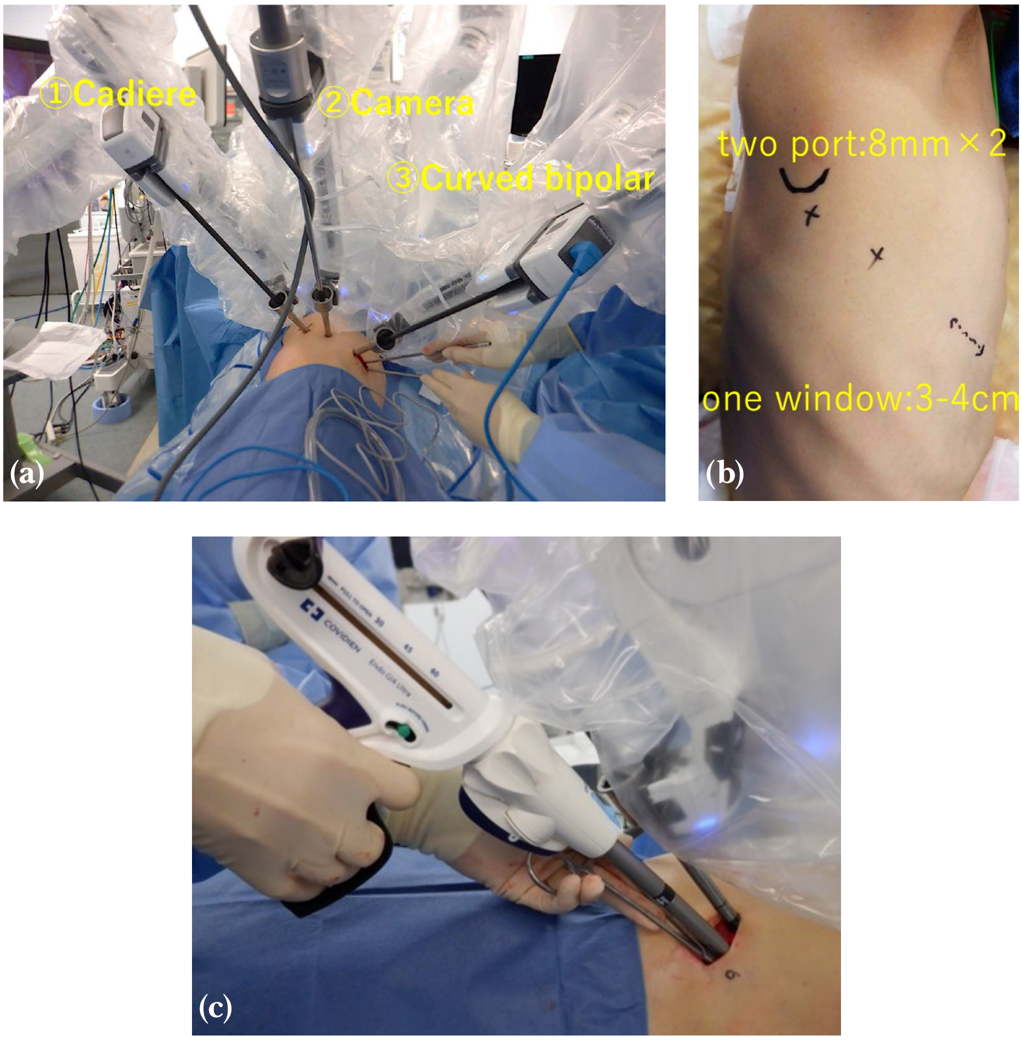

Fig. 1 Typical images of the body surface and port placement during the two ports and one-window method in robotic-assisted thoracic surgery.
(a) Port placement during right lobectomy. The assistant surgeon can use two cotton swabs to expand the operative view. (b) Preoperative skin marking for right lobectomy. A single 3–4-cm working port window was created. Second and third ports for two 8-mm trocars were created on the same ICS line as the single window. (c) The assistant surgeon can use a mechanical stapler or energy device to dissect the vasculature.

