Uniportal & biportal robotic anatomic lung resection (without CO_2 insufflation): technique, initial experience and cost

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Background: While first applied in thoracic surgery two decades ago, different studies over the past 10 years confirmed the safety and feasibility of robotic-assisted thoracic surgery (RATS). While initially performed with a multiportal approach (mRATS), the technological advancement now allows a uniportal technique for anatomic lung resections without the use of carbon dioxide (CO_2) insufflation.

Methods: We retrospectively analyzed data of the first 13 patients who underwent uniportal RATS (uRATS) or biportal RATS (bRATS) for anatomic lung resection at the Department of Thoracic Surgery St. Claraspital Basel and Hirslanden Clinic Beau-Site & Lindenhof Bern in 2023 using the da Vinci Xi platform. Analyzed data included approach, resected segment or lobe, duration of surgery, blood loss, conversion, number of lymph nodes resected, histology, tumor stage, postoperative complications, chest tube duration, length of hospital stay (LOS) and costs.

Results: In total, 13 patients underwent robotic-assisted anatomic lung resection. For five patients (38.46%) a uniportal approach was used and for eight patients (61.54%) a bRATS approach was used (with robotic stapling). We report no intraoperative complications with zero conversions to video-assisted thoracic surgery (VATS) or thoracotomy. uRATS and bRATS showed no significant difference in perioperative blood loss (uRATS mean: 46.40±45.11 mL, bRATS mean: 16.25±12.75 mL) (P=0.09), duration of operation (uRATS mean: 142.40±49.50 min, bRATS mean: 132.63±38.27 min) (P=0.69) and number of lymph nodes resected (uRATS mean: 11.00±5.57, bRATS mean: 18.14±15.02) (P=0.45). Patients who underwent surgery with a uniportal approach showed similar postoperative chest tube duration (uRATS mean: 3.40±1.52 days) compared to a bRATS approach (bRATS mean: 3.88±3.60 days) (P=0.78). Additionally, LOS was comparable between the groups (uRATS mean discharge after 4.00±1.22 days and bRATS mean discharge after 5.00±2.33 days) (P=0.33). One patient developed a prolonged postoperative air leak, managed conservatively in an outpatient setting. When comparing the cost of uRATS and bRATS to conventional uniportal VATS anatomic lung resections, robotic surgery was costlier resulting in lesser earnings with a mean difference in earnings before interest, taxes, depreciation and amortization of 1,097.6 CHF (Swiss francs).

Conclusions: uRATS and bRATS anatomic lung resections without the use of CO_2 insufflation are safe and feasible approaches with good perioperative outcomes. Due to its improved ergonomics and better maneuverability RATS allows for a profound lymphadenectomy. RATS procedures may take a bit longer than VATS procedures due to the set-up and docking of the robotic system, as well as due to the fact that the team is still in the learning phase with this technique. Overall, with the currently relatively expensive robotic platform, RATS results in higher overall costs compared to VATS.

Keywords: Uniportal robotic-assisted thoracic surgery (uRATS); biportal robotic-assisted thoracic surgery (bRATS); robotic anatomic lung resection; non-small cell lung cancer (NSCLC)

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Introduction

With globally 2.3 million newly diagnosed lung cancer cases and 1.8 million deaths annually, lung cancer is the most common cause of cancer-related deaths worldwide and is responsible for the highest mortality rate in men and women (1). Non-small cell lung cancer (NSCLC) is the most common type of lung cancer and accounts for 85% of all lung cancer cases. Adenocarcinomas represent 40% of all NSCLC, while 25–30% are squamous-cell carcinomas and 5–10% are large cell carcinomas (2).

Minimally invasive radical resection with lymphadenectomy is the current standard approach for all types of NSCLC in stage I as well as for stage II and a feasible approach for stage IIIA NSCLC in a combined multimodality approach, e.g., following neoadjuvant therapy (2).

Currently, the most established surgical approach is video-assisted thoracic surgery (VATS), which shows significant advantages over conventional thoracotomy in terms of perioperative complications, length of hospital stay (LOS) and mortality rate, while maintaining similar oncologic outcomes and long-term survival (3-7). VATS can be performed by either a multiport technique with three or four ports or by the uniportal approach (uVATS), in which the camera and instruments are inserted through only one single small muscle-sparing incision. Uniportal VATS has been shown to have similar surgical outcomes compared to multiport VATS, while additionally improving the patient's short-term quality of life, especially regarding postoperative pain due to involvement of only one intercostal space (8,9).

The transition from open surgery to VATS required adaptation to a reduced two-dimensional visual field, smaller incisions limiting the range of instrument movement and an increased instrument length, which amplifies tremor. These conditions are associated with a more complex learning curve (10,11).

Robotic-assisted thoracic surgery (RATS) partially overcomes the limitations of VATS by providing the surgeon with a three-dimensional visual field, a 360-degree range of instrument movement and tremor suppression.

Since its first use over three decades ago, robotic-assisted surgery became the standard approach for certain surgical procedures and is regularly used, among others, in the fields of urology, gynecology, otorhinolaryngology, cardiac and general surgery (12).

