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ORIGINAL ARTICLE

# Pure Robot-Assisted Uniportal Anatomical Lung Resection for Non-Small Cell Lung Cancer: Technical Aspects and Early Outcomes

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## ABSTRACT

**Objective:** Minimally invasive anatomic lung resections are the standard for early non-small-cell lung cancer, and the robotic approach has gained popularity and the latest frontier is the uniportal robotic (uRATS) approach. The goal of our study is to share our series showing technical details, feasibility and early outcomes.

**Methods:** From December 2024, we started the uRATS programme for selected patients. Continuous and dichotomous variables were recorded about surgery and the perioperative period. Non-parametric tests were used to compare the data between uRATS and contemporary patients treated with robotic multiport RATS.

**Results:** In 4 months we performed two segmentectomies and five Lobectomy through uRATS, while one patient was converted due to incomplete fissure. No severe perioperative complications occurred and in the comparison with the multiport approach, no significant differences in operative time, conversions and complications were observed.

**Conclusions:** The Uniportal RATS approach was safe and feasible with adequate surgical and oncologic post-operative results.

## 1 | Introduction

Minimally invasive lung resections are the standard for curative intent treatment of early non-small-cell lung cancer [1, 2] and in the last years robot-assisted thoracic surgery (RATS) has gained popularity among thoracic surgeons from the pioneering development by Melfi et al. in the early 2000s [3]. The RATS approach has several advantages over standard thoracoscopy (VATS), such as the increased and immersive three-dimensional view, the availability of articulated instruments and the intuitive management allowing a safe and oncologically sound procedures. However, the current standard for RATS lung resection is the multi-port approach [4] with four or five ports leading to a potential intercostal injury and consequent post-operative pain more invasive than a single access surgery, even if a direct comparison has not yet been completed. Large scale studies and meta-analysis showed no differences between uniportal and multiportal thoracoscopic resection regarding the post-operative pain indices [5, 6], but no effective comparative studies have been performed between uniportal and multiportal RATS lung resection.

Pure uniportal RATS lung resection was first defined and described by Gonzalez-Rivas in 2022 [7] as a procedure in which every device for dissecting or stapling is driven by the robot through a single intercostal incision under the complete control of the first surgeon sitting at the console. The evidence about the pros and cons of this approach is still weak and the spread of this technique is incomplete, especially due to the intrinsic complexity and fear of several conflicts and the struggle of the robot arms in the single port.

The aim of this study was to report our initial experience with pure uniportal RATS anatomical lung resection with the DaVinci Xi platform for early stage NSCLC focussing on technical aspects, safety, feasibility, early post-operative and oncological results.

## 2 | Materials and Methods

Based on the experience of the first author (S.B.) in uniportal thoracoscopic lung resection (over 200 procedures) and multiport RATS procedures (over 100 thymectomy and over 50 lung resection) at Careggi University Hospital, Florence, we considered starting a uniportal RATS programme in December 2024 for early stage NSCLC. Exclusion criteria were: clinical locally advanced stage with mediastinal lymph node metastasis, hilar calcification at the pre-operative computer tomography scan (CT), and central lesion with the possibility of sleeve resection.

The clinical stage was assessed by whole-body CT scan (wb-CT), positron emission tomographic scan (PET-scan), bronchoscopy, and if indicated, endobronchial or oesophageal ultrasound (EBUS/EUS) or video-mediastinoscopy to rule out a suspected hilar or mediastinal nodal disease. Clinical and pathological stages were resumed with the American Joint Committee on Cancer 8th Edition TNM Classification [8].

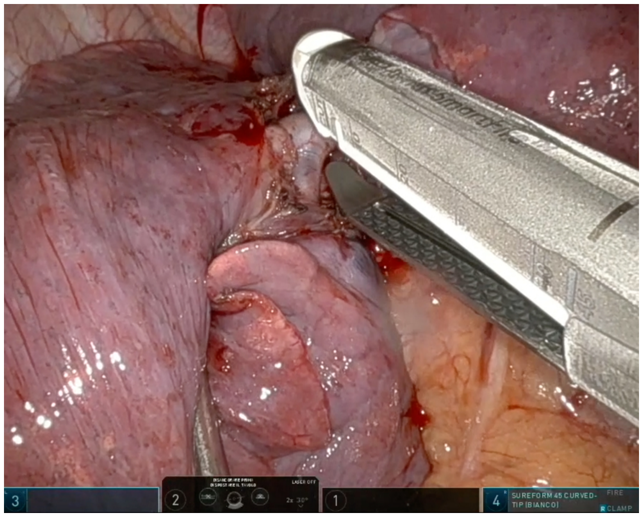
All patients were evaluated by our institutional Multidisciplinary Tumour Board (MTB) and the individual treatment was decided based on clinical stage, patient performance and the most recent international guidelines [9].

