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Featured Article

Comparison of uniportal robotic-assisted thoracic surgery pulmonary anatomic resections with multiport robotic-assisted thoracic surgery: a multicenter study of the European experience

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Background: Robotic-assisted thoracic surgery (RATS) has seen increasing interest in the last few years, with most procedures primarily being performed in the conventional multiport manner. Our team has developed a new approach that has the potential to convert surgeons from uniportal video-assisted thoracic surgery (VATS) or open surgery to robotic-assisted surgery, uniportal-RATS (U-RATS). We aimed to evaluate the outcomes of one single incision, uniportal robotic-assisted thoracic surgery (OSI-RATS) against standard multiport RATS (M-RATS) with regards to safety, feasibility, surgical technique, immediate oncological result, postoperative recovery, and 30-day follow-up morbidity and mortality.

Methods: We performed a large retrospective multi-institutional review of our prospectively curated database, including 101 consecutive U-RATS procedures performed from September 2021 to October 2022, in the European centers that our main surgeon operates in. We compared these cases to 101 consecutive M-RATS cases done by our colleagues in Barcelona between 2019 to 2022.

Results: Both patient groups were similar with respect to demographics, smoking status and tumor size, but were significantly younger in the U-RATS group [M-RATS =69 (range, 39–81) years; U-RATS =63 years (range, 19–82) years; P<0.0001]. Most patients in both operative groups underwent resection of a primary non-small cell lung cancer (NSCLC) [M-RATS 96/101 (95%); U-RATS =60/101 (59%); P<0.0001]. The main type of anatomic resection was lobectomy for the multiport group, and segmentectomy for the UNIRATS group. In the M-RATS group, only one anatomical segmentectomy was performed, while the U-RATS group had twenty-four (24%) segmentectomies (P=0.0006). All M-RATS and U-RATS surgical specimens had negative resection margins (R0) and contained an equivalent median number of lymph nodes available for pathologic analysis [M-RATS =11 (range, 5–54); U-RATS =15 (range, 0–41); P=0.87]. Conversion rate to thoracotomy was zero in the URATS group and low in M-RATS [M-RATS =2/101 (2%); U-RATS =0/101; P=0.19]. Median operative time was also statistically different [M-RATS =150 (range, 60–300) minutes; U-RATS =136 (range, 30–308) minutes; P=0.0001]. Median length of stay was significantly lower in U-RATS group at four days [M-RATS =5 (range, 2–31) days; U-RATS =4 (range, 1–18) days; P<0.0001]. Rate of complications and 30-day mortality was low in both groups.

Conclusions: U-RATS is feasible and safe for anatomic lung resections and comparable to the multiport conventional approach regarding surgical outcomes. Given the similarity of the technique to uniportal VATS, it presents the potential to convert minimally invasive thoracic surgeons to a robotic-assisted approach.

Keywords: Uniportal robotic-assisted thoracic surgery (U-RATS); multiport robotic-assisted thoracic surgery (M-RATS); robotic lung resections; lung cancer

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Introduction

The evolution of video-assisted thoracic surgery (VATS) has come to the point of being synonymous with the term 'minimally invasive surgery'. Through years of practice, diligent surgeons all around the world, along with technical engineers and support teams, have invested their skills, time and effort to develop and perfect minimally invasive access into the thorax with minimal damage to surrounding tissues, whilst maximizing surgical and oncological outcomes. From standardizing VATS procedures, from multiportal to uniportal, robotic-assisted surgery has peaked amongst thoracic surgeons as an exciting new premise for innovation, but complex access to training, scarcity of on-demand platform access and already having so many thoracic surgeons adopting uniportal VATS worldwide, have all made it difficult to justify a reversal back to multiportal procedures, which currently is the conventional approach for robotic-assisted thoracic surgery (RATS). Our team has developed a new approach, which has the potential to convert surgeons from uniportal VATS or open surgery to robotic-assisted surgery, uniportal-RATS (U-RATS). We aimed at evaluating one single incision, uniportal robotic-assisted thoracic surgery (OSI-RATS) outcomes when compared to standard multiport robotic-assisted thoracic surgery (M-RATS), with regards to safety, feasibility, surgical technique, immediate oncological result, postoperative recovery and 30-day follow-up morbidity and mortality.