While first applied in thoracic surgery two decades ago, different studies over the past 10 years confirmed the safety of RATS, which led to a steady increase in its utilization for anatomic lung resections (13-16). Similar to VATS, the initial approach was multiportal (mRATS) with four incisions (one camera port and three utility ports). The introduction of the da Vinci Xi system (Intuitive Surgical, Sunnyvale, CA, USA) allowed to reduce the number of ports from four to two (biportal RATS; bRATS) and finally from two to one (uniportal RATS; uRATS) (17). Due to

Highlight box

Key findings

- Performing anatomic lung resections through uniportal robotic-assisted thoracic surgery (uRATS) and biportal RATS (bRATS) without carbon dioxide insufflation is a safe and feasible approach that yields good perioperative results.
- Both approaches are viable and demonstrate comparable perioperative outcomes.
- Due to enhanced maneuverability, visualization and ergonomics, RATS allows a profound lymphadenectomy with overall low blood loss and low conversion rates.
- The costs for RATS are currently higher compared to video-assisted thoracic surgery.

What is known and what is new?

- Since RATS was introduced two decades ago it marks a steady increase in utilization for anatomic lung resections.
- Our data supports the good perioperative outcomes of RATS reported in literature and highlights the current advantages and disadvantages of uRATS and bRATS anatomic lung resections.

What is the implication, and what should change now?

- With the increasing popularity of robotics among thoracic surgeons worldwide, the outlook for RATS anatomic lung resection in the future is very promising, with more research and development expected to improve the technology and its applications, especially for uRATS.

slender arms and 8 mm trocars, the uniportal approach could be established. Additionally, in 2018 the da Vinci SP (Single Port) (Intuitive Surgical) system was introduced, which is especially designed for uniportal usage, as the camera and three instruments are inserted through a single trocar and can be utilized independently intrathoracically. First attempts have been made to utilize the da Vinci SP platform in thoracic surgery and it is routinely used in urology and otorhinolaryngology (17,18). However, the single-port da Vinci SP system exhibits several distinctions when compared to its multi-port counterpart, the da Vinci Xi system. A primary divergence is the absence of an integrated robotic stapler in the da Vinci SP system. Consequently, thoracoscopic stapling necessitates manual operation by the surgical assistant, who must work in conjunction with the single-port system via the identical single access port. Furthermore, the physical dimensions of the da Vinci SP system preclude its deployment through the intercostal space. This restriction confines its use to subxiphoidal (subcostal) approaches exclusively, a limitation not shared by the more versatile da Vinci Xi system (19). This highlights the distinct features and limitations of the single-port da Vinci SP system in robotic-assisted surgery. However, it is important to note that ongoing advancements could potentially expand its application in uRATS in the future.

Initial experiences reported in the literature indicate that the utilization of the da Vinci Xi system for anatomical lung resection in RATS yields promising results, even in the context of advanced procedures such as sleeve resections (20-24).

The learning curve of RATS has been reported to be similar than VATS, although surgeons with previous VATS experience might benefit from a more intuitive experience and rapid increase in expertise (25,26).

mRATS and multiportal VATS, as regularly used in visceral surgery, and some thoracic procedures, e.g., thymectomy, sympathectomy and anatomic lung resections, are typically performed with insufflation of carbon dioxide (CO_2), requiring each trocar to have an air seal (27).

Uniportal VATS and uRATS can be performed without the use of CO_2 insufflation, as selective one-lung ventilation is usually sufficient for surgical exposure. Although silicon pads are available for the uniportal approach and allow the usage of CO_2 insufflation, it is reported that the movement of instruments is less flexible using silicon pads for air sealing compared with the standard uniportal approach. Additionally, the use of CO_2 insufflation can be associated with the risk of complications such as CO_2 embolism, hemodynamic alterations such as decreased venous return and bradycardia and acid-base disorders with arterial hypoxia (28). However, it is crucial to underscore that these risks are substantially mitigated when overpressure conditions are meticulously avoided, thereby significantly reducing the probability of associated complications. We present this article in accordance with the TREND reporting checklist (available at https://jovs.amegroups.com/article/view/10.21037/jovs-23-47/rc).

Methods

In this article we present data of the first 13 consecutive patients who underwent uRATS or bRATS anatomic lung resection without the use of CO_2 insufflation at the Department of Thoracic Surgery St. Claraspital Basel and Hirslanden Clinic Beau-Site & Lindenhof Bern in 2023.

All patients underwent standard preoperative examination as well as staging according to the current guidelines.

The standard uniportal robotic set-up requires one incision of 3–5 cm with three robotic arms inserted through 8–12 mm trocars. One trocar is utilized for the camera, as the other two arms are used as working arms for the energy device or stapler as well as a grasper (17). The set-up for uRATS is shown in *Figure 1* and the intraoperative set-up for a biportal robotic-assisted approach is shown in *Figure 2*.

Statistical analysis

Categorical variables were compared using two-tailed *t*-test for independent samples, Chi-Square test and Fischer's exact test. Data is reported as mean and standard deviations. Statistical calculations were made using SPSS Version 29.0.0 (www.ibm.com, IBM®).

