Uniportal VATS approach to sub-lobar anatomic resections: literature review and personal experience

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Abstract: Surgical scientific literature contains relatively little information regarding the surgical outcomes of anatomic sublobar resections performed with the uniportal video-assisted thoracoscopic surgery (U-VATS) technique. This paper attempts to evaluate the role of U-VATS segmentectomies in the landscape of a minimally invasive approach to the treatment of early stage non small cell lung cancer (NSCLC).

Keywords: Uniportal video-assisted thoracoscopic surgery (U-VATS); single access; segmentectomy; sub lobar resection; non small cell lung cancer (NSCLC); single port

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Pulmonary lobectomy has been considered as the standard surgical procedure for lung cancer, since the prospective randomized controlled study published by the U.S. Lung Cancer Study Group in 1995 (1) showed a lower local recurrence rate and a better long-term survival rate when performing lobectomies compared to sublobectomies.

Nevertheless, technical advances in non small cell lung cancer (NSCLC) early diagnosis and in thoracic surgery techniques have changed the treatment approach to early stage NSCLC (2,3). The extensive application of high-resolution computed tomography (HRCT) in NSCLC screening programmes for high-risk former smokers has increased the detection of an even greater number of tiny NSCLC (<2 cm) and pure ground-glass opacity (GGO) lesions (4). This phenomenon has led to a modification of the 8th Edition of TNM classification of lung cancer (5), introducing tumors of ≤1 cm that are classified into a new T1a group, and had also led to the inclusion of the presence of GGO lesions as a radiological classification criterium suggestive of minimally invasive or noninvasive NSCLC (6).

This scenario has renewed surgeons' interest in sublobar resections, not only for high-risk but also for fitting patients with early stage I NSCLC.

Simultaneously, anatomical segmentectomies (introduced as a surgical approach to benign lesions in 1939) has reemerged as a treatment option for such less-invasive NSCLC.

Compared with wedge resections, typical segmentectomies can ensure an adequate distance of the lesion from the margins, thereby reducing tumor recurrence and improving long-term survival (7) resulting in the most tailored surgical approach in the landscape of personalized medicine.

Although more evidence is claimed to definitively establish the role of intentional segmentectomies in the surgical treatment of early stage NSCLCs, a recent meta-analysis disclosed that segmentectomies produce similar survival outcomes compared to lobectomies in patients affected by stage I NSCLC (8).

Additionally, patients with multifocal partially solid tumors/purely GGO lesions may also be perfect candidates for segmentectomies, as they may require multiple and/or repeated resections (9) as claimed by Gonzalez-Rivas (10), who described "en bloc segmentectomies (2 or 3 combined segments)" for several GGOs located in different adjacent segments or located in the intersegmental plane.

In case of intentional segmentectomies, patient selection is of fundamental importance. The usual indications for a lung segmentectomy include: small (<1 cm) GGO lesions (<50%); tumor less than 2 cm in diameter without thoracic lymph node involvement and non malignant lung disease, where it's necessary to preserve normal lung parenchyma.

In properly selected patients, even more evidences suggest that anatomic segmentectomies represent a valid alternative to lobectomies, offering a better quality of postoperative life, a lower operative morbidity and increased possibility for the patient to undergo a second or third surgical resection in case of a newly diagnosed NSCLC, without compromising oncological principles (11-23).

Surgeons who properly select tumors and achieve adequate margins and lymph node sampling describe comparable outcomes between segmentectomies (24,25) and lobectomies.

The role of extensive lymph node dissection in terms of recurrence-free survival and postoperative treatment planning remains of supreme importance also for segmentectomies. Results from National database studies demonstrate that a worse outcome in segmentectomies is often associated with a less extensive mediastinal lymph node dissection (26,27).

Since the traditional multiport video-assisted thoracoscopic surgery (MP-VATS) has become the standard approach for thoracic procedures (28), many reports address the role of thoracoscopic segmentectomy as the best lung-sparing operation for early stage NSCLC.

Compared with lobectomy, VATS segmentectomy achieves equivalent oncological results with less postoperative pain, lower post-operative morbidity and mortality (29) associated with a shorter chest tube duration (30) and hospitalization (31) and lower medical costs (32,33).

Since the earliest report of uniportal VATS (U-VATS) segmentectomy published by Diego Gonzalez-Rivas in 2012 (34), the feasibility and the advantages of U-VATS have been described in different fields of thoracic surgery. Despite the initial mistrust towards this technique, U-VATS has progressively emerged as a less invasive technique than the conventional MP-VATS, and various surgical groups have adopted this technique worldwide (35).

U-VATS has shown to be safe and feasible, even in complex procedures such as sleeve resections (36,37), segmentectomies (34,38,39) and vascular reconstructions (40,41).