Methods

Patients and outcomes

We performed a large retrospective multi-institutional review of our prospectively curated database, including 101 consecutive U-RATS procedures performed from September 2021 to October 2022, in the European centers that our main surgeon operates in. The database cases were gathered as follows: from Spain (Coruna, Cadiz, 33 cases), Romania (51 cases), Portugal (5 cases), Germany (4 cases), Turkey (2 cases), Luxembourg (2 cases) and United Kingdom (4 cases). All cases were performed by the same surgeon and assistant, and most of the patients (81.18%) were operated in two centers: Coruña and Bucharest. We compared these cases to 101 consecutive M-RATS cases done by a completely different surgical team in Barcelona, Spain, from 2019 to 2022. Both groups were gathered along with the surgeons' learning curve, and the surgeons performing M-RATS were not part of the U-RATS team, and vice-versa. In both M-RATS and U-RATS surgeries, the teams consisted of two surgeons: one main surgeon at the console, and one as a bedside assistant. For the sake of comparing the two groups of surgical cohorts, we chose to exclude the cases that were not pulmonary anatomical resections, such as mediastinal tumor resections/ thymectomies and pulmonary wedge resections. All patients signed the informed consent and the uniportal robotic-assisted procedure was thoroughly explained as a new approach. At all stages the patients were given the option for an alternative standard, conventional M-RATS procedure and our Hospital Ethical Council approved the inclusion of these cases in this study (IRB 1545/2022).

The included patients had a preoperative checklist consisting of bloodwork, imaging and functional investigations, including positron emission tomography (PET)-computed tomography (CT), spirometry, echocardiography, brain magnetic resonance imaging (MRI)/ CT with intravenous contrast, bronchoscopy/endobronchial ultrasound transbronchial needle aspiration (EBUS-TBNA) for diagnosis and staging. Those who were not diagnosed before surgery benefited from a diagnostic intraoperative wedge resection with frozen section before continuing with the anatomic resection.

U-RATS technique

Despite seeming unattainable or not reproducible for anatomic resections 15–20 years ago, the uniportal approach into the thorax with minimally invasive VATS (1) has now become the norm in many thoracic centres around the world, proving to be feasible, safe, and oncologically equivalent to open surgery (2). There should be no debate that one single, minimal incision generally produces less postoperative pain and more often prompts a faster recovery. It also lessens the risk of injury and intercostal bleeding, and perhaps improves the postoperative psychological impact of a procedure (3). Robotic-assisted surgery has arrived in a time where most surgeons have already adopted VATS or are in the process of training in VATS procedures, particularly uniportal VATS, so any new technology like RATS inherently has to overcome multiple shortcomings: adequate exposure, training opportunities, and infrastructure at home institutions. This creates an interdependent cycle as follows: new technology is acquired mainly in accordance with surgeons' demands, but surgeons demand the technology only after training and evidence-based results make it necessary, so only thereafter would patients consider it desirable or preferable (4).

We define the pure U-RATS as a surgical approach performed with a robotic platform through one single, minimalized incision that utilizes robotic staplers. We utilize the following acronyms for this approach: U-RATS, uniportal-RATS, URATS, UNI-RATS and OSI-RATS. For this surgical technique, the use of robotic staplers is key to ensuring safety during this approach, as in other hybrid procedures (5) this very important step of stapling vascular or bronchial structures relies on the assistant in the most critical part of the surgery. At our institution, we use the da Vinci Xi® Surgical System (Intuitive Inc., Sunnyvale, California, United States). Also, at the beginning of the learning curve, we advise having readily available instruments for open surgery or VATS in the case of emergent or unexpected conversion. We consider it essential to have prior skills and knowledge of the operating system, console, patient cart, energy devices, tools and bed side assistance for minimally invasive VATS/RATS.

Routinely, double lumen selective intubation under general anesthesia is performed. A 3-to-4-cm incision is made in the 7th intercostal space between the middle and anterior axillary line. A non-traumatic wound protector is placed. The robot is docked from the left side of the patient for the right approach and vice versa. Targeting is done in the posterior corner of the wound. For the right approach, the arms used are 2, 3 and 4 whilst arm number 1 cancelled, and for the left approach, arms number 1, 2 and 3 are used, and the 4th arm is cancelled (6). To avoid collision, we place all arms centered in FLEX position and parallel. Also, to minimize the space taken by the cuff of the trocars, transoral trocars [transoral robotic surgery (TORS)] can be used (7). As we do not use CO_2 insufflation there is no need for caps seal. At all times, 8-mm trocars are used and changed with a 12-mm trocar when stapling is needed. The 30° camera is used and placed on the posterior trocar (on arm number 2 for right approach and on arm number 3 for the left approach).

A long-curved suction (subxiphoid instruments) can be used both for suctioning during surgery but also as a retractor. Mostly, a Fenestrated Grasper and Maryland bipolar are used on the other two arms. Other preferred instruments are long tip-up and vessel sealer. Robotic 45 staplers are used, and the benefit of maximal angulation translates in safer vessel approach. The resected pulmonary lobe/segment is extracted in an endobag through the incision. A single chest drain is placed in the posterior corner of the wound. Closure of the wound is done as for uniportal VATS.

