Turkish Journal of Thoracic and Cardiovascular Surgery 2020;28(4):648-655
http://dx.doi.org/doi: 10.5606/tgkdc.dergisi.2020.19436

Original Article / *Özgün Makale*

Robot-assisted lobectomy versus completely portal robotic lobectomy: What is the difference?

Robot yardımlı lobektomi ve tamamen portal robotik lobektomi karşılaştırması: Aradaki fark nedir?

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ABSTRACT

Background: This study aims to compare robot-assisted lobectomy versus completely portal robotic lobectomy.

Methods: Between January 2014 and December 2019, a total of 41 patients (10 males, 31 females; median age 62 years; range, 50 to 68 years) underwent robotic anatomical pulmonary resection in our institution were retrospectively analyzed. The patients were consecutively divided into two groups: the first 20 (48.8%) patients underwent pulmonary resection by robot-assisted lobectomy technique, while the next 21 (51.2%) patients underwent pulmonary resection by completely portal robotic lobectomy with four arms. Data including age, sex, diagnosis, surgery type and duration, rate of conversion to open surgery, and length of stay of the patients were recorded. The operation time, docking time, console time, and closure duration for each patient were also noted.

Results: There was no statistically significant difference in age, sex, comorbidities, complications, length of hospital stay, adequate lymph node staging, or tumor size and side between the two groups (p>0.05). However, the mean console and operation times were statistically significantly shorter in the patients receiving completely portal robotic lobectomy with four arms (p=0.001).

Conclusion: The advantage of completely portal robotic lobectomy with four arms is relative, although it significantly shortens the operation time. Based on our experiences, this technique may be preferred in case of inadequate lung deflation, as carbon dioxide insufflation allows sufficient workspace for robotic lung resection.

Keywords: Carbon dioxide insufflation, completely portal robotic lobectomy, robot-assisted lobectomy, robotic pulmonary resection.

ÖZ

Amaç: Bu çalışmada, robot yardımlı lobektomi ve tamamen portal robotik lobektomi karşılaştırıldı.

Çalışma planı: Ocak 2014 - Aralık 2019 tarihleri arasında kliniğimizde robotik anatomik akciğer rezeksiyonu yapılan toplam 41 hasta (10 erkek, 31 kadın; medyan yaş 62 yıl; dağılım, 50-68 yıl) retrospektif olarak incelendi. Hastalar ardışık olarak iki gruba ayrıldı: ilk 20 (%48.8) hastaya robot yardımlı lobektomi ile akciğer rezeksiyonu uygulanır iken, sonraki 21 (%51.2) hastaya dört kollu tamamen portal robotik lobektomi ile akciğer rezeksiyonu uygulandı. Hastaların yaşı, cinsiyeti, tanısı, cerrahi tipi ve süresi, açık cerrahiye dönme oranı ve hastanede yatış süreleri kaydedildi. Ameliyat süresi, robotun hastaya bağlanma süresi, konsol süresi ve insizyonların kapatılma süreleri de her hasta için kaydedildi.

Bulgular: İki grup arasında yaş, cinsiyet, eşlik eden hastalıklar, komplikasyonlar, hastanede yatış süresi, yeterli lenf nodu örneklemesi veya tümör büyüklüğü ve tarafı açısından istatistiksel olarak anlamlı bir fark görülmedi (p>0.05). Ancak, dört kollu tamamen portal robotik lobektomi yapılan hastalarda ortalama konsol ve ameliyat süreleri istatistiksel olarak anlamlı düzeyde daha kısa idi (p=0.001).

Sonuç: Dört kollu tamamen portal robotik lobektominin avantajı, her ne kadar ameliyat süresini kısaltsa da, görecelidir. Deneyimlerimize göre, bu teknik, karbon dioksit pompalanması robotik akciğer rezeksiyonu yeterli alan sağladığından, yetersiz akciğer sönmesinin olduğu durumlarda tercih edilebilir.