Ethics consideration

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Ethical approval was not required as the research data contained no personal and sensitive data, including anonymized health-related personal data, which do not fall within the scope of the Federal Act on Research involving Human Beings (Swiss Federal Human Research Act, HRA). Informed consent was obtained from all patients.

Results

Data of the first 13 patients (n=13) undergoing robotic-

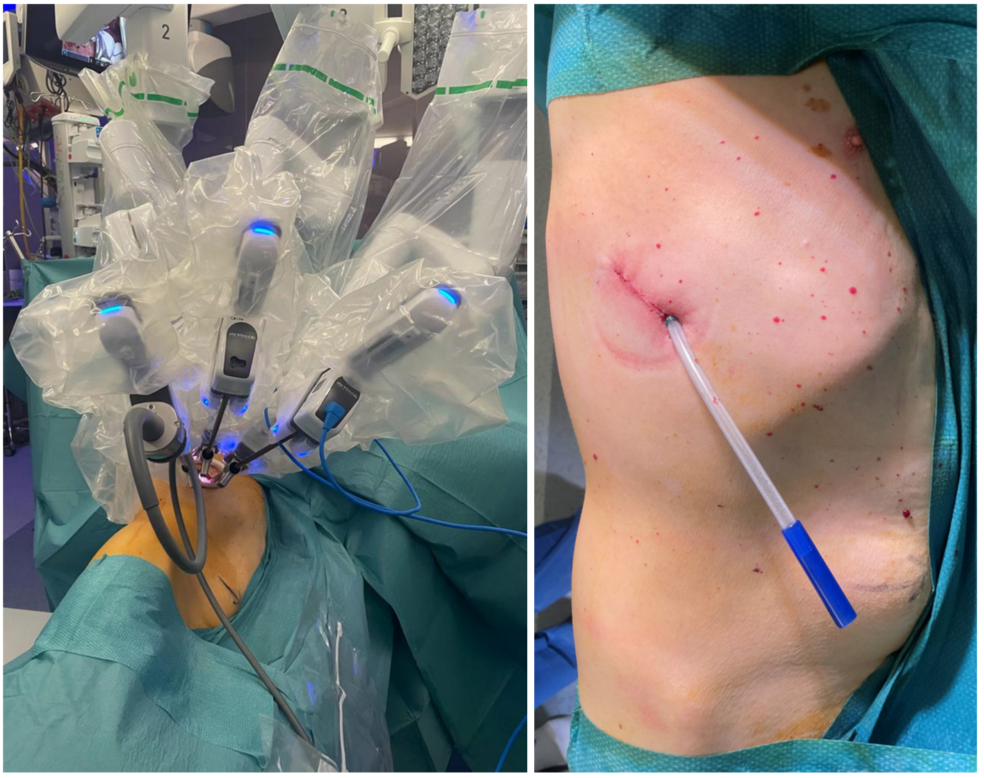

Figure 1 Uniportal RATS: set-up and incision. RATS, robotic-assisted thoracic surgery.

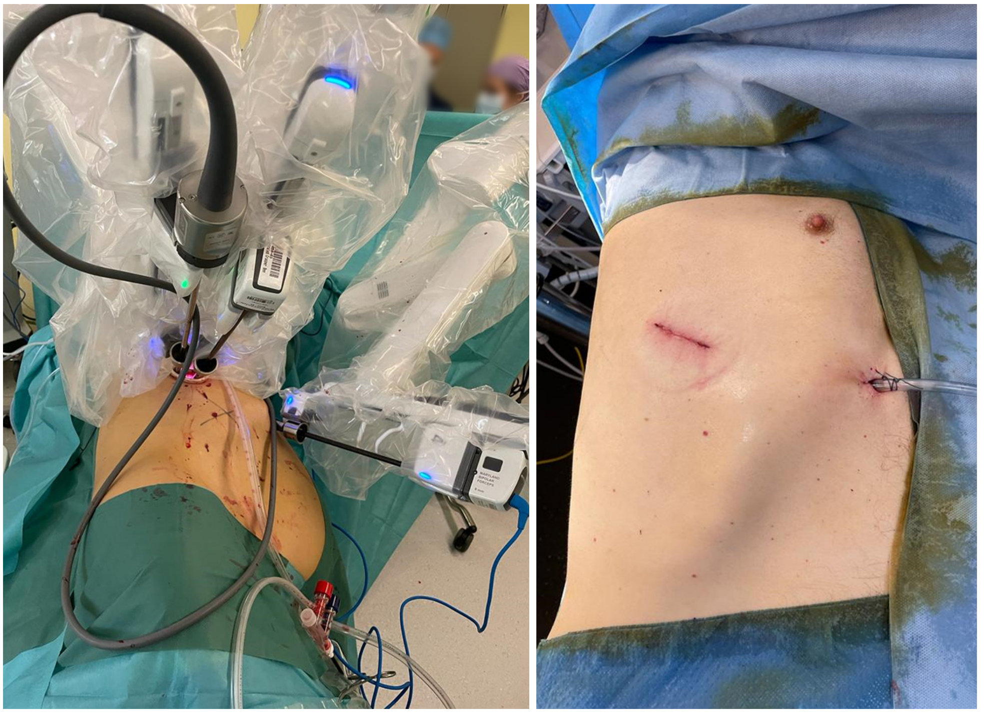

Figure 2 Biportal RATS: set-up and incisions with an additional subxiphoid port for robotic stapling (12 mm port). RATS, robotic-assisted thoracic surgery.