Potential advantages for patients undertaking surgery with U-VATS technique are: reduced intercostal nerve injury compared with traditional surgery and less postoperative pain. During U-VATS procedures, the insertion of the camera and surgical devices is perpendicular to the plane of the chest, causing less compression on the intercostal nerves and significantly reducing subsequent paresthesia. In contrast, MP-VATS, with more incisions at different intercostals spaces, damages intercostal nerves at several sites worsening postoperative pain. Jutley *et al.* (42) found a significant difference in visual analogue scale (VAS) pain scores in patients who underwent U-VATS procedures compared with those who were treated with MP-VATS technique for spontaneous pneumothorax. The uniportal group had a lower median score of 0.4 (visual analogue range 0–4) while the three-port technique group reported a median pain score of 0.8 (P=0.06, Mann-Whitney test). The maximum score trend was similar (1.4 *vs.* 2.6, respectively; P<0.001, Mann-Whitney test). A higher residual pain score (VAS 0.5) was found in the MP-VATS group when compared to U-VATS (VAS 0.3). Regarding neurological complications, 86% of uniportal patients reported no symptoms and the other 14% only referred mild 'numbness' or 'swelling'. On the contrary, only 42% of patients in the three-port group reported no symptoms, and a similar number experienced 'numbness'. Although no randomized studies have been published proving that U-VATS is better than the conventional approach or even thoracotomy, meta-analysis studies indicate that conventional VATS has better results than thoracotomy, but U-VATS reveales more favorable outcomes than the multiportal approach (43). There is a statistically significant reduction in the length of hospital stay (6.2±2.6 *vs.* 6.7±3.4 days, P<0.0001), a reduction of postoperative drainage stay (4.5±2.2 *vs.* 5.4±2.9 days, P=0.0006) and overall morbidities (12.0% *vs.* 13.7%, P=0.009) for patients undergoing U-VATS lobectomies compared to the multiportal approach.

Segmentectomy techniques comparison

The better postoperative outcomes of U-VATS versus open thoracotomy segmentectomy has been well illustrated by Surendrakumar (44), who retrospectively analyzed 86 consecutive patients who underwent open or U-VATS segmentectomy. The author found similar results in terms of surgical outcomes, equivalent R1 resection margins and nodal stations exploration. No postoperative deaths were described in the U-VATS group while one was reported in the open-surgery group. Patients in the U-VATS group had a shorter hospital stay [median of 4 days (range, 1–15 days) *vs.* median of 6 days (range, 3–27 days), P=0.01], without any difference in the incidence of complications or readmissions to the hospital over time. Many studies have been conducted with the aim to assess the advantages of U-VATS *vs.* MP-VATS. Ji (45) evaluated 458 patients who received U-VATS or MP-VATS major anatomical resections: there were no differences between the two groups in the number (P=0.278) and stations (P=0.564) of lymph nodes sampled, postoperative morbidity (P=0.414) or mortality (P=0.246), and in pain scores on the third day after surgery (P=0.630). Surgical time was longer in the U-VATS group (P=0.042) with a greater intraoperative blood loss (P<0.001), but the conversion rate was even higher in the MP group (P=0.018). Patients in the U-VATS group experienced a shorter chest tube stay (P=0.012), a shorter postoperative hospitalization (P=0.005) and lower pain scores on the first (P=0.014) and second (P=0.006) day after surgery. Authors concluded that U-VATS lobectomies and anatomical segmentectomies are technologically more demanding than when approached through MP- VATS, but the least invasive surgery leads to experiencing less pain in the early postoperative period. Similar results were described by Han *et al.* (46) on a total of 45 patients who underwent pulmonary segmentectomy by U-VATS or MP-VATS between March 2006 and October 2015. The surgical time in the U-VATS segmentectomy group (148±65 min) was longer than in the MP-VATS segmentectomy group (107±68 min), although this difference was not statistically significant (P=0.073). The number of resected lymph nodes (n=24) was higher (P=0.031) in a relatively small population (n=3) in the MP-VATS group compared to the U-VATS group. Although no significant difference was registered in intraoperative events (P=0.412) and prolonged air leak (>5 days) (P=0.610), postoperative morbidity (P<0.001) and hospital stay (P=0.029) were lower in the U-VATS group. Lee (47) retrospectively analyzed 84 patients who underwent a U-VATS or MP-VATS anatomic segmentectomy: despite anesthesia and surgical times were similar in the two groups (215 *vs.* 220 minutes, respectively, P=0.276 and 180 *vs.* 198 minutes, respectively, P=0.396), blood loss (50 *vs.* 100 mL, P=0.013), chest tube duration (2 *vs.* 3 days, P=0.003) and hospital stay [4 days (range, 1–14 days) *vs.* 4 days (range, 1–62 days), P=0.011] were significantly lower in the uniportal group. The number of dissected lymph nodes tended to be lower in the uniportal group (5 *vs.* 8, P=0.056). Wang (48), in a propensity-matched analysis on 223 patients, compared the perioperative outcomes of U-VATS and MP-VATS lobectomies and segmentectomies; after propensity matching, 46 patients resulted eligible in each group. No significant differences were found between the two groups in terms of length of hospital stay and complication rate, but U-VATS lobectomies and segmentectomies were associated with shorter operative time (P=0.029), higher numbers of sampled lymph nodes (P=0.032), and less intraoperative blood loss (P=0.017). Moreover, the width of the wound resulted being a better outcome in favour of U-VATS *vs.* MP-VATS (39). The feasibility and safety of U-VATS has also been assessed during complicated segmentectomies. A complicated segmentectomy does not belong to the conventional segmentectomy and it's is rarely discussed in surgical literature. The comparison between U-VATS and MP-VATS in complicated segmentectomies was reported by Chen (49), who evaluated 96 U-VATS and 68 MP-VATS complicated segmentectomies between July 2010 and March 2017. After propensity matching, the author analyzed 56 patients in each group. Despite surgical times and blood loss were not significantly different between the two groups, U-VATS complicated segmentectomies showed a shorter duration of pleural drainage and postoperative hospital stay (2.8 *vs.* 3.6 days and 4.2 *vs.* 5.3 days, respectively) (P<0.01). Both the intraoperative and postoperative complication rates were not significantly different as well. No 30-day mortality was observed in the series.