Anahtar sözcükler: Karbon dioksit pompalanması, tamamen portal robotik lobektomi, robot yardımlı lobektomi, robotik akciğer rezeksiyonu.

Received: February 03, 2020 *Accepted*: April 05, 2020 *Published online*: October 21, 2020

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Cite this article as:
Akkuş M, Seyrek Y. Robot-assisted lobectomy versus completely portal robotic lobectomy: What is the difference?. Turk Gogus Kalp Dama 2020;28(4):648-655

Minimally invasive thoracoscopic surgery decreases thoracotomy morbidity; thus, it has been progressively promoted in recent years. While video-assisted thoracoscopy (VATS) is currently the most popular minimally invasive surgery technique, the interest in and feasibility of robotic approaches are growing.[1] Robotic surgery is designed to obviate the restrictions of minimally invasive surgery techniques. Technical advances are essential to shorten and enhance surgery. With increasing experience, surgeons modify the surgical approaches to facilitate the operation.

Discussions regarding the port placement for optimum approaches in robotic surgery have usually centered on total port versus VATS-based methods. In a study, Melfi et al.[2] reported the first series of robot-assisted lobectomies (RALs) using an access thoracotomy and three robotic arms through port positions similar to those used by the anterior VATS approach. Later on, Cerfolio et al.[3] published a lobectomy series performed using completely portal robotic lobectomy (CPRL-4), a modified technique using four robotic arms with carbon dioxide (CO_2) insufflation during surgery.

To the best of our knowledge, few studies have compared the feasibilities of RAL and CPRL-4 so far. In the present study, we aimed to compare VATS and completely portal robotic lobectomy based on our experiences.

PATIENTS AND METHODS

Between January 2014 and December 2019, medical data from 75 patients who underwent robot assisted thoracic surgery using the da Vinci® Surgical System version Si (Intuitive Surgical Inc., Mountain View, California, USA) were retrospectively analyzed. Only patients with a biopsy-proven histopathological diagnosis of a lung carcinoma with tumor sizes smaller than 5.0 cm without mediastinal nodes involvement (cN0-cN1) were included in the study. The patients received robotic anatomical pulmonary resection. Patients with a suspected mediastinal lymph node involvement (N2), having tumors in the segmental bronchus or more proximally, having chest wall involvement requiring rib resection, having previous preoperative radiation or chemotherapy, and who required re-thoracotomy were not considered eligible for robotic surgery. The presence of N1 disease was not contraindicated for robotic pulmonary surgery in this study. Lesions without a preoperative diagnosis were excised by traditional VATS wedge resection, followed by intraoperative frozen-section examination.

Among the 75 patients who underwent robotic thoracic surgery, 41 (10 males, 31 females; median age 62 years; range, 50 to 68 years) underwent anatomical pulmonary resection in our institution. The patients were consecutively divided into two groups: the first 20 (48.8%) patients underwent pulmonary resection by RAL, while the next 21 (51.2%) consecutive patients underwent pulmonary resection by CPRL-4. Data including age, sex, diagnosis, surgery type and duration, conversion rate, and length of stay were reviewed retrospectively. Clinical and pathological staging were based on the 8th edition of the Tumor, Node, Metastasis (TNM) staging system for non-small cell lung cancer.[4] All operations were performed by a single thoracic surgery team. Clinical staging was based on computed tomography (CT) of the chest and whole-body positron emission tomography (PET), as well as mediastinoscopy and/or endobronchial ultrasound. The CT-guided needle biopsy and intraoperative wedge resections were used for histopathological diagnoses. The anatomical pulmonary resections included only lobectomies, as all tumors were peripheral. All patients underwent R0 resection and removal of all visible lymph nodes. The N2 mediastinal lymph node stations (2R, 4R, 7, 8, and 9 in the right side of the chest and stations 5, 6, 7, 8, and 9 in the left side of the chest) and N1 hilar lymph nodes (stations 10 and 11) were routinely dissected in each pulmonary resection. The operation time for each patient was recorded as the sum of docking time, console time, and closure duration. The docking time was defined as the time between the first incision (opening of all ports including utility incision) and the surgeon sitting at the console. The console time was defined as the time from the surgeon sitting at the console to the removal of the resected material and undocking of the robotic arms from the patient following bleeding and air leak control.