Table 1 Patient characteristics (n=13) presented as mean ± standard deviation or number (%)

Characteristics	Total	RATS approach	
		Uniportal	Biportal
Age (years)	71.62±9.62	63±10.91	77±4.21
Sex			
M	9 (69.23)	4 (80.00)	5 (62.50)
F	4 (30.77)	1 (20.00)	3 (37.50)

RATS, robotic-assisted thoracic surgery; M, male; F, female.

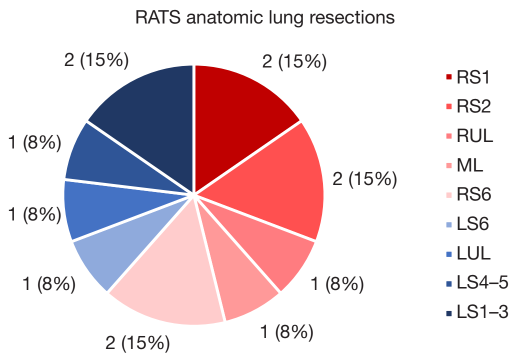

Figure 3 RATS anatomic lung resections and location of segments and lobes in number (%). RATS, robotic-assisted thoracic surgery; RS1, right segment 1; RS2, right segment 2; RUL, right upper lobe; ML, middle lobe; RS6, right segment 6; LS6, left segment 6; LUL, left upper lobe; LS4–5, left segment 4 and 5 (lingula); LS1–3, left segment 1–3 (apical trisegments).

assisted anatomic lung resection at the Department of Thoracic Surgery St. Claraspital Basel and Hirslanden Clinic Beau-Site & Lindenhof Bern in 2023 was analyzed. Patient characteristics including age and gender as well as the approach are shown in *Table 1*. Five (38.46%) patients underwent pure uRATS and in eight (61.54%) an additional 12 mm port was used (bRATS) for the use of the robotic stapler (subxiphoid position in right sided resections and as anterior as possible in left sided resections).

Figure 3 demonstrates the overall distribution of anatomic lung resections performed as well as the resected segments or lobes. *Table 2* shows all segmentectomies and lobectomies performed for each approach. Of all performed resections, segmentectomy was performed in 10 (76.92%) of the cases and in 3 (23.08%) cases lobectomy was performed. Most performed resections were apical segmentectomies including right segment 1 (n=2), right segment 2 (n=2) and apical trisegmentectomy (n=2).

Table 2 RATS anatomic lung resections (segmentectomies and lobectomies) for uniportal RATS and biportal RATS presented as number or number (%)

Resections	Total	RATS approach	
		Uniportal	Biportal
Anatomic lung resections	13	5 (38.46)	8 (61.54)
Lobectomies	3 (23.08)	1 (20.00)	2 (25.00)
Right upper lobe	1	–	1
Middle lobe	1	–	1
Left upper lobe	1	1	–
Segmentectomies	10 (76.92)	4 (80.00)	6 (75.00)
Right S1	2	–	2
Right S2	2	1	1
Right S6	2	1	1
Left S1–3	2	1	1
Left S4–5	1	1	–
Left S6	1	–	1

RATS, robotic-assisted thoracic surgery; S1, segment 1; S2, segment 2; S6, segment 6; S1–3, segment 1–3 (apical trisegments); S4–5, segment 4–5 (lingula).

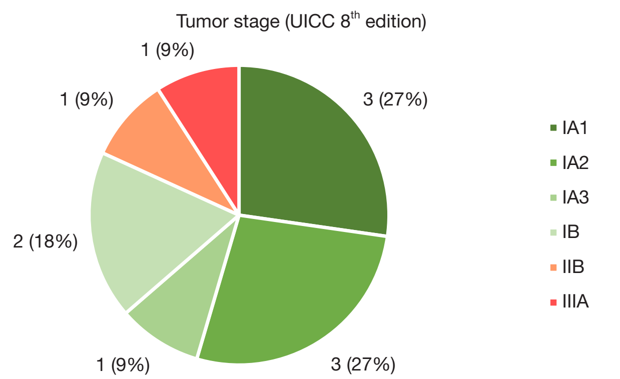

Figure 4 Postoperative tumor stage [UICC 8th edition (29)] for lung cancer (n=11) in number (%). N=2 was benign and is not represented in this figure. UICC, Union for International Cancer Control.

Figure 4 shows, that 81.82% (n=9) of all resections performed in patients with lung cancer were postoperatively staged as stage I, 9.09% (n=1) had postoperative stage IIB and 9.09% (n=1) showed postoperative stage IIIA due to mediastinal lymph node involvement.

Table 3 shows the total number of anatomic lung

Table 3 Type of anatomic lung resection and postoperative tumor stage [UICC 8th edition (29)] presented as number

p-TNM stage (lung cancer)	Total (n=13)	Type of anatomic lung resection	
		Segmentectomy (n=10)	Lobectomy (n=3)
IA1	3	3	0
IA2	3	3	0
IA3	1	0	1
IB	2	2	0
IIB	1	0	1
IIIA	1	0	1
–	2	2	0

N=2 showed no malignancy. UICC, Union for International Cancer Control; p-TNM, pathological tumor/node/metastasis staging.