M-RATS technique

As the technology evolved, many hospitals around the world started robotic programs and as a result, there is a need for standardization of procedures. Currently, a consensus for number of ports and placement is not in place, making it dependent on the surgical expertise of the team, location of tumor and technical skills (8). However, the conventional M-RATS comprises of a series of standard features: four ports, an additional 4-cm utility incision, CO_2 insufflation and use of caps seal, 8-mm trocars and 12-mm trocar for stapling devices. The robotic surgical program at our colleagues' center is organized as follows: seven surgeons (of which six have undergone a learning curve while performing those cases). The surgeries are divided into two key stages: lymphadenectomy (performed by one of the surgeons) and anatomical resection (performed by another surgeon). The program started with only one afternoon session per week, then progressed to two sessions per week, and now it has reached four sessions per week. On the learning curve, the surgeon in training starts with the lymphadenectomy whilst the more experienced one does the lobectomy. Four ports are made in either the 7th or 8th intercostal space, no air seal is used nor utility incision, a port being enlarged at the end for extraction. In the anterior port, a 12-mm trocar is placed for endostapling. In the other three ports, 8-mm trocars are used.

Statistical analysis

We analyzed and reported categorical variables for statistical significance using Fisher's exact test. Numerical variables were compared using the Student's *t*-test. A P value less than 0.05 was considered significant and all tests of significance were two-sided. Numerical continuous data is expressed as a median value with standard deviation (SD). Statistical calculations were performed using Microsoft Excel (Microsoft 365, Microsoft, USA) and MedCalc calculator (MedCalc Software Ltd., 2022). We reported categorical variables as n (%) and continuous variables as a mean ± SD or median [interquartile range (IQR), 25th to 75th percentile].

Results

Patients in both the M-RATS and U-RATS groups were similar with respect to gender smoking, comorbidity and pulmonary function tests (see *Table 1*). Patients were significantly younger in the U-RATS group [M-RATS =69 (range, 39–81) years; U-RATS =63 (range, 19–82) years; P<0.0001]. Most patients in both operative groups underwent resection of a primary non-small cell lung cancer (NSCLC) [M-RATS 96/101 (95%); U-RATS =60/101 (59%); P<0.0001]. The type of resections performed were also similar between the two groups as shown in *Table 1*, but the number of each type of resection was different: in the M-RATS group 93 (92%) lobectomies were performed, whilst in the U-RATS group only 51 (50%) lobectomies were performed (P<0.0001). In the M-RATS group only one anatomical segmentectomy was performed, whilst in the U-RATS group 24 (24%) segmentectomies were performed (P=0.0006). Also, there were significantly more complex and extended surgical resections in the UNIRATS group: twenty-two (22%) compared to four (4%) in the M-RATS group. Pathologic staging was different between the two groups (P=0.0003) as shown in *Table 1*. There was a significant difference in median tumor size [M-RATS =2.6 (range, 0.3–8.9) cm; U-RATS =3.3 (range, 1.0-9.0) cm; P=0.003]. The two study groups had a different histologic distribution: the M-RATS group had significantly more patients with adenocarcinoma [M-RATS =65/101 (64%); U-RATS =42/101 (42%); P=0.001] and squamous lung cancer [M-RATS =21/101 (21%); U-RATS =10/101 (10%); P=0.04], whilst the U-RATS group was significantly more heterogenous—other type of lesions: M-RATS =5/101 (5%); U-RATS =41/101 (41%); P<0.0001. A higher incidence of primary NSCLC in the M-RATS cases and a higher incidence of secondary lesions or benign lesions in the U-RATS cases correlate with the respective ratio of lobectomy to segmentectomy in between the two groups. All M-RATS and U-RATS surgical specimens had negative resection margins (R0) and contained an equivalent median number of lymph nodes available for pathologic analysis [M-RATS =11 (range, 5–54); U-RATS =15 (range, 0–41); P=0.87]. Conversion rate to thoracotomy was zero in the U-RATS group and low in M-RATS [M-RATS =2/101 (2%); U-RATS =0/101; P=0.19]. Median operative time was also statistically different [M-RATS =150 (range, 60–300) minutes; U-RATS =136 (range, 30–308) minutes; P=0.0001]. Chest drains were routinely used in both groups, drainage being removed after significantly more days in the M-RATS group [M-RATS =5 (range, 0–21) days; U-RATS =2 (range, 1–17) days; P<0.0001]. Median length of stay was significantly lower in U-RATS group at four days [M-RATS =5 (range, 2–31) days; U-RATS =4 (range, 1–18) days; P<0.0001] (*Table 2*). There was also a significant difference in the number of patients who did not experience any complications (M-RATS =59/101 (58%); U-RATS =90/101 (89%); P<0.0001). Most of the complications were pleural complications such as persistent air leaks, and they were more common in the M-RATS group (M-RATS =36/101 (36%); U-RATS =5/101 (5%); P<0.0001). Similar number of patients required reintervention: three in the M-RATS group (3%) and three (3%) in the U-RATS (3%) (P=1.00). In the U-RATS group, reintervention was done through a minimally invasive approach each time: one for chylothorax (reintervention by uniportal VATS) and two bronchopleural fistulas (reintervention by U-RATS). There was minimal postoperative mortality in the study population, one case (1%) in the U-RATS group due to acute respiratory distress syndrome (ARDS) in a single lung postoperatively, and two (2%) cases in the M-RATS group (*Table 2*).