A written informed consent was obtained from each patient. The study protocol was approved by the Institutional Review Board of Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital (No. 2018/57). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Surgical technique

Both RAL and CPRL-4 were both used for robotic pulmonary resections. In both approaches, the patient was intubated with a double-lumen endotracheal tube and positioned in lateral decubitus. The robot was positioned at the patient's head. Once the port placements were completed, the robot was docked. The surgeon, then, took position at the console in the same room. Docking was adjusted so that the arm could move toward the lesion and the robot and the transverse axis of cart angle to the vertebral column were at 30 degrees. The distances between the ports were ap-proximately 9 cm for both techniques to allow smooth robotic arm function. Maryland bipolar curved forceps and prograspers were used through the ports during both techniques and viewed through a 30-degree camera.

In RAL, three port incisions and a 3-cm access port were opened at the positions indicated in Figure 1. The first port (camera, 12 mm) was inserted at the 7th and 8th intercostal space (ICS) on the posterior axillary line (7th for upper lobectomies, 8th for lower lobectomies), the second port (12 mm) at the 6th and 7th ICS on the subscapular line, and the third port (12 mm) at the 6th and 7th ICS on the anterior axillary line. All ports were also used for stapling. The access port (AP), which was covered by a soft tissue skin retractor, was placed at the 5th ICS on the midclavicular line and used for the suction, lung retraction, and specimen removal by the bed surgeon.[5]

In CPRL-4, the chest was entered through the 7th and 8th midaxillary ICS and was used as the camera port. The thoracoscopic camera was, then, inserted and pneumothorax was induced with CO_2 (pressure/flow <10 mmHg and 8 mL/sec). The CO_2 was, then, insufflated into the thoracic cavity using an electronic variable-flow insufflator to the CO_2 pressure (Figure 2). Using the camera visualization as a guide, three additional ports were placed in the 7th and 8th ICS anteriorly, posterior axillary, and paravertebral over the mid-fissure area. A fifth port was opened at 8th and 9th ICS (12 mm) in front of the anterior axillary port and below the camera port and used as a service port by the bed surgeon for aspiration, stapling, and introduction of materials such as gauze (Figure 3). Note that these ports were placed on the track of the oblique fissure. Placing four ports in the same ICS limited injury to multiple intercostal neurovascular bundles. A camera was introduced through the midaxillary port and the robotic prograspers were introduced through the remaining three ports in 7th and 8th ICS. The anterior port was extended to 3 cm with an extraction incision, after the lobectomy was performed to remove the specimen from the chest. A size 28 French chest tube was inserted through the 8th and 9th ICS port, and the lung was inflated under visualization.

In general, we used the service port for stapling in CPRL; in some cases, we had to undock the robotic

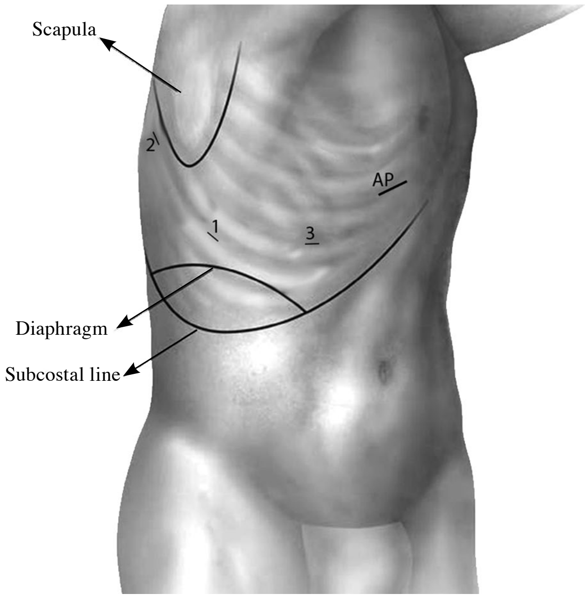

Figure 1. Port locations in robot-assisted lobectomies.
AP: Access port.