Table 4 Postoperative histopathological findings presented as number (%)

Histopathologic findings	Total
NSCLC	10 (76.92)
Adenocarcinoma	9 (90.00)
Squamous cell carcinoma	1 (10.00)
Neuroendocrine tumor	1 (7.69)
Typical carcinoid	1 (100.00)
Benign	2 (15.38)
Amyloidosis	1 (50.00)
Sarcoidosis	1 (50.00)

NSCLC, non-small cell lung cancer.

resections, segmentectomies as well as lobectomies performed associated with the postoperative lung cancer stage. *Table 4* shows the postoperative histopathological results. In one case, postoperative histopathologic evaluation showed intrapulmonary infiltration of amyloidosis and in another case infiltration of sarcoidosis. In 76.92% of patients (n=10), there was histopathological confirmation of NSCLC, of which 90% (n=9) were adenocarcinomas and 10% (n=1) squamous cell carcinomas. In one case (7.69%) histopathologic results confirmed a neuroendocrine tumor (typical carcinoid) and in two cases (15.38%) no malignancy was found.

The mean operating time was 136.38±39.56 min for all RATS anatomic lung resections without significant difference between the uRATS (mean: 142.40±49.50 min) and the bRATS group (mean: 132.63±38.27 min) (P=0.69), as shown in *Table 5*. No intraoperative complications were encountered. Thus, we report zero conversions to VATS or thoracotomy. Mean blood loss was low with 27.85±30.48 mL, without significant difference between the uRATS (mean: 46.40±45.11 mL) and the bRATS group (mean: 16.25±12.75 mL) (P=0.09). Numbers of resected lymph nodes with a mean of 16.00±12.34 lymph nodes were similar in both groups without significant difference (uRATS mean: 11.00±5.57, bRATS mean: 18.14±15.02) (P=0.45).

Mean postoperative chest tube removal was after 3.69±2.78 days (uRATS mean: 3.40±1.52 days, bRATS mean: 3.88±3.60 days) (P=0.78). Mean LOS was 4.62±1.90 days (uRATS mean: 4.00±1.22 days, bRATS mean: 5.00±2.33 days) (P=0.33). All patients could be discharged home, without any patient requiring postoperative rehabilitation in an inpatient setting.

Postoperative pain was assessed through the numerical

Table 5 Perioperative outcomes presented as mean ± standard deviation or number

Outcomes	Total	RATS approach		P value
		Uniportal	Biportal	
Duration (min)	136.38±39.56	142.40±49.50	132.63±38.27	0.69
Blood loss (mL)	27.85±30.48	46.40±45.11	16.25±12.75	0.09
Number of resected LNs	16.00±12.34	11.00±5.57	18.14±15.02	0.45
Chest tube removal (POD) (days)	3.69±2.78	3.40±1.52	3.88±3.60	0.78
LOS (days)	4.62±1.90	4.00±1.22	5.00±2.33	0.33
Conversion	0	0	0	–

RATS, robotic-assisted thoracic surgery; LNs, lymph nodes; POD, postoperative day; LOS, length of hospital stay.

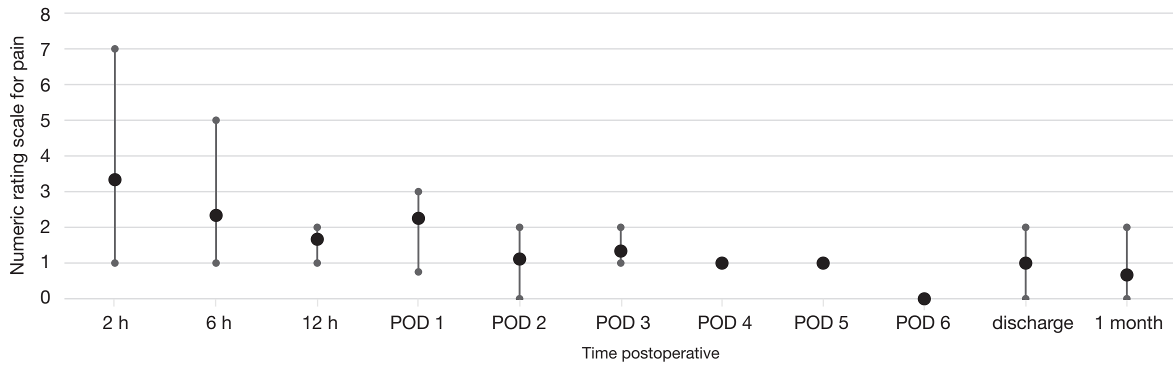

Figure 5 Postoperative pain reported for uniportal RATS presented as maximum, average, minimum of NRS scores. h, hours; POD, postoperative day; RATS, robotic-assisted thoracic surgery; NRS, numeric rating scale.