Table 1 Patient characteristics, operative details and pathology[†]

Parameter	M-RATS (n=101)	U-RATS (n=101)	P value
Patients			
Gender (male:female)	63:38	60:41	0.66
Age (years)	69 [39–81]	63 [19–82]	<0.0001
Smoker	52 (51%)	52 (51%)	1.00
FEV_1 (%)	95 [44–171]	90 [54–130]	0.07
DLCO (%)	79 [42–127]	76 [35–107]	0.11
Operative details			
Laterality (right:left)	58:43	57:44	0.88
Lobectomy	93 (92%)	51 (50%)	<0.0001
RUL	27	18	
RML	7	2	
RLL	22	14	
LUL	21	5	
LLL	16	12	
Pneumonectomy	3 (3%)	4 (4%)	0.70
Segmentectomy	1 (1%)	24 (24%)	0.0006
Other (combined resections, extended surgery, sleeve, lung sparing, tracheal/carinal resections)	4 (4%)	22 (22%)	0.09
Operative time (minutes)	150 [60–300]	136 [30–308]	0.0001
Chest drain removal (days)	5 [0–21]	2 [1–17]	<0.0001
Conversion to open	2 (2%)	0	0.19
Pathology			
Tumor size (cm)	2.6 [0.3–8.9]	3.3 [1.0–9.0]	0.003
Histology			
Adenocarcinoma	65 (64%)	42 (42%)	0.001
Squamous	21 (21%)	10 (10%)	0.04
Carcinoid	10 (10%)	8 (8%)	0.63
Others	5 (5%)	41 (41%)	<0.0001
R0	101 (100%)	101 (100%)	1.00
Number of lymph nodes	11 [5–54]	15 [0–41]	0.87
Stage			0.0003
I	65 (64%)	27 (39%)	
II	19 (20%)	25 (36%)	
III	12 (13%)	17 (25%)	

[†], all values reported are medians with range variations, unless otherwise specified. IQR, interquartile range; M-RATS, multiportal robotic-assisted thoracic surgery; U-RATS, uniportal robotic-assisted thoracic surgery; FEV_1, forced expiratory volume in 1 second; DLCO, diffusing capacity of the lungs for carbon monoxide; RUL, right upper lobe; RML, right middle lobe; RLL, right lower lobe; LUL, left upper lobe; LLL, left lower lobe.

Table 2 Postoperative outcomes†

Parameter	M-RATS (n=101)	U-RATS (n=101)	P value
LOS (days)	5 [2–31]	4 [1–18]	<0.0001
ICU stay (days)	1	1	1.0
Complications			
None	59 (58%)	90 (89%)	<0.0001
Air leaks >5 days	36 (36%)	5 (5%)	<0.0001
Fistula	1 (1%)	3 (3%)	0.33
Empyema	1 (1%)	1 (1%)	1.00
Hemothorax	3 (3%)	0 (0%)	0.19
Other	1 (1%)	2 (2%)	0.56
Reintervention	3 (3%)	3 (3%)	1.00
30 days mortality	2 (2%)	1 (1%)	0.56

†, all values reported are median with range variations, unless otherwise specified. LOS, length of stay; ICU, intensive care unit; M-RATS, multiportal robotic-assisted thoracic surgery; U-RATS, uniportal robotic-assisted thoracic surgery.