Figure 2. Electronic variable-flow CO_2 insufflator and near CO_2 gas tank.
CO_2: Carbon dioxide.

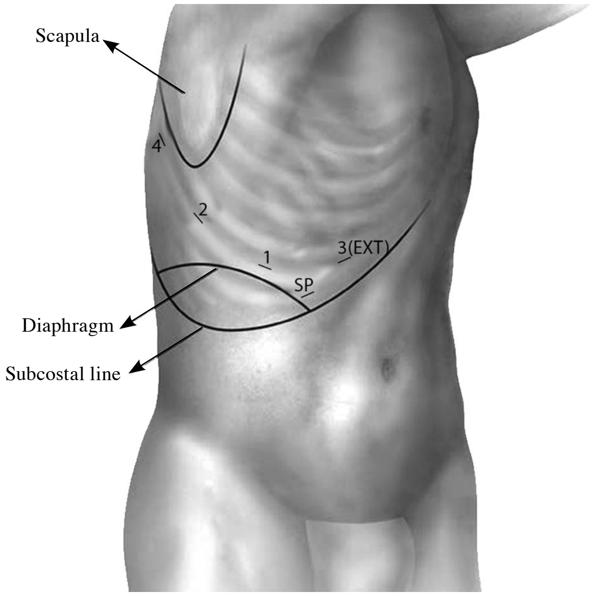

Figure 3. Port locations in CPRL-4.
CPRL-4: Completely portal robotic lobectomy with four arms; EXT: Extraction incision; SP: Service port.

arm at the posterior axillary port and use a stapler through a 12-mm port. In contrast, since there was no service port, we always undocked a robotic arm to use the stapler in RAL, as the access port did not usually provide a suitable angle for stapling.

Statistical analysis

Statistical analysis was performed using the IBM SPSS for Windows version 22.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency. The variable distributions were checked with the Kolmogorov-Smirnov test. The Mann-Whitney U test was used to compare quantitative data. The chi-square test was used to compare qualitative data. A p value of <0.05 was considered statistically significant.

RESULTS

Of the patients, 13 (31.7%) had comorbidities including coronary artery disease (n=4 RAL and n=5 CPRL-4) and diabetes mellitus (n=2 RAL and n=2 CPRL-4). No statistically significant differences in age, sex, body mass index, comorbidities, complication, hospital stay, adequate lymph node staging, or tumor size or side were observed between the groups (p>0.05, Table 1). The mean duration of hospitalization was 6.4±3.5 days in the RAL group and 6.7±2.7 days in the CPRL-4 group (p=0.113). The median estimated blood loss was lower in the CPRL-4 group (270 vs. 220 mL, respectively); however, the difference was not statistically significant (p>0.05).

Table 1. Demographic and clinical data of RAL and CPRL-4 groups

	RAL group (n=20)				CPRL-4 group (n=21)				
	n	%	Mean±SD	Median	n	%	Mean±SD	Median	*p*
Age (year)			58.2±13.8	62.0			63.2±9.4	65.0	0.396†
Sex									0.929‡
Male	5	25.0			5	23.8			
Female	15	75.0			16	76.2			
Side									0.606‡
Right	13	65.0			12	57.1			
Left	7	35.0			9	42.9			
Size (cm)			3.3±1.1	3.3			2.6±0.8	2.5	0.113†
Lymph node staging			4.7±0.7	4.8			4.9±1.1	5	0.487†
Blood loss (mL)			258±3.2	270			218±3.5	220	0.339†
Complication			7±35				5±23.8		0.965‡
Comorbidities			6±30				7±33.3		0.427‡
Hospitalization (day)			6.4±3.5	5.0			6.7±2.7	6.0	0.412†
Docking time (min)			21.9±4.7	22.5			18.6±3.9	21	0.375†
Console time (min)			253.2±22.4	285			214.4±30.2	205	0.001†
Operation time (min)			274.4±11.2	292.5			229.3±32	245	0.001†