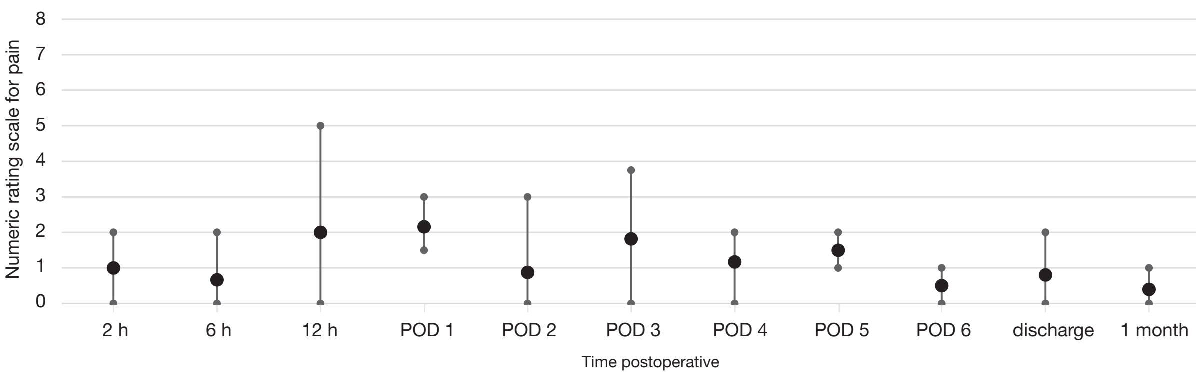

Figure 6 Postoperative pain reported for biportal RATS presented as maximum, average, minimum of NRS scores. h, hours; POD, postoperative day; RATS, robotic-assisted thoracic surgery; NRS, numeric rating scale.

rating scale (NRS). At the end of each operation, an intercostal block was performed with ropivacaine (5 mg/mL). The postoperative NRS reported by the patients were very similar for uRATS (*Figure 5*) and bRATS (*Figure 6*), with a slight difference noted in the average pain reported 2 hours postoperative (*Figure 7*). As postoperative days (PODs) progressed, both procedures showed a decreasing trend in pain, with minimal pain reported at discharge and at the clinical follow-up 1 month postoperative (*Figure 7*).

All intraoperative and postoperative complications during the first 30 postoperative days were recorded and evaluated using the Clavien-Dindo grading system and are shown in *Table 6*. During the postoperative stay, one patient developed a prolonged air leak, requiring discharge with a chest tube on POD 7 and removal thereof on POD 12 in an outpatient setting. One patient in the bRATS group showed multiple postoperative complications [atrial fibrillation and severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)-infection], both required medications. No patient required re-operation or surgical intervention. There was no statistically significant relationship between uniportal or biportal approach and the presence of complications (yes/no) (P=0.83) as well as the specific postoperative complications (P=0.41).

Mean earnings before interest, taxes, depreciation, and amortization (EBITDA) for robotic-assisted resections was 1,809.5 CHF (Swiss francs), while mean EBITDA for uniportal VATS was 2,907.1 CHF over the last 12 months, meaning RATS is costlier with a current difference in EBITDA of 1,097.6 CHF.

Discussion

Compared to VATS lobectomy and segmentectomy, RATS

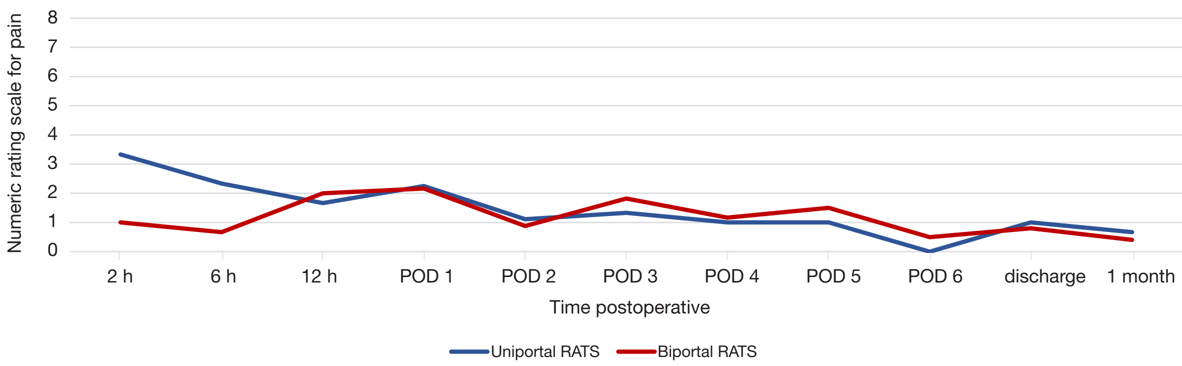

Figure 7 Average postoperative pain reported (NRS) for uniportal RATS and biportal RATS. h, hours; POD, postoperative day; RATS, robotic-assisted thoracic surgery; NRS, numeric rating scale.