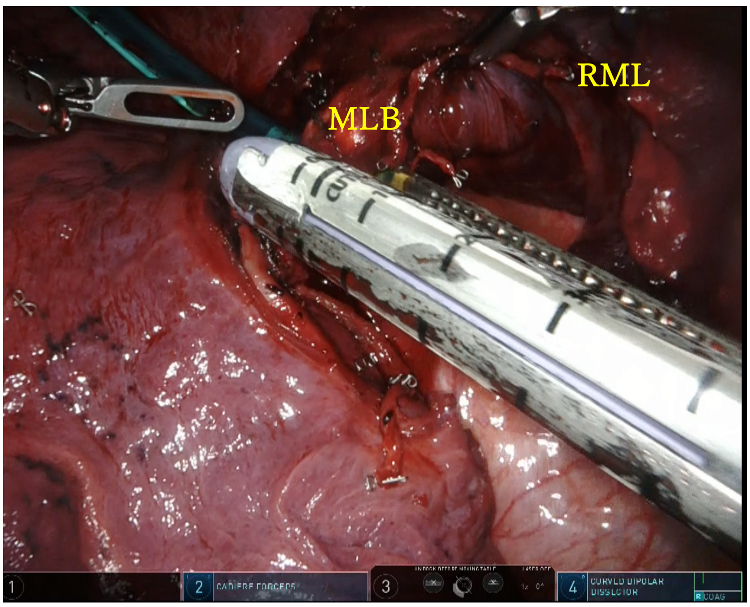

Fig. 2 Two ports and one-window method using fusion surgery for right middle lobectomy.
During the surgery, the stapler is held carried by the bedside assistant through the assistant port.
RML, right middle lobe; MLB, middle lobar bronchus.

Table 1 Patients' clinical characteristics

Variables	n = 21
Age(years)	69 ± 10(50–86)
Gender	
Male	17
Female	4
BMI	23.7 ± 5.0(17.8–33.4)
Smoking index	697 ± 672(0–2340)
Histology	
Adenocarcinoma	14
Squamous cell carcinoma	2
AdSq	1
Pleomorphic	1
Other	3
Clinical tumor size(mm)	23.5 ± 11.0(8–43)
p-stage(8th edition)	
0	0
IA1	4
IA2	6
IA3	3
IB	5
IIA	0
Other	3

Values are presented as mean ± standard [range], as appropriate.
BMI, body mass index.

Table 2 Details of surgery and postoperative results

Variables	n = 21
Laterality(righr/left)	(16/5)
Lobectomy	
RUL	9
RML	2
RLL	5
LUL	0
LLL	5
Surgery time(min)	121.0 ± 21.3(70–162)
Console time(min)	73.1 ± 17.6(35–97)
Blood loss(mL)	20.7 ± 21.1(1–76)
Duration of chest tube drainage(day)	3.1 ± 2.2(1–9)
Length of hospital stay(day)	4.4 ± 2.2(3–10)
Conversion to thoracotomy	0
Morbidity	3(14.3%)
Mortality	0

Values are presented as mean ± standard deviation [range], as appropriate.
RUL, right upper lobectomy; RML, right middle lobectomy; RLL, right lower lobectomy; LUL, left upper left upper; LLL, left lower lobectomy.

become widely adopted in robot-assisted lobectomy for early-stage lung cancer. The use of wristed instruments and a stable camera platform allows for precise dissection and vessel handling within the confined thoracic cavity. The multiport approach is associated with reduced surgical invasiveness, decreased perioperative complications, and shorter hospital stays. Furthermore, oncological safety and procedural accuracy are well maintained. Despite its advantages, the multiport system also has several limitations. The need for multiple incisions may increase the risk of port-site complications, including bleeding, infection, and postoperative pain. Additionally, careful port placement is required to avoid external arm collisions and instrument interference, which can prolong the setup time and increase procedural complexity. Furthermore, the multiport approach may result in higher costs compared to conventional thoracoscopic surgery, due to the use of multiple robotic instruments and consumables. These factors should be considered when selecting surgical strategies for individual patients. In contrast, the reduced-port system has been developed to address these issues by minimizing the number of incisions while maintaining sufficient surgical field exposure. Two ports and one-window RATS approaches may lead to lower postoperative pain, improved cosmetic outcomes, and shorter operative setup times. Furthermore, creating a one-window approach eliminates the need for CO_2 insufflation, which can also contribute to cost reduction.

Creating all incisions within the same intercostal space in two ports and one-window RATS surgery can further contribute to the reduction of postoperative pain by minimizing intercostal nerve irritation. This approach is considered to contribute to the reduction of postoperative pain and the improvement of activities of daily living. These advantages make the two ports and one-window RATS system an attractive option for selected patients undergoing minimally invasive thoracic surgery, including robot-assisted lobectomy.