RAL: Robot-assisted lobectomy; CPRL-4: Completely portal robotic lobectomy with four arms; SD: Standard deviation; † Mann-Whitney U test; ‡ Chi-square test.

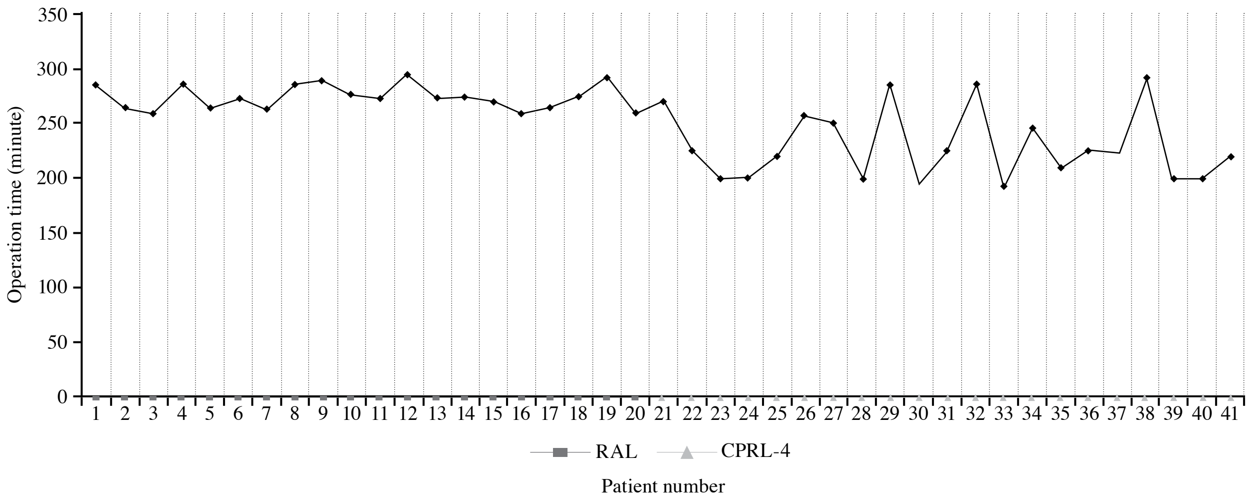

Figure 4. Reduction trend in operation time (RAL, CPRL-4).

RAL: Robot-assisted lobectomy; CPRL-4: Completely portal robotic lobectomy with four arms.

No patients required postoperative intensive care unit (ICU) stay longer than 24 h. The mean console and operation duration were significantly shorter in the CPRL-4 patients (p=0.001) (Table 1, Figure 4).

Cervical mediastinoscopy was performed in 20 (52.6%) patients with PET-negative lymph nodes with the smallest diameters exceeding 1 cm. Pathological staging included Stages I, II, and III in 44%, 46%, and 10% of patients, respectively. Histopathology included an adenocarcinoma (55.3%, n=21), squamous cell carcinoma (26.3%, n=10), carcinoid tumors (5.3%, n=2), small cell carcinoma (7.8%, n=3), and metastatic lung tumors (5.3%, n=2). In addition, one case had sequestration and two had

Table 2. The distribution of lobectomies, histopathology and pathological staging