Learning curve

VATS segmentectomy requires excellent understanding of the hilar/mediastinal anatomy, much more than in lobectomies, to properly identify and expose the segmental structures, and more ability in handling instrumentation. Segmentectomies are not all equivalent; they can be classified into two groups: typical and atypical segmentectomies. Typical segmentectomies are simple procedures, e.g., right S1 and lingular segmentectomies (where parenchymal division involves 1 or 2 planes), while atypical ones are challenging procedures (e.g., S3 or S7, S8 segmentectomies) with the need of two or more intersegmental plane resections.

Typical segmentectomies have been relatively frequently described in a VATS (50) setting while, in contrast, atypical segmentectomies are technically feasible but remain challenging and reports are still limited (51,52).

Due to the complex anatomic orientation, mainly in case of atypical segmentectomies, it's absolutely crucial to plan the operation by performing, preoperatively, a HRCT scan with 3D reconstruction to assess the lateral, the axial and the sagittal views in order to recognise the segmental anatomical structures (including veins, arteries and bronchus) and identify any anatomic variation (53).

Despite segmentectomies remain a challenging procedure, especially in minimally invasive surgery, data from surgical literature seem to demonstrate that the learning curve of U-VATS segmentectomies may be shorter than the MP-VATS one.

In fact, while McKenna (54) and Petersen (55) suggested a length of learning curve for MP-VATS lobectomy of at least 50 procedures, Hernandez-Arenas (56), evaluating U-VATS lobectomy and segmentectomy learning curve in a high volume training Center, found that one surgeon can complete the learning curve after only 30 cases. Cheng *et al.* (57), analyzing data from a retrospective observational study on 40 patients who underwent U-VATS segmentectomy with a cumulative summative analysis and one-way ANOVA, confirmed that the learning curve resulted completed after 33 patients, with no conversion to three-port VATS, two-port VATS or open thoracotomy. In our experience (58) the cumulative sum analysis on 46 consecutive patients who underwent U-VATS major lung resection showed that the learning curve resulted completed after 25 cases. Using the cut-off of 25 patients, the whole populations was divided in group A (first 25 patients of the experience) and group B (the last 18 patients). The mean operative time in group B was significantly shorter than in group A (164.00±24.46 *vs.* 191.40±50.45 min, respectively, P=0.04). There were no differences in demographic characteristics, number of removed lymph nodes, chest tube duration and hospital stay among the two groups. The number of conversions was higher in group A (4 *vs.* 0; P=0.07), as the number of major complications, like reinterventions for bleeding (2 *vs.* 0; P=0.22). There was no postoperative 30-day-related death.

No intraoperative vessel injury or anatomical variants causing significant changes in the surgical plan was reported by Duan *et al.* (59), who evaluated 156 consecutive patients with lung lesions who received anatomical pulmonary segmentectomy by U-VATS between 2015 and 2016. There was a significant correlation between the surgical time and the cumulative sum of the number of VATS segmentectomies performed by the surgeon (r=−0.593, P<0.001). The average surgical time of 123 min reported by the Author resulted absolutely in line with the similar surgical literature (38,60,61), while a progressive reduction in operative time directly correlated with the number of procedures performed by each operator.