Table 6 Postoperative complications presented as number or number (%)

Complications	Total	RATS approach	
		Uniportal	Biportal
Anatomic lung resections	13	5	8
Patients with complications	3 (23.08)	1 (20.00)	2 (25.00)
Postoperative complications			
Clavien Dindo Grade I	1	–	1
Prolonged air leak (>5 d)	1	–	1
Clavien Dindo Grade II	3	1	2
Atrial fibrillation	2	1	1
SARS-CoV-2-infection	1	–	1

RATS, robotic-assisted thoracic surgery; d, days; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

has been repeatedly shown to be non-inferior or better in terms of duration of operation, perioperative blood loss, conversion rate, postoperative chest tube duration, LOS, overall postoperative complications, mortality, re-intervention, overall survival, and disease-free survival (30-32). Large retrospective studies have confirmed low rates of major complications after RATS anatomic lung resections, with the most common complications including prolonged air leak, pneumonia, atelectasis and atrial arrhythmia (33,34). In our cohort, both uRATS and bRATS showed comparable rates of complications, with complications (only Clavien-Dindo stage I to II) (35) occurring in three out of 13 patients (23.08%).

The duration of hospitalization is highly dependent on chest tube duration, overall chest tube management, postoperative pain and presence of complications. Literature shows similar data regarding LOS and chest tube duration in uRATS compared to uVATS, but it is important to note that most specialized centers have their own postoperative criteria for chest tube removal, which might impair data comparability between centers (36).

Additionally, due to an increased implementation and standardization of screening procedures, earlier stages of NSCLC are expected to be detected. In Switzerland, and generally in Europe, a wide-spread screening implementation is expected to be implemented in the coming decades. Currently, in Europe no uniform recommended screening protocol has been established, but data from the United States (US) showed evidence of higher lung cancer incidence at 6.5-year follow-up in patients who received low-dose computed tomography compared to chest X-rays, as well as a stage shift with more stage I and stage II and less stage III and stage IV diagnoses of lung cancer (37). With early detection of lung cancer, which often results in the identification of smaller tumors, more lung sparing resections can be performed, which also leads to reduced surgical trauma (38,39). For NSCLC in early stages with a limited tumor size of ≤2 cm, anatomic lung resections in the form of sublobar segmentectomies were shown to be non-inferior to lobectomy regarding disease-free survival and show similar overall survival (40,41). This necessitates a transition towards more precise minimally invasive lung surgery (sublobar resections), thereby amplifying the relevance of RATS in the coming decades. This is a trend that has already been observed in certain reports, with RATS sublobar resections reported to be safe and feasible

(42-44).

RATS may unfold its full potential especially for more complex procedures, such as sleeve resections or *en-bloc* chest wall resection (e.g., in Pancoast tumors) (45,46). RATS may also be beneficial due to its advantages for anatomic segmentectomies as these present increased complexity due to intraparenchymal dissection, reduction of vessel and bronchial size, more frequent anatomical variants and the challenge of defining the intersegmental plane for sublobar parenchymal resection (38).

RATS with its three-dimensional magnified view and refined maneuverability allows for more surgical precision compared to traditional VATS. In our cohort, segmentectomies were preferred whenever the tumor size was ≤2 cm. Hence, segmentectomies represent the majority of resections performed. For larger tumors and depending on tumor stage, lobectomy was performed, according to the current guidelines.

A shift from multiport RATS to uRATS or bRATS has been observed in recent studies and shows comparable perioperative and postoperative results including conversion rates, blood loss, hospital stay and postoperative complications (47). Additionally, both show low postoperative pain and good cosmetic results.

Pure uRATS is RATS performed through a single intercostal incision, without rib spreading, using the robotic camera, robotic dissecting instruments and robotic staplers, all controlled through the surgeon console.

uRATS can be performed with the use of conventional handheld staplers and a uniportal access usually in the sixth intercostal space, or as pure uRATS with the use of robotic staplers with an access usually in the seventh intercostal space. Although the robotic stapler offers a better maneuverability compared to the handheld stapling device, the joint of the robotic stapler has to leave the trocar to be able to move. Hence, this might require more distance between the incision (intercostal space) and the structure that needs to be controlled and divided. Therefore, an additional port, offering a wider intercostal space (to harbor the 12 mm stapler trocar) and a lower intercostal space (or even subxiphoid position for right sided resections) might be more suitable (17). Like this, crowding of instruments in the intercostal space can also be avoided and tension as well as trauma in the intercostal space due to overlapping of the trocars can be reduced. The assistant port in bRATS is typically used for one of the robotic arms, especially for stapling. This leaves more room in the intercostal space of the main incision to pass a suction or grasper in between the two robotic arms (camera and instrument).

The most common reasons for choosing a biportal approach in our cohort included limited intercostal width and/or the requirement to create a better distance from the port to the area of dissection when intending to use the robotic stapler.

Due to currently limited utilization of the uniportal and biportal robotic technique for anatomic lung resections, data on operating time and complications is still limited. Conflicting results have been reported on operating time using uRATS *vs.* mRATS (30,36,47).