	RAL (n=20)	CPRL-4 (n=21)	Total (n=41)
	n	n	n
Stage IA	4	4	8
Stage IB	5	5	10
Stage IIA	5	6	11
Stage IIB	4	4	8
Stage IIIA	2	2	4
Adenocarcinoma	9	12	21
Squamous cell carcinoma	4	6	10
Carcinoid tumor	1	1	2
Small cell carcinoma	2	1	3
Metastatic lung tumor	2	-	2
Bronchiectasis	2	-	2
Sequestration	-	1	1
Right upper lobectomy	7	5	12
Middle lobectomy	2	-	2
Right lower lobectomy	3	6	9
Left upper lobectomy	3	4	7
Left lower lobectomy	5	6	11

RAL: Robot-assisted lobectomy; CPRL-4: Completely portal robotic lobectomy with four arms.

bronchiectasis. All patients with malignancies had peripheral tumors. Surgical resections included right upper (29.2%, n=12), middle (4.8%, n=2), right lower (22%, n=9), left upper (17%, n=7), and left lower (26.8%, n=11) lobectomies (Table 2). Three (7.3%) patients underwent conversion to thoracotomy due to arterial bleeding during robotic resection (n=1 in RAL and n=2 in CPRL-4). No postoperative mortality occurred in either group. Twelve (29.2%) patients experienced complications including atrial fibrillation (n=2 RAL and n=2 CPRL-4), pneumonia (n=2 RAL), and prolonged air leak (n=3 RAL and n=3 CPRL-4).

DISCUSSION

Robotic surgery is a safe and feasible method with a low incidence of complications.[6] The RAL technique, first introduced by Melfi in 2001, has been modified over time. The CPRL-4 technique, introduced by Cerfolio and Dylewski[7] in 2011, is an important modification in robotic surgery. In the present study, we attempted to demonstrate why CPRL-4 was an improvement in robotic lobectomy based on our surgical experience.

The RAL technique, which utilizes a visualization method similar to that for VATS, is advantageous, as it uses a non-rib-spreading utility incision from the start of surgery. The utility port is useful, as it allows a feeling of tissue resistance, the possibility of finger palpation of the lung to identify sub-centimetric lesions, retraction of the lung by bed surgeon, a rapid conversion with the possibility of enlarging the same utility incision in case of vascular bleeding, wedge resections before lobectomy when required, removal of the specimen, and comfortable sponge access in case of hemorrhage.[8,9] Novice bed surgeons may not be able to quickly perform appropriate lung retraction, which may increase the operation time. Additionally, the most important disadvantage of RAL is that CO_2 insufflation cannot be used, as the utility incision is open to room air. Nevertheless, surgeons experienced in VATS may feel comfortable performing RAL owing to its similarities to the VATS technique.[12]

The CPRL-4 is a totally endoscopic robotic video-assisted approach involving four robotic arms and warm CO_2 insufflation. The technical changes made in the CPRL-4 technique compared to RAL include the addition of a posterior fourth robotic arm to allow console surgeons to retract the lung by themselves and the use of warm CO_2 insufflation to increase the size of the surgical field. Lobectomy materials are removed from the thoracic cavity through a subcostal trans-diaphragmatic incision or extraction incision, which is a port enlarged at the end of the procedure.[10,11] In our study, the specimens were removed by enlarging the anterior port to 3 cm at the end of the lobectomy procedure. The additional fourth arm provided console surgeons with better control over the field, since they did not require the bed surgeon's assistance to retract the lung and did not spend time communicating on retraction. Moreover, robotic arms occasionally disturb bed surgeons during surgery, while they struggle to stay stationary while retracting the lung; thus, this technique also prevents possible bed surgeon trauma. In our opinion, instead of the higher cost, the most

Table 3. Comparison of RAL and CPRL-4 in case of requirements and outcomes

	RAL	CPRL-4
Utility thoracotomy	Present	Absent/extraction incision is opened after lobectomy
Number of ports opened	3 ports + 1 access port	4 ports + 1 service port
Economy	Lower cost compared to CPRL	Higher cost due to use of an extra robotic arm
CO_2 insufflation	Not efficient/not used	Very efficient
Bed surgeon	Experienced surgeon	No need for experience
Number of robotic arms used	3	4
Console surgeon	VATS experience facilitates	Should have robotic surgery experience
Palpation of the tumor	Possible through access port	Not possible
Feeling tissue resistance	Possible through access port	Not possible
Conversion to open thoracotomy	Easier by enlarging access port	More time consuming due to absence of access port
Hospitalization	No difference	No difference
Complication	No difference	No difference