Key points: localization of small/non-palpable lung lesions and intersegmental plane identification

VATS segmentectomy is particularly valuable for the resection of small, non-visible or non-palpable tumors. During mono o multiportal VATS procedures, though, it's often difficult to palpate and identify small and deeply located nodules. Many techniques have been proposed to overcame this obstacle: intraoperative ultrasonography (62), hook-wire (63), hook-wire and lipiodol or a radioisotope (64), CT fluoroscopy (65), electromagnetic navigation bronchoscopy (66,67), combined techniques in hybrid operation theatres (68), preoperative injection of drugs, dyes (69-72) radionuclides (73), and contrast medium injection (lipiodol, barium) (74,75). Each of these localization methods has their own advantages and drawbacks. At present, the most commonly used technique is CT-guided hookwire localization (63), but the hookwire dislodgement before surgery is, unfortunately, relatively frequent. Thaete *et al.* (76) reported a dislodgement rate of 12% in cases without an initial pneumothorax and of 33% in cases with pneumothorax occurrence. According to Chen *et al.* (63), situations responsible for dislodgment of the hookwire may be: (I) during transfer to the operating room, the hookwire can be pulled as the chest wall and shoulder girdle move in relation to the lung; (II) the friction between the chest wall and the hookwire makes the hookwire dislodge during surgical deflation of the lung; (III) when the surgeons apply traction on the hookwire to tent the lung to facilitate resection, the hookwire can dislodge. In addition, dislodgement of the hookwire is related to the size and depth of the lesion. The most common complication of hookwire localizzation is pneumothorax, which can occur during the procedure itself. The incidence of pneumothorax

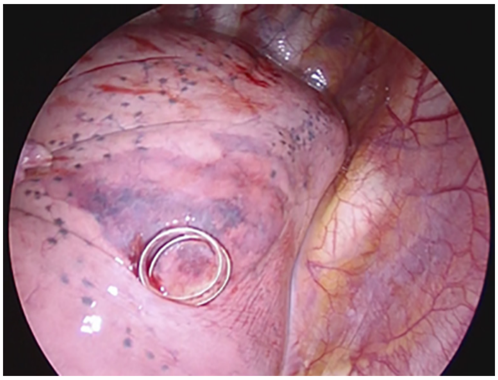

Figure 1 Intraoperative view of the microcoil deployed partially inside the nodule and partially along the visceral pleura.

in these cases is around 18% (63).

Intraoperative ultrasonography (62) with convex probe allows the surgeon to localize subcentimetric lesions, but the depth of the nodules significantly influences the quality of the images (excellent resolution up to 1.5 cm). The complete collapse of the lung or the use of high frequencies can help to better visualize the targets.

Many techniques based on preoperative injection of drugs, dyes (69-72), radionuclides (73), and contrast medium injection (lipiodol, barium) (74,75) have been proposed. The main disadvantage of these procedures is the necessity to perform surgery immediately after localization. The electromagnetic navigation bronchoscopy (66,67) is directly performed in the operating room, with the aim to identify small peripheral lesions by injecting methylene blue, which results visible on the visceral pleura thus allowing the affected segment to be resected. This technique doesn't need facilities such as a fluoroscope, radiotracers, radioprobes, hookwires or coils and has the obvious advantage of not exposing the patient and the surgeons to radiations; on the other hand, methylene blue has the tendency to spread in the parenchyma adjacent to the injection site and this makes it of primary importance to perform surgery immediately after the localizzation. When the localization is performed with Lipiodol (74), the tracer can be aspirated at alveolar level, causing acute damage and inflammation. Additionally, in patients affected by silicosis, colour might be difficult to visualize. Localization with barium (75) under fluoroscopic guidance offers the advantage of allowing greater flexibility in the organization of the operating room; it remains in site longer than other dyes and, interestingly, the surgeon can be able to palpate the barium balls during VATS. However, parenchymal damage can occur, creating an acute inflammation with neutrophils and histiocytes infiltration in the barium containing site, which can alter histological diagnosis, especially in the case of pure GGOs. In the attempt to overcome all these obstacles, we recently described our experience with a nouvelle technique in preoperative computed tomography (CT)-guided embolization microcoil (14-mm diameter ×14 cm length, synthetic fiber-coated, stainless steel, Cook, Bloomington, IN, USA) localization of GGO nodules in 30 patients undergoing uniportal VATS lung resection (77). The coil has the peculiarity to be deployed beneath the nodule and partially along the transpulmonary route till the pleural space, with the distal tail of the coil left above the visceral pleura surface, serving as a guidance for the surgeon (*Figure 1*). No special instrumentation as fluoroscopy is needed in the operating theatre to identify the coil. The mean procedure time resulted being of 35±15 minutes. In 5 cases, the localization procedure was complicated by asymptomatic pneumothorax and in 1 case the pneumothorax required chest tube insertion. In all cases, conversion to thoracotomy was avoided as all nodules were identified and resected through uniportal VATS. The advantages of the use of microcoils, usually adopted for vessels embolization, are numerous: they are commonly used, easy to acquire and inexpensive compared with radionuclides; they can also be safely kept in the human body for days; after implantation, coils can be felt like a certain degree of hardness in the lung parenchyma and they are radiopaque, all aspects that enable finding the position by visual inspection, palpation, and, if required, fluoroscopy during surgery; coil placement is easy and has good repeatability (78) (*Figure 2*).