### 2.1 | Ethical Statement

The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This retrospective study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The retrospective analysis of the data did not require approval from the Institutional Review Board. Standard informed consent was obtained from all patients because of the non-experimental purpose of this study.

### 2.2 | Surgical Technique (Video)*

All the procedures were performed by the first author who had adequate experience in both uniportal VATS and mRATS techniques. The assistant surgeon was a resident or a young consultant with adequate experience in VATS lung resection and RATS assistance. The patient was placed in a full lateral appropriate decubitus and under general anaesthesia and one-lung ventilation (OLV). A utility incision approximately 5–6 cm long was made in the mid-axillary line just anterior to the latissimus dorsi at the fifth (for right upper lobes) or sixth intercostal space (all other procedures Surgical technique (Video 1) and a wound retractor was placed (Alexis S—Applied Medical). The Xi DaVinci robotic platform was introduced from the patient's back using three robot arms out of the four available, as previously described by Gonzalez-Rivas [7]. We placed the camera in the posterior part of the incision and, in order to avoid collisions, the other two arms were inserted one in the middle and the last one in the anterior edge of the incision, working in parallel (Figure 1). We used the Maryland Bipolar forceps on the right hand and the Bipolar Fenestrated Forceps on the left (Figure 2), both to grasp and



**Video 1** | An explicative surgical video showing a right lower lobectomy with our uniportal pure robotic approach. To view this video in the full-text HTML version of the article, please visit https://onlinelibrary.wiley.com/doi/10.1002/rcs.70114.

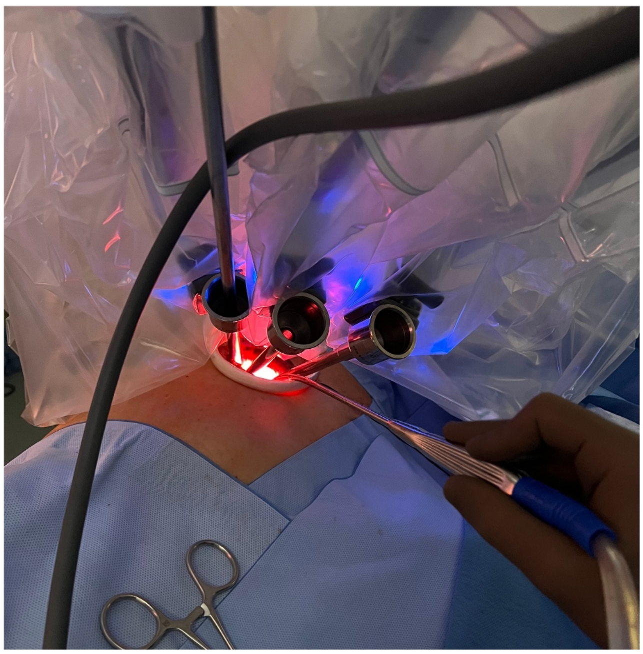


**FIGURE 1** | Trocars placement in our uRATS approach: camera at the posterior edge of the space and the other two arms medially and at the anterior edge of the access.

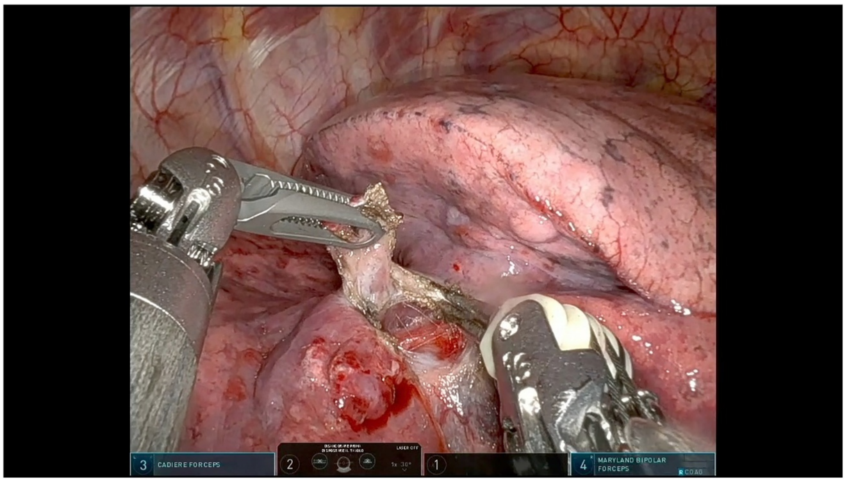



**FIGURE 2** | The left and right arm effectively worked in parallel during hilar lymph node dissection in right lower lobectomy.