RAL: Robot-assisted lobectomy; CPRL-4: Completely portal robotic lobectomy with four arms.; CO_2: Carbon dioxide; VATS: Video-assisted thoracoscopic surgery.

important disadvantage of CPRL-4 is the need for surgical experience in robotic lobectomy, which can be assessed by RAL.[12] Table 3 shows a comparison of these two techniques.

The creation of enlarged workspace in non-invasive techniques results in shortened operation times. The CPRL-4 uses CO_2 insufflation and a fourth robotic arm to create the workspace.[12] In our study, heated CO_2 (37°C) was used with a pressure <10 mmHg. While a higher CO_2 insufflation pressure provides a better view of the surgical field, pressure exceeding 10 mmHg may cause hypercarbia.[13] No instances of postoperative hypercarbia or acidosis were detected in our study. The CO_2 extends the endoscopic field by lowering the diaphragm and compressing the lung. The CO_2 pressure also facilitates dissection of hilar structures and fissure and detachment of the pulmonary parenchyma in patients with pleural adhesions.[14] Moreover, heated CO_2 reduces visual interference caused by cauterization smoke and prevents potential lung parenchyma desiccation and further inflammation.[15] The RAL technique cannot maintain CO_2 insufflation due to the utility incision that is open to room air. In our opinion, the use of CO_2 is practical in robotic lobectomy. When the selective tube is displaced during the operation, the surgical field may be compromised due to ventilation of the operated lung; however, the use of CO_2 prevents inflation of the operated lung and protects the workspace; thus, in these cases, the use of CO_2 insufflation is essential. The downside of CO_2 insufflation is that it can only be used in completely portal approaches in non-invasive surgery. The CO_2 is pumped into the chest cavity through trocar valves at 6 to 10 mmHg; therefore, surgeons should not remove the port trocar or open utility incision during surgery, as CO_2 would escape the thorax and compression against the lung would disappear.

In our study, console time and operation time significantly differed between the groups. The two main explanations for the difference in console time include time-consuming processes in which the bed surgeon assisted in retracting the lung due to the need for verbal communication between the two surgeons and the bed surgeon's struggle with the robotic arms to maintain the correct retraction. Secondly, and most importantly, time loss is inevitable in cases with inadequate lung deflation, since we must then wait for the lung to deflate during surgery. Finally, we should mention that both our RAL and CPRL operation times were slightly longer than the previous studies in the literature,[12] as this study presents our initial reports on these techniques.

Nonetheless, there are some limitations to this study. A limited number of patients was included in both groups due to the single-institution design. Additionally, the study has a retrospective nature; the pain scores were unable to be evaluated; and patients requiring pneumonectomy or sleeve lobectomy and with tumors larger than 5 cm were not offered robotic surgery due to limited capabilities. Since our patient group is limited, we were unable to exclude our former patients in both groups from the study to achieve a more correct operation time comparison.

In conclusion, the advantage of completely portal robotic lobectomy with four arms is relative, although it significantly shortens operation time. It costs more to perform than robot-assisted lobectomy; however, we prefer the completely portal robotic lobectomy with four arms technique for robotic lobectomy in our clinic, as we find carbon dioxide insufflation during robotic lobectomy to be quite useful. Based on our experience, the completely portal robotic lobectomy with four arms may be preferred in case of inadequate lung deflation, as carbon dioxide insufflation allows sufficient workspace for robotic lung resection. Nevertheless, further large-scale, head-to-head, prospective studies are needed to draw a firm conclusion.

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding

The authors received no financial support for the research and/or authorship of this article.

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