Recognition of the intersegmental plane is a key step in segmentectomy. Classically, the intersegmental veins are considered the anatomical landmarks during the dissection of the central portion of the intersegmental plane, but no anatomic landmarks are present on the visceral pleura, making the completion of segmentectomies sometimes very hard. Moreover, the identification of the intersegmental plane during segmentectomy is crucial to achieve the oncological proper excision with respect to adequate margins and the conservation of normal lung parenchyma. This step still remains the most challenging part of the procedure, especially in patients with chronic obstructive pulmonary disease (COPD), where the hyperinflated state of the lung parenchyma makes the intersegmental plane identification even more challenging. The historically most utilized technique for the identification of intersegmental

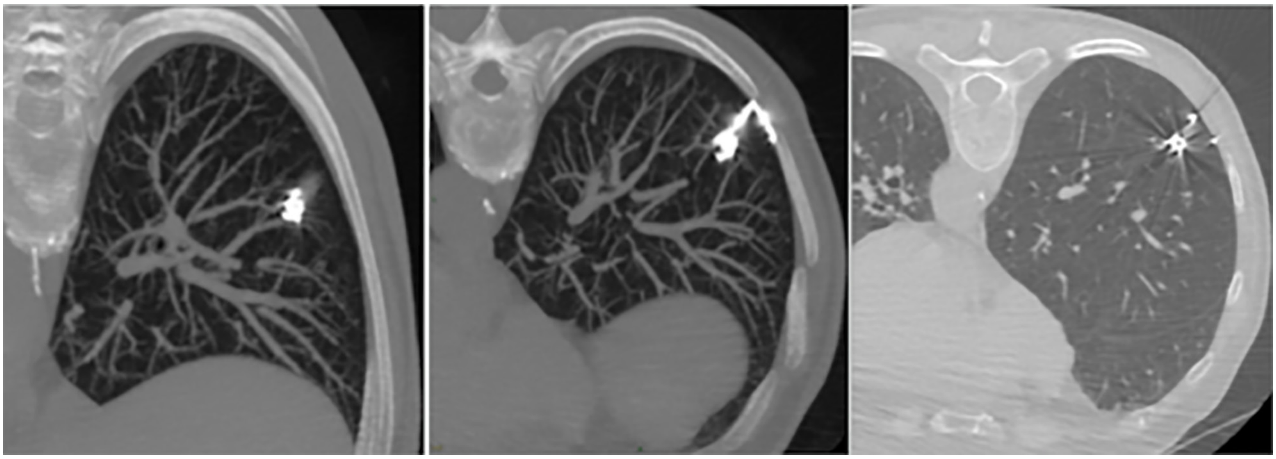

Figure 2 CT-images showing nodule localization by microcoil in different scanning planes.

planes during open and VATS procedures is the creation of a demarcation line between the target segment and residual parenchyma by inflating the lung after the segmental bronchus closure (79).

However, the presence of collateral canals that permit retrograde inflation of the target segment despite the closure of the segmental bronchus, may result in a difficult identification of the intersegmental line especially in COPD patients, where the emphysematous lungs often become overinflated. Several methods have been described in the effort to overcome these difficulties. In 2007, Okada *et al.* proposed a bronchoscopic selective ventilation of the segmental bronchus (60), while Kamiyoshihara *et al.* (80) proposed the inflation of the involved segment only by instilling oxygen through a butterfly needle into the bronchus subtending the segment. In order to obtain the demarcation between inflated and deflated lung, leaving only the target segment inflated, a slipknot bronchial ligation of the segmental bronchus during VATS segmentectomy was proposed by Oizumi *et al.* (81) in 2014. As an alternative to lung inflating procedures, many authors evaluated the efficacy of dyes injection into the segmental pulmonary artery (82) or peripheral segmental bronchus following the ligation of the pulmonary vein (83,84). Kato and colleagues (85) described the technique of 3-dimensional lung segmental color mapping from multislice CT angiography to understand the individual lung segmental anatomy and variations of the segmental vessels and bronchi. A 98% completion rate for segmentectomy using 3-dimensional reconstruction images was reported. Also, they emphasized that the intersegmental vein could be a guide for the parenchymal dissection (86).

A novel technique is the virtual assisted lung mapping (VAL-MAP) (87) that allows for bronchoscopic multi-spot dye markings to provide "geometric information" to the lung surface, using three-dimensional virtual images. It allows the surgeon to constantly reconfirm the actual anatomy, thereby avoiding the misidentification of vessels and preventing inadequate resections. In addition, the VAL-MAP technique allows intraoperative guidance and seems to be valuable for technically challenging segmentectomies. In 2009, an experimental study conducted on pigs (88) showed the feasibility of intersegmental plane identification under near infrared (NIR) imaging and indocyanine green (ICG) administration. ICG is a NIR fluorescent dye. The technique is based on the evaluation of blood supply to the lung by using the arterial segmentation instead of the traditional bronchial segmentation. ICG is administered intravenously through a peripheral vein after segmental artery ligation and segmental boundaries are evaluated under NIR thoracoscopy. The lung appears on the monitor as divided into two areas, blue and white, according to the blood flow (blue is the vascularized lung, white is the devascularized parenchima). On the wave of this preliminary experience, Misaki and colleagues (89) reported their experience on patients who underwent NIR thoracoscopy after intravenous ICG injection. This method, depending on blood flow and avoiding reinflation of the lung, resulted suitable not only for patients with normal parenchyma, but also and especially for those with emphysematous lungs. On the basis of the encouraging results published on the use of NIR/ICG in intersegmental plane identification MP-