Discussion

Definition and standardization

In conjunction with the American Association of Thoracic Surgeon's *Consensus statement on definitions and nomenclature for robotic thoracic surgery*, Cerfolio *et al.* (9) define two types of robotic thoracic surgery access: robotic portal and robotic-assisted, the latter consisting of a utility incision with trocars placed through it. As an important point of distinction between the two, complete isolation of the pleural cavity and CO_2 insufflation coventionally occurs for the robotic portal, but in the case that the pleural cavity communicates with the exterior through the incision, it is considered robotic-assisted. We define our uniportal approach as robotic-assisted, but the method can be adapted even for CO_2 insufflation, by isolating the wound and using caps sealing for the trocars.

Learning curve

The learning curve in minimally invasive thoracic approaches is dependent on many factors and for robotic thoracic surgery it is demonstrated to be steeper than VATS, however surgeons that are already skilled in a uniportal approach or multiport VATS usually will find it faster to acquire robotic skills (10). When both groups of patients for M-RATS and U-RATS were compared, a shorter surgical time was noted for the U-RATS group, however the difference might result from the simplified docking in U-RATS.

Docking and undocking

Regardless of experience, the docking for U-RATS is much faster than M-RATS. This is mostly due to the advantage of a single incision. This is particularly important since at least at the beginning of a robotic program, most centres have different or inconsistent staff, so it requires less reliance on a numerous team and their experience. This also translates to a faster undocking in case of emergency conversion because all trocars are placed in the same incision. The entire patient cart is lifted (possible even with trocars and instruments still mounted-on but retracted from the wound for safety) and then pulled by the tech/staff assistant. The scrubbed assistant can introduce a sponge stick just like in VATS to control bleeding, all under one minute, while the main surgeon can scrub-in, and the nurse technicians prepare the VATS/open surgery instruments. At this point, the nurse circulator can stow the patient cart safely. This improves the ease of flow for the team and provides structured roles to focus on case of an imminent conversion.

Bedside assistant

Another important aspect is the role of the bedside assistant. In the beginning of the learning process, we consider it advisable to function in pairs of two experienced surgeons (RATS/VATS), one main at the console and the other as the bedside assistant. As this is an exclusively robotic-assisted approach, the role of the assistant is important for retraction, exposure with a traction when needed, supervising and re-adjusting the arms and joints when needed.

Conversion

It is reported that when it comes to minimally invasive surgery, conversion is usually forced by calcified lymph nodes (11), but in our group there was no conversion for U-RATS and for the two cases of M-RATS conversion, this was needed for bleeding control and tactical purposes. None of these cases were related to the learning curve or the experience of the surgeons and were independent of the number of ports. Conversion can be done to thoracotomy or VATS depending on surgical team's experience and skills.

Complex resections

Robotic surgery proves to be superior in dissection, mostly in regard to lymphadenectomy (12) and in very difficult procedures such as sleeves or carinal resections (13). One can argue in favor for the use of robotics in these cases but not in situations that a VATS procedure might give the same benefit. However, it is important to scale this approach to one's progress on the learning curve as it is not advisable to use robotic technology whilst inexperienced in managing more difficult cases. As Prof. Valerie Rusch said: "*cannot do complex cases robotically without achieving excellence in easy cases*" [Society of Thoracic Surgeons (STS) Robotic Thoracic Surgery Course]. In our U-RATS group, we had twenty-two (22%) complex sleeve resections and in the M-RATS group, four (4%) cases of bronchial sleeve resections with no conversion. The robotic approach is superior for dissection in these cases, and considering a cautionary preoperative plan, has optimal oncological outcomes (14,15).

There have been several hybrid or bi-portal approaches (16) reported. We find the bi-portal approach extremely valuable as a transition stage from multiport to uniportal surgery, a step that we recommend at the beginning of the learning curve. When compared to hybrid uniportal robotic-assisted approach, we consider that our technique resolves the need to rely on the assistant for the critical steps of the surgery such as stapling and, mirroring the uniportal VATS approach, makes for a faster learning curve. Already the technique has gained interest, and similar results in terms of safety and surgical outcomes have been reported (17). The robotic approach has proven to be less invasive (18), thus allowing for a shorter hospital stay, and in our comparative groups, patients that underwent a uniportal approach had a faster discharge from hospital. Postoperative complications as shown above were low in both groups, and so were the reinterventions. It is noted that three cases in both groups required reintervention, but the U-RATS group had a higher number of complex extended resections such as sleeve lobectomy, carinal resections and reconstruction, and bronchoplasty.

Conclusions

The U-RATS approach is safe, feasible and comparable to conventional multiport robotic-assisted thoracic surgery, offering excellent perioperative and postoperative outcomes. The caution strategy before starting the uniportal technique is the transition through bi-portal RATS to U-RATS. We consider our approach a safe and reliable conversion for minimally invasive thoracic surgeons, particularly uniportal, who are interested in evolving to robotic-assisted surgery.

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Footnote

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