The da Vinci system was originally designed as a multi-port system. Therefore, there are several issues with reduced port RATS, especially in URATS. First, because three 8.0-mm-diameter arms are inserted through a single incision, there is a risk of interference and collision between the arms. The instructions for the da Vinci Xi Surgical System recommend maintaining a port spacing of 3–4 cm. Second, a third arm is not used, and specific techniques are required to create a good surgical field. Third, because the instrumentation used for URATS differs from that used for traditional RATS, assistants need to be familiar with the techniques of uniportal VATS, and surgeons must practice avoiding instrument collisions [9]. Therefore, the role of the assistant is difficult in URATS. Fourth, in patients with a small chest cavity, the insertion and angulation of the stapler may be compromised by the limited space [7]. The da Vinci stapler is particularly difficult to maneuver when performing URATS in small-bodied Japanese patients. Therefore, we devised the two ports and one-window approach, which allows limited use of a manual stapler at the main window. The two ports and one-window method has some advantages over URATS. First, the use of a second port in this approach allows the da Vinci stapler and forceps to be maneuvered around all parts of the thoracic cavity without interference. In addition, at the end of the operation, the window can be used as an incision for removing the resected lung and inserting a thoracic drain. Second, in contrast to conventional RATS, the main port of the two ports and one-window method is placed on the cranial side, making dealing with emergencies, such as massive bleeding and calcified lymph nodes, easier. A quick transition to the two-window method for bleeding and mechanical operation problems is possible. Third, because the two ports and one-window method only use three arms and does not require CO_2 insufflation, this procedure is cheaper than traditional RATS. The high cost of the robotic platform is one of the main limitations of the introduction and maintenance of RATS in many hospitals worldwide.

We have developed a systematic "fusion surgery" approach by combining a robotic procedure with manual maneuvers. In this approach, the table surgeon retracts the lung and staples the pulmonary vasculature and bronchus from the assist port to better perform and teach this approach and other robotic thoracic operations. Fusion surgery has educational advantages. Although high-quality surgery should be maintained, academic surgeons need to teach younger thoracic surgeons how to safely perform minimally invasive surgeries. However, in Japan, console surgeons are currently limited to those with a Board of Thoracic Surgeons certification. Fusion surgery can assist young surgeons in performing robotic surgery [12]. In our method, the assistant surgeon can use two cotton swabs to expand the operative view (Fig. 1b) and a mechanical stapler or energy device to dissect the vasculature (Fig. 1c, Fig. 2). This approach could help improve their surgical skills and efficiency, as well as reduce the operative time and enhance safety (Table 2).

The present study has several limitations. First, assistants who are involved in the two ports and one-window method must have the skills required for the two-window method in VATS. Second, because this study reports our experiences during the initial introductory period of the two ports and one-window method, the cohort may have comprised a high number of patients with a relatively good condition. Therefore, there were no cases of left upper lobectomy. The efficacy of the two ports and one-window method needs to be determined, and cases including left upper lobectomy need to be accumulated. Third, this retrospective study had a small sample size. Fourth, because this study focused on evaluating the effect of a reduced number of ports in robotic pulmonary resection, we did not evaluate the oncological outcomes, such as survival or recurrence. Further studies are required to evaluate the oncological outcomes of patients who have undergone the two ports and one-window approach.

Recently, in robot-assisted lobectomy, both the da Vinci SP (Single Port) system have been developed with the aim of achieving minimal invasiveness while ensuring safety and surgical precision. In particular, the SP system enables single-incision surgery, offering excellent cosmetic outcomes and the potential to reduce postoperative pain. However, one major limitation of the SP system is that it is not suitable for intercostal approaches, making it impossible to perform procedures in the same manner as conventional thoracoscopic surgery. In addition, performing delicate dissection and vascular control within the confined thoracic cavity through a single port is technically and visually challenging, particularly in cases with complex anatomy or severe adhesions. Furthermore, evidence regarding the oncological safety and long-term outcomes of SP lobectomy remains insufficient at this time.

On the other hand, the two-port and one-window approach maintains the safety and operability of traditional multiport techniques while minimizing the number of incisions. This approach allows for stable visualization and precise dissection, contributing to safe vascular handling and systematic lymph node dissection. Moreover, the reduced-port approach enables the use of standard robotic instruments, which can help reduce overall procedural costs.

In conclusion, while the SP system is highly appealing in terms of cosmetic outcomes and single-incision surgery, the reduced-port multiport system currently offers a more practical and versatile approach in robot-assisted lobectomy, providing advantages in safety, operability, and cost-effectiveness.

In the future, we aim to attempt the technique for thoracoscopic surgery used in our department, which uses the one-window method [13], by further reducing the number of ports. We believe that reduced port RATS lobectomy can be performed with just one port (using Cadiere forceps) and one window (with an 8-mm, 0° endoscope and curved bipolar forceps). As the number of ports decreases, the assistant's support becomes even more important, but we believe that reducing the number of ports will be possible with some experience. The main importance of reducing the number of ports is in reducing the patient's burden. However, if too much focus is placed on reducing ports at the expense of maintaining safety, this would be counterproductive. The main goal is to perform RATS with an approach that is similar to thoracoscopic surgery that has been established and is well practiced in the institution. Although there are differences in instruments and devices, RATS may be able to be performed more safely and quickly when the surgeon and the assistant have a shared understanding of the operative field, surgical approach, and the direction of stapling.

CONCLUSION

Our early results suggest that the two ports and one-window method is safe, feasible, and provides excellent perioperative outcomes.

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DATA AVAILABILITY

Not applicable.

DECLARATIONS
CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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