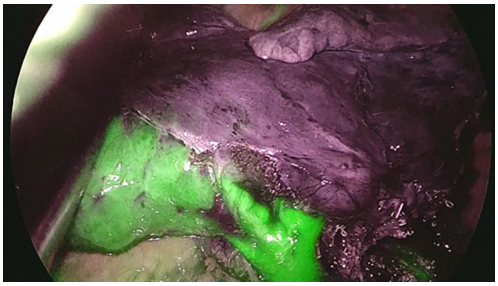

Figure 3 Intraoperative findings after ICG injection under NIR vision. ICG, indocyanine green; NIR, near infrared.

VATS (90) and robotic segmentectomy (86), we decided to apply this technique to U-VATS segmentectomy (91). After ligation and transection of segmental vessels and bronchus, the camera is switched from standard white light to NIR light mode via a footswitch. Five to 7-mL bolus of ICG (2.5 mg/10 mL) depending on the weight of the patient and lung parenchyma status is intravenously administered through a peripheral vein. More ICG is needed in patients affected by emphysema to clearly visualize the intersegmental plain. NIR imaging starts immediately before the application of the contrast agent to gain a perfect dynamic and well-contrasted view of the boundaries between vascularized and non-vascularized lung segments. Immediately after ICG injection, we administer a 10-mL bolus of saline solution. In about 30–40 seconds after injection and during NIR visualization, the segment that needs to be resected appears "light grey" while the rest of the lung "switches on" in blue/green (*Figure 3*). Maximum green intensity is gained in about 1 min. The limits of the segment to be resected are marked by electrocautery during NIR visualization.

Case series and personal experience

Data from principal studies on U-VATS segmentectomies are summarized in *Table 1*.

In 2013, Gonzalez-Rivas (96) reported his pionieristic experience on 17 U-VATS anatomic segmentectomies. Lingulectomy represented the most frequent segmentectomy. The mean surgical time was 94.5±35 minutes (40–150 minutes). The mean number of nodal stations explored was 4.1±1 (range, 0–5) with a mean of 9.6±1.8 (range, 7–12) lymph node resections. The median tumor size was 2.3±1 cm (range, 1–4 cm). The median chest tube duration was 1.5 days (range, 1–4 days) and the median length of hospital stay was 2 days (range, 1–6 days). He reported no conversion to MP-VATS or open surgery. Compared to thoracotomic segmentectomies, uniportal thoracoscopic segmentectomies were associated with a shorter length of hospital stay and with equivalent morbidity and mortality (97).

In 2016, Han (38) reported his experience on 30 U-VATS segmentectomies. A 3- to 4-cm intercostal surgical incision was performed in 16 patients, and a 2-cm intercostal incision in 14 patients. The most frequently removed segment was the upper left division (9 patients, 30%). The U-VATS segmentectomy was completed in all patients except for one (96.7%), who underwent lobectomy after the lesion was not found in the initially removed segment. The mean surgical time was 159±56 min, and it wasn't influenced by the size of the surgical incision. The right middle and superior segments tended to require shorter operation times (97.1±44.9 min) than the other segments (P<0.001). The chest tube drainage was removed 4.6±1.6 days after the operation. One patient died (3.3%) during the post-surgical hospital stay because of septic shock.

Duan *et al.* (59) described their experience on 156 cases of U-VATS anatomical pulmonary segmentectomies performed between 2015 and 2016. They completed U-VATS pulmonary segmentectomies in 151 (96.8%) patients. Most cases involved the R1–2 and the left trisegment. Lung cancer was found in 130 cases and benign lesions in 26 cases. The comparison between operations performed in 2015 and 2016 showed that surgical time and blood loss were significantly lower during the second year (146±56 *vs.* 113±32 min and 63±17 *vs.* 54±13 mL respectively), so as complication rates (13.5% *vs.* 5.8%).

The role of U-VATS segmentectomy in elderly *vs.* non-elderly patients was addressed by Huang (95), who examined 139 elderly (124 lobectomies, 15 segmentecomies) and 278 non-elderly cases (248 lobectomies, 30 segmentectomies). Non statistical differences were found in between the two groups in segmentectomy population in terms of operative time, intraoperative blood loss, number of nodal stations explored and harvested lymph nodes. Elderly patients showed higher risk of postoperative complications, although without statistical significance (P=0.35).