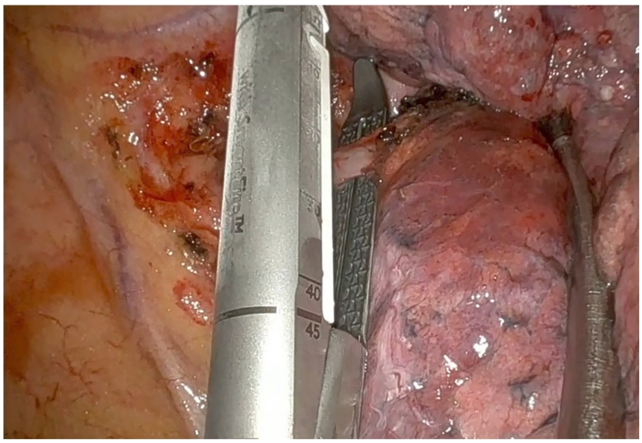


**FIGURE 3** | Vascular stapling using SureForm 45 mm of the first pulmonary artery branch during left upper lobectomy.

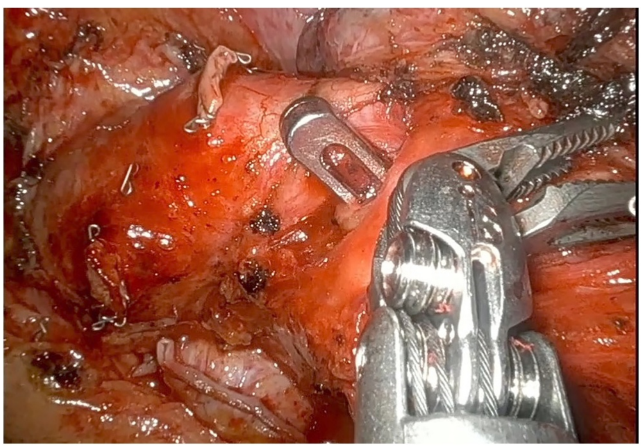


**FIGURE 4** | Dissection of the left upper bronchus is facilitated using TipUp forceps.

dissect, and the robotic stapler SureForm 45 mm with curved tip was installed on the right hand to suture and divide the pulmonary vessels (Figure 3), bronchus and lung parenchyma. Sometimes, for a safer dissection, we used the Tip-Up forceps, in particular on the superior pulmonary vein and left upper bronchus (Figure 4).

During the lung resection, we also performed a systematic hilar and mediastinal lymph node dissection. The bedside assistant surgeon plays a crucial role in exposing and retracting the lung with long curved standard VATS forceps (D'Amico or snake, Scanlan) or sucker. Before the docking, a paravertebral intercostal nerve block with 0.75% naropin was performed in every patient and acetaminophen 1000 mg and ketoroloac 30 mg every 8 h were administrated in the post-operative period among our standardised ERAS programme. After surgery, a 24F chest tube was positioned anteriorly in the chest apex.

### 2.3 | Statistical Analysis

Statistical analysis and data reporting were performed using SPSS 24.0 software (SPSS Inc., Chicago, IL). Continuous variables are expressed as median and interquartile range (IQR); categorical variables were reported with count and percentages. The comparison between uRATS and mRATS parameters was conducted with Mann–Whitney test and the Chi-squared test (or Fisher's test as appropriate) for dichotomous variables.

## 3 | Results

From December 2024 to March 2025 we completed 7 pure uniportal RATS anatomical lung resection (6 men, median age 74 IQR 35.25) including 2 simple segmentectomies (right S6 and lingulectomy) and 5 lobectomy (2 RUL, 2 RLL -Surgical technique Video 1-, LUL); a compromised patient scheduled for pure uniportal RATS anatomical right S6 was immediately converted to thoracotomic wedge because he was not able to maintain the OLV and also for the presence of a highly incomplete interlobar fissure. Demographic and functional data are depicted in the Table 1.