Compared to bRATS, uRATS is reported to show lower postoperative pain (Visual Analogue Scale; VAS) scores (30). Our results indicate similar postoperative pain for both approaches. Nonetheless, the interpretation of these findings necessitates the consideration of several critical factors. The inherently subjective nature of pain perception introduces variability into the average pain scores reported by individual patients. Additionally, the presence of pre-existing chronic pain in some patients and the general nature of pain assessment conducted by nursing staff, which often encompasses overall rather than surgical-area-specific pain, may confound the results. Furthermore, the use of pre-existing pain medication by some patients due to chronic pain can complicate postoperative pain management. In addition, patient-specific factors such as intolerance to certain analgesics or the presence of comorbidities may limit the range of available analgesics, introducing another layer of complexity. These considerations underscore the need for a nuanced approach to interpreting the comparative efficacy of uRATS and bRATS in managing postoperative pain. In summary, a methodologically rigorous approach that incorporates objective measures, accounts for contextual factors, and employs standardized tools is crucial for meaningful comparisons of postoperative pain outcomes between different surgical approaches. By implementing these strategies, we can enhance the reliability and validity of pain score comparisons in surgical research.

The rate of prolonged postoperative air leak is reported to be significantly lower when a uniportal approach is employed, as opposed to a multiportal approach. However, these findings may be influenced by confounding variables such as the presence of adhesions and other factors that contribute to the complexity of the surgical procedure (47). The abovementioned results are consistent with our findings. Both robotic approaches theoretically allow a fast conversion to VATS or thoracotomy although in case of major intraoperative bleeding, uRATS might be superior to mRATS, as the trocars can be disconnected more rapidly and allow for faster conversion to uVATS or thoracotomy and achievement of hemostasis (47). The outcomes of the surgical procedure are highly influenced, among others, by the extent of the disease, patient anatomy and variants, and the surgeon's experience. Additionally, some authors also recommend the biportal method as a useful transition stage from the initial multiportal to uniportal robotic-assisted anatomic lung resections (47).

While the patients included in our study undoubtedly represent a carefully selected group of patients with early tumor stages, resectable tumors and given operability, demographically we can see a clear overlap with reported NSCLC populations. Currently mean age at diagnosis is reported to be around 70 years by several national registries in Europe and the US, which is consistent with the mean age of our patient cohort (48,49). Additionally, the incidence of lung cancer was historically higher in males than females, as it is the case in our cohort. Yet, in the past decades incidence rates converged and crossed over in specific age groups in several countries. This is partially attributable to changes of modifiable risk factors such as smoking habits but is not yet fully explained.

NSCLC may be categorized into different subgroups, with the most frequent being adenocarcinomas (40%) and squamous cell carcinomas (25%) (50-52). While adenocarcinomas are overrepresented our cohort, the typical location of NSCLC in the upper pulmonary lobes is consistent with reported data (53,54). Carcinogenic factors responsible for this distribution have not been definitively proven, though genetic and local factors are thought to contribute to this distribution pattern.

The major factor making RATS seem feasible from an oncological standpoint is the extent and completion of lymphadenectomy due to increased range of motion and maneuverability of the surgical instruments. While results are not yet conclusive, using a robotic approach may result in higher quantity of resected lymph nodes compared to a video-assisted approach. Nevertheless, no difference in upstaging the N-factor could be identified (15,32,55-60). European Society for Medical Oncology (ESMO) guidelines for early and locally advanced NSCLC recommend mediastinal lymph node sampling (MLNS) from six stations with three hilar and three mediastinal stations including the subcarinal space (61). Whether complete mediastinal lymph node dissection (MLND) or MLNS is the preferred approach is a topic of debate (62-64).

Comparing costs between VATS and RATS, especially for uniportal or biportal approaches, is difficult. Most conducted studies use varying definitions, methodologies and cost basis (e.g., depreciation costs, postoperative costs) (65). Comparability between studies is further hindered by the different conducted operations including lobectomies and segmentectomies or more complex procedures (66). In our study we report the EBITDA, which requires consideration of several factors, including the procedure, diagnosis, insurance status, postoperative stay on the intensive care unit (ICU) and in-hospital procedures including blood work, among others. Our cost calculation supports the findings that RATS is costlier than VATS and is thus consistent with most reported literature on this topic (56,67-69). Even in a diagnosis-related group (DRG)-driven healthcare system like Switzerland's, hospitals can still earn money from robotic surgery for anatomic lung resections.

This study is limited as it is a retrospective study with a limited patient population. Rigorous multicenter randomized prospective studies are required to further evaluate this issue. A better understanding of patient characteristics for selecting patients that are suitable for RATS lung resection and identifying predictors may be valuable. Additionally, further follow-up for long-term outcomes is necessary.

Conclusions

uRATS and bRATS are feasible approaches for anatomic lung resection. Our data shows no intraoperative and low postoperative complication rates. In our experience, occasionally a second port (bRATS) was necessary and useful for originally intended uRATS approaches, however, the outcomes were not significantly affected by the different approaches (uRATS *vs.* bRATS). We do not report significant differences in perioperative complications and LOS between the uRATS or bRATS approach. Between the two groups operating time, blood loss, numbers of resected lymph nodes, chest tube removal and length of stay were similar. The cost for RATS at our institution was higher compared to conventional uniportal VATS.

Biportal approaches may be a valuable transitional step in the process of adopting uRATS for anatomic lung resection in resectable NSCLC, especially when robotic stapling is used.

Further research is needed to determine the optimal approach for robotic-assisted anatomic lung resections and more rigorous trials comparing uniportal and biportal approaches may provide valuable insights for the future.

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