Lin *et al.* (94) EP conducted a retrospective observational study comparing Uniportal VATS segmentectomies and lobectomies. They analysed 79 patients (32 segmentectomies, 47 lobectomies) affected by early stage NSCLC (T1a for segmentectomies, 7.3±2.4 mm; T1b/T1c for lobectomies 16.2±9.0 mm). In this study, no statistically significant differences between U-VATS

Table 1 Summary of literature published up to date on uniportal VATS segmentectomies

Author	Year	#	Operative time (min)	Blood loss (mL)	Nodal stations	Nodes	Chest tube duration	P.O. complications	P.O. stay	30-day mortality	Histology	Diameter	Conversion
Gonzalez-Rivas (34)	2012	1	150	–	–	–	–	–	2	–	Hamartoma	1	0
Nachira (92)	2013	17	94.5±35 [40–150]	–	4.1±1 [0–5]	9.6±1.8 [7–12]	1.5 [1–4]		2 [1–6]	–		2.3±1 [1–4]	0
Wang (93)	2013	$5^{\$}$, $14^{\&}$	156±46	38.4±25.9	–	22.9±9.8	–	2	4±1.4 [3–8]	0	15 malignant, 4 benign	–	0
Han (38)	2016	30	159±56 [30–236]	–	–	7.7±5.7	4.6±1.6	4 (13.3%)	–	1 (3.3%)	21 malignant, 9 benign	1.6±0.5 [0.9–2.7]	0
Lin (94)	2016	32	186.5±57.0	77.3±50.9	3.4±0.9	13.6±5.8	4.7±1.6	2	6.0±2.6**	–	–	0.7±0.2 [0.4–1]	0
Cheng (57)	2016	40	174.2±51.5	81.9±57.4	5.5±1.6	13.1±7.0	5.9±2.5	3	4.6±1.5**	0	MIA	0.3±1.3	–
Shih (39)	2016	52	3.31±0.97	63.27±78.38	–	19.20±10.73	–	–	5.7±1.9**	–	–	–	0
Surendrakumar (44)	2017	31	–	–	4 [1–7]	–	2 [1–24]	4 (13%)	4 [1–15]**	0	24 NSCLC	18 [3–43]	5
Duan (59)	2018	151	123±45 [40–240]	60±14	–	–	–	13 (8.3%)	4.2±1.6 [2–14]	0	130 NSCLC, 26 benign	1.1±0.7, 1.2±0.5 [0.7–2.5]	3 (1.9%)
Huang (95)	2018	15^{E}	$211.9±17.4^{E}$	$94.67±18.6^{E}$	$5.60±0.35^{E}$	$15.40±2.64^{E}$	$5.00±0.74^{E}$	3^{E} (20%)	$5.04±1.30^{E}$	–	45 NSCLC	$0.82±0.0^{E}$	0
		30^{NE}	$202.7±8.5^{NE}$	$66.83±8.59^{NE}$	$2.37±0.33^{NE}$	$11.57±1.59^{NE}$	$4.17±0.47^{NE}$	3^{NE} (10%)	$4.70±0.48^{NE}$			$0.80±0.06^{NE}$	
Lee (47)	2019	33	180 [115–360]	50 [20–500]	–	5 [0–25]	2 [1–11]	7 (21.2%)	4 [1–14]	–	32 NSCLC	1.9±2.2	1
Courrent series	2019	66	176.67±53.17	–	–	13.4±9.96	3.70±0.99	7	4.10±1.86	0	64 malignant, 2 benign	1.73±0.94	–

**HS, hospital stay; $^{\$}$, segmentectomy; $^{\&}$, lobectomy; ^{E}, elderly; ^{NE}, non elderly. MIA, microinvasive adenocarcinoma; VATS, video-assisted thoracoscopic surgery; NSCLC, non-small cell lung cancer.

Table 2 Clinicopathological characteristics of patients undergone uniportal VATS segmentectomy

Variables	Total (n=66)
Preoperative characteristics	
Age (years)	65.70±12.52
Gender (M)	29 (43.9%)
Smoking	23 (34.8%)
COPD	27 (40.9%)
Hypertension	38 (57.6%)
Cardiovascular diseases	25 (37.9%)
ASA score	2.32±0.47
Pre-op FEV1%	95.00±15.90
Pre-op FVC%	112.00±18.97
Neoadjuvant therapy	0 (0%)
Intraoperative results	
Primary lung cancer	45 (68.2%)
Lesion dimension (cm)	1.73±0.94
Lymph nodes removed	13.40±9.96
Operative time (min)	176.67±53.17
Right side lobectomy	31 (46.9%)
Conversion	0 (0%)
Postoperative outcomes	
Reoperation for bleeding	0 (0%)
Chest tube duration (days)	3.70±0.99
Hospital stay (days)	4.10±1.86
Minor complications	11 (16.67%)
Thirty-day mortality	0 (0%)

VATS, video-assisted thoracoscopic surgery; COPD, chronic obstructive pulmonary disease.