The median skin-to-skin time was 135 (IQR 45) minutes, the console time was 113 (44 IQR) minutes and the estimated blood loss was 26.5 (IQR 17.75) mL. Although the surgical procedures were different, the median number of stapler cartridges used was 7.5 (IQR 2.5).

**TABLE 1** | Demographic and functional data of the patients scheduled for anatomic uRATS resection.

| Patients | Sex | Age | PS ECOG | ASA | Comorbidities | Scheduled surgery | FEV1 (%) | DLCO (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | Female | 38 | 0 | 2 | Sjogren syndrome | RLL | 63 | 51 |
| 2 | Male | 38 | 0 | 2 | Pulmonary embolism, ulcerative colitis | Right s6 | 97 | 83 |
| 3 | Female | 74 | 0 | 3 | Hypertension, diabetes mellitus | Lingulectomy | 111 | 98 |
| 4 | Male | 80 | 1 | 3 | Pulmonary embolism, obesity | Right S6 | 103 | 99 |
| 5 | Male | 65 | 0 | 3 | Hypertension, renal stones | RLL | 99 | 83 |
| 6 | Male | 74 | 1 | 3 | Hypertension | LUL | 76 | 96 |
| 7 | Male | 80 | 1 | 3 | Hypertension, COPD | RUL | 66 | 77 |
| 8 | Male | 80 | 1 | 3 | COPD, diabetes mellitus | RUL | 50 | 54 |

Abbreviations: ASA, American Society of Anaesthesiologists; COPD, chronic obstructive pulmonary disease; DLCO, diffusing capacity of the lungs for carbon monoxide; FEV1, forced expired volume at first second; LUL, left upper lobectomy; PS ECOG, performance status Eastern Collaborative Oncologic Group; RLL, right lower lobectomy; RUL, right upper lobectomy.

**TABLE 2** | Intraoperative and post-operative data.

| Patients | Console time | OT | Surgery performed | Cartridge numbers | LOS | ICU stay | Pathology and TNM | Number of dissected lymph nodes | Lymph node station dissected | Margins in mm |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 136 | 150 | RLL | 7 | 3 | 0 | ADC t3n1 | 8 | 10r, 11r, 7, 8, 9 | 70 |
| 2 | 113 | 135 | Right s6 | 6 | 2 | 0 | NET 1c0 | 5 | 11r, 7, 8, 9 | 2 |
| 3 | 120 | 140 | Lingulectomy | 8 | 3 | 0 | ADC 1b0 | 7 | 10L, 11L, 7, 5, 6 | 13 |
| 4 | NA | NA | Wedge converted | NA | 10 | 6 | SCC 1b0 | 2 | 11r, 9 | 14 |
| 5 | 100 | 120 | RLL | 5 | 5 | 0 | SCC 2b0 | 11 | 2r, 4r, 7, 9, 10r, 11r | 46 |
| 6 | 176 | 200 | LUL | 9 | 4 | 1 | SCC 2a0 | 8 | 5, 7, 9, 10L, 11L | 25 |
| 7 | 88 | 100 | RUL | 11 | 7 | 0 | SCC 2a0 | 22 | 2r, 4r, 7, 10r, 11r | 30 |
| 8 | 92 | 105 | RUL | 8 | 8 | 1 | SCC 1b0 | 20 | 2r, 4r, 7, 9, 10r, 11r | 30 |

Abbreviations: ADC, adenocarcinoma; ICU stay, intensive care unit; LOS, length of stay; LUL, left upper lobectomy; NET, neuroendocrine tumour; OT, operative time; RLL, right lower lobectomy; RUL, right upper lobectomy; SCC, squamous cell carcinoma.

Neither postoperative nor perioperative complications occurred in patients treated with pure uniportal RATS resection and the median ICU stay was 0 days (IQR 1) and hospital length of stay was 4 (IQR 4) days. The patient who underwent thoracotomy developed pulmonary embolism and consequent respiratory failure, but he recovered in 10 days. Regarding the oncological results, every patient had a R0 resection with free margins (median 27.5 mm IQR 28.75), median retrieved lymph nodes were 8 (IQR 12.25), the median number of dissected stations was 5 (IQR 2), median number of dissected hilar lymph node stations was 2 (IQR 1), whereas dissected mediastinal stations were 3 (IQR 1) (Table 2). Regarding the post-operative pain, the median numerical analogue score (NAS) on post-operative day (POD) 0, 1, 2 and 3 were 0, 1, 2 and 1; five patients needed supplemental opioid administration (tramadol, median 100 mg iv). Two patients needed empirical antibiotic therapy: the converted patient (patient 4) due to the concomitant pulmonary embolism and lung opacity at the chest-X ray, while elevated levels of white blood cells (WBC) were detected in a COPD patient; overall, the median WBC levels at POD 0 and 1 were $12.5 \times 10^9$/l (IQR 7.06) and $10.75 \times 10^9$/l (IQR 12.6), respectively.