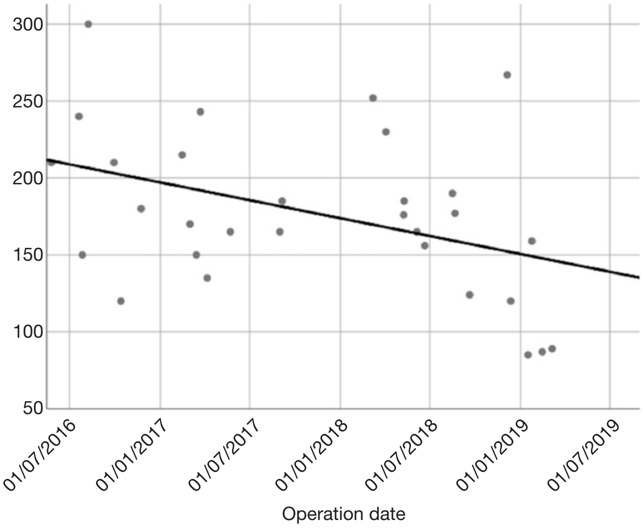

Figure 4 Pearson's correlation for operative time. Y= −kX + p (k=−0.405, P=0.027).

anatomical segmentectomies and U-VATS lobectomies were found in terms of surgical time, intraoperative blood loss and number of staplers used. On the contrary, there was a statistically significant difference between the number of lymph nodes removed (13.6±5.8 for segmentectomies *vs.* 16.7±6.2 for lobectomies) and the duration of drainage stay (4.7±1.6 for segmentectomies *vs.* 5.9±3.2 for lobectomies). In this experience, segmentectomies seemed to allow a more rapid post-operative recovery. However, in the conclusions it became clear that they represent a technically more difficult procedure than lobectomies and therefore must be performed only by surgeons who are highly specialized in anatomic pulmonary resections with minimally invasive techniques.

Our experience

In our Department of General Thoracic Surgery at Policlinico Universitario "A.Gemelli" IRCCS in Rome, Italy, 66 Uniportal VATS segmentectomies were performed between May 2016 and August 2019. Our surgical technique is widely described elsewere (92). The mean age of patients was 65.70±12.52 years, 43.9% (29) of the patients were male and 34.8% (23 patients) were active smokers. The principal clinicopathological characteristics of the patients are reported in *Table 2*. The main indication to an anatomical segmentectomy was a primary lung cancer or a pulmonary metastasis. The mean diameter of the lesions was 1.73±0.94 cm at pathological examination with a mean of 13.40±9.96 lymph-nodes sampled (*Table 2*). In 45 (68.2%) patients the diagnosis was a primary lung cancer, in 19 (28.8%) a pulmonary metastasis and in 2 cases (3.0%) a benign lesion with [18F]-fluorodeoxyglucose (FDG) up-take at the preoperative positron emission tomography/computed tomography (PET/CT). The mean operative time was 176.67±53.17 minutes and it followed a trend of reduction during our experience, well represented by the inverse linear function: y= −kx + q (Pearson's correlation Coefficient k=−0.405, P=0.027), *Figure 4*. There was no conversion to

Table 3 Oncological outcomes

Variables	Total (n=66)
R+ resections	0 (0%)
Adjuvant therapy	3 (4.54%)
Alive with disease	2 (3.03%)
Dead of disease	1 (1.52%)
Dead of other causes	1 (1.52%)
Overall survival (months)	18.36±10.55
Disease free-survival (months)	17.42±10.54

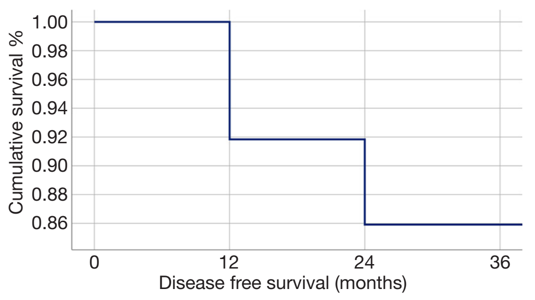

Figure 5 Disease free survival (DFS): 1-y: 92%, 2-y: 86%, 3-y: 86%.

other surgical approaches and intraoperative mortality was null. The incidence of post-operative complications was 10.66% (7 cases). All complications were minor, like air-leakage (4 cases), pneumonia (2 cases) and atrial fibrillation (1 case). The mean chest-tube duration was 3.70±0.99 days, with a post-operative hospital stay of 4.10±1.86 days. Thirty-days mortality was null. All resections were radical. Only 3 (4.54%) patients underwent adjuvant therapy. At a mean follow-up of 18.36±10.55 months, 2 (3.03%) patients were alive with metastatic disease and 1 (1.52%) dead because of progression of the disease (*Table 3*). The mean disease-free survival was 17.42±10.54 months (92% at 1 year, 86% at 2 years) (*Figure 5*).

Conclusions

U-VATS segmentectomy is a technically feasible and safe procedure, with a reasonable learning curve and low percentage of conversion in multiportal or open procedures. Perioperative results show benefits in terms of width of the surgical wound, postoperative pain and faster recovery after U-VATS segmentectomy when compared with multiportal or open approaches. To the best of our knowledge, no other studies report long term results. More data are needed to definitively establish the role of segmentectomy and in particular U-VATS segmentectomy in the treatment of early NSCLC.

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Footnote

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