Comparing the intraoperative and peri-operative outcomes of these patients with a similar population of 40 patients undergoing multiport RATS lung resection between 2021 and 2024, we did not observe significant differences regarding operative time (130 vs. 135 min) conversion (1/40, 2.5% vs. 1/8, 12.5%) complication rate (10/40 25% vs. 2/8 25%) and the development of at least one complication in 12.% versus 12.5% of patients. The post-operative median NRS values recorded from uRATS and mRATS patients were at POD 0 were 0 (IQR0) versus 1.25 (IQR 1.5); at POD 1 were 1 (IQR 2.75) and 1 (IQR 2.5); at POD 2 were 2 (IQR 1.63) versus 2 (IQR 2.5), respectively. All these differences were not statistically significant.

## 4 | Discussion

Robot assisted thoracic surgery (RATS) is an increasingly used technology among thoracic surgeons and the last frontier is the application of the robotic platform to single-access surgery, reducing at the minimum the invasiveness of lung resection and, at the same time, maintaining the advantages of the RATS approach. Our report showed the feasibility and safety of uniportal pure RATS lung resection, demonstrating neither intraoperative problems nor postoperative complications and the only conversion was made electively due to functional and anatomical issues. Regarding the oncological effectiveness, our data show complete resection in all patients with large and free margins and a median of 8 retrieved lymph nodes. No complications developed in the post-operative time, the length of stay can be considered short and the post-operative pain was well controlled in all patients, with a low requirement for mild opioids (tramadol median 100 mg, one administration). Moreover, the comparison between uRATS and mRATS procedures failed to demonstrate significant differences among the two different approaches, confirming the safety of the pure uRATS approach.

We are all aware of the main disadvantage of robotic surgery, which is represented by the direct and indirect costs , and in a spending review period, every effort should be made to reduce the financial impact of this kind of surgery. With this in mind, we chose to use two or three multi-use instruments and only one disposable robotic stapler, avoiding the purchase of the *trans*-oral robotic trocars (TORS) or modified thinner trocars. Moreover, the operating theatre occupation time and operative time (median 135 min) were shorter than expected and the absence of post-operative complications and the reduced operative staff (one console surgeon and one assistant) could influence the overall cost of the RATS procedure as well.

From a technical point of view, the single access in the original technique [7] is performed in the sixth or seventh intercostal space ensuring a right distance to the pulmonary hilum and the chest; however, we found that robotic arms could also well operate in a 'fly-mode' with the trocars not necessarily in the access but flying some centimetres above. This is particularly true for robotic staplers, which need more external space to work effectively. In our experience, we started with the single access in the sixth space in a RLL and the robot arms worked properly without conflicts or difficulties in dissecting the hilar structures; we considered this as a right position for a potential emergency conversion. Indeed, the uniportal approach has the great advantage, compared to the multiport approach, of an easy and prompt conversion and, using the sixth or fifth intercostal space, the hilar structures have an easy access and even complex manoeuvres such as a pulmonary artery taping during bleeding could be performed from the right space without discomfort. On the other hand, the conversion from multiport RATS could be challenging because of the need to first detach the robot arms anteriorly and posteriorly and then, to perform the emergency thoracotomy in a different and more cranial space, prolonging the time to effectively control the bleeding and increasing the intercostal injury and consequently the post-operative pain.

Another advantage of the uniportal RATS approach is the use of the same view as the uniportal VATS approach. Switching from uniportal VATS to multiport RATS may also be tricking for expert surgeons. In fact, in the multiport robotic setting, the camera comes from the diaphragm and this view is completely different from the direct view of the uniportal approach and it could cause some disorientation to the surgeon, since some dissecting steps and manoeuvres could be different too. Moreover, the three dimensional, immersive, enhanced, completely firm and first surgeon-controlled view is one of the greatest advantages of the robotic platform.

Another technical advantage of the uniportal RATS approach is the availability of two grasping instruments, which allow a great exposure and safe dissection despite the absence of tactile feedback. Moreover, as already cited, the assistant plays a crucial role in retracting the lung and removing fluids and blood in the operating field, manoeuvres that in multiport RATS are more complex and often require an additional assistant port. These findings are corroborated from our data by the number of explored stations and lymph nodes retrieved that is absolutely adequate for early stage NSCLC and comparable to the other surgical approaches [10, 11]. Different from Mercadante et al. [12] who described the need of intracavitary crossing of the robotic instruments, with consequent counter-intuitive dissection and the necessity of modifying the controller before starting the surgery, we used all the instruments in parallel and we did not register any difficulties in stapling the vessels with the 45-mm robotic staplers. However, we encountered some issues in isolating and stapling the left upper lobe bronchus and we sorted it out using the Tip-Up forceps and a loop around it, allowing an anterior traction of the bronchus far from the pulmonary artery. Noteworthy, because the Xi platform is armed with 45-mm staplers, which need a particular and larger trocar of 12 mm, in this situation we removed all the instruments except for the camera from the access to reduce the risk of struggling and conflict, achieving a safe dissection and smooth stapling of the bronchus. Moreover, a new thinner (8 mm) and shorter (30 mm) stapler is now available for the XI platform and it seems very effective for small vessels, especially during segmentectomy. Because of the reduced diameter, the need for a particular and larger trocar is avoided and intercostal nerve injury could be reduced. Regarding the console controller, we used the arms number 2, 3, 4 on the right side and 1, 2, 3 on the left and it is fundamental to change the controller configuration manually before surgery.

The pure robotic approach has the great advantage that stapling is not demanded by the assistant [13] and that the robot controlled staplers can compress the structures in a uniform way (SmartFire technology ). This is particularly important especially for the lung parenchyma, because it significantly reduces the risk of laceration and consequently lowers the risk of prolonged air leak and/or lung haematomas. In our series, although small, we included some elderly patients with COPD and emphysema and we did not register any prolonged air leak and the post-operative chest X-rays did not show any lung opacities or consolidation. From a technical point of view, to staple the parenchyma, we always use the black extra thick reload of the 45-mm stapler (Figure 5), which ensures adequate sealing of the stapling line and a quick and effective suture also in emphysematous parenchyma.

The uniportal RATS approach merges the advantages and difficulties of uniportal VATS and multiport RATS lung resection and then the surgeon should have overcome the learning curves of both techniques and in particular the surgeon should master the view, the steps and the conflicts of uniportal VATS but at the same time he/she should be completely proficient in the management of the robotic platform, instruments and strugglings.

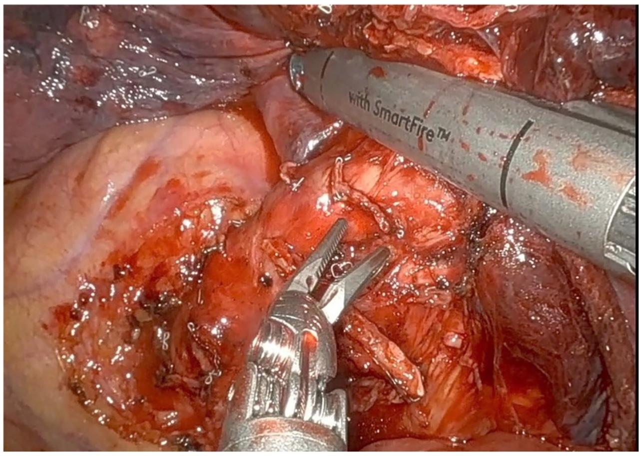



**FIGURE 5** | Use of black cartridge armed on SureForm 45 mm for dividing the lung parenchyma.

In conclusion, our case series reported the feasibility, safety and the oncological effectiveness of pure uniportal RATS lung resection, showing good outcomes also related to the use of robotic staplers. Larger and prospective long-term studies should be designed to implement the evidence of uniportal RATS lung surgery.

We hope that our data, although small and preliminary, could play a role in approving, developing and spreading this approach.

### Consent

In accordance with Italian laws for retrospective observational studies, we granted a waiver of informed consent from study participants.

### Conflicts of Interest

The authors declare no conflicts of interest.

### Data Availability Statement

The data underlying this article will be shared on reasonable request by the corresponding authors.

### Disclaimer

This is an off-label use of the Intuitive Robotic system and we are aware that all surgeons using this approach do so under their own responsibility. Our opinions and experiences about this technique do not represent the views of Intuitive surgical, which is still evaluating this technique for safety and efficacy.

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