

NON-INTUBATED VIDEO-ASSISTED THORACIC SURGERY FROM MULTI TO UNIPOINT APPROACHES: SINGLE-CENTRE EXPERIENCE

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ABSTRACT

The success and evolution of video-assisted thoracic surgery (VATS) renewed the interest for thoracoscopic operations in awake patients. Non-intubated, or tubeless, procedures found progressive credit and uptake. In particular, non-intubated uniportal VATS represents the latest stage in its evolution. An increasing number of more complicated procedures have been successfully carried out with this combined modality.

In the early 2000s, the Awake Thoracic Surgery Research Group at the University of Rome Tor Vergata started an investigational programme of thoracic operations performed without general anaesthesia and one-lung ventilation. Since that date >1,000 operations have been successfully carried out. Initially, non-intubated anaesthesia was successfully employed in non-oncologic conditions such as pneumothorax, emphysema, pleural infection, and interstitial lung disease. Oncologic conditions such as malignant pleural effusion, peripheral lung nodules, and mediastinal tumours were successively approached. Major operations are now being performed in this way. Uniportal access was progressively adopted with significant positive outcomes in postoperative recovery, patient acceptance, and economical costs. Operations of this kind overcome many anatomical and technical challenges satisfying the patient, surgeon, physician, nurse, and economical administrator. The hindrance caused by operating with a breathing lung is that it requires a particular set of skills but experience demonstrates that the learning curve is no longer than that required for any other new endoscopic procedure.

Other investigations have involved the biological impact of the procedure, demonstrating lower concentrations of inflammatory and stress mediators with a lower degree of immune-depression. Psychological preselection of the most suitable patients for non-intubated surgery is one of our fields of investigation. Non-intubated thoracic surgery is projected towards the future and still represents a nearly unexplored and potentially fruitful field.

Keywords: Thoracic surgery, video-assisted thoracic surgery (VATS), thoracic epidural anaesthesia (TEA), intercostal block.

INTRODUCTION

The entry of video-assisted thoracic surgery (VATS) in the field of thoracic surgery represented the watershed between the classic open surgery and new methods. The initial three-port technique rapidly evolved into uniportal access.¹ A small single-port incision was used to perform VATS

operations, assuring adequate mobility of the instruments and the valid surgical access.²⁻⁵ In 2000 Migliore et al.^{6,7} applied this approach in 58 patients, safely performing a variety of minor procedures. In 2004 Rocco et al.⁸ published an article about the use of the uniportal VATS to perform wedge pulmonary resection and subsequently a multiplicity of other operations.^{4,9} Minor and major

procedures such as carinal resection, bronchial sleeve, and vascular reconstruction^{10,11} have more recently been successfully carried out both for diagnostic and curative intent.

At the same time, VATS resuscitated interest in thoracic operations in awake patients. Indeed, non-intubated thoracic surgery is not a new strategy; it was developed early in the 20th century and was employed for a long time with variable results until the advent of general anaesthesia (GA) with one-lung ventilation. However, this anaesthetic modality produced several important adverse effects. Indeed, mechanical ventilation-related lung injuries occur in 4% of major lung resections carrying a mortality rate as high as 25%.¹² Sugawara et al.¹³ found that single-lung ventilation could induce inflammatory responses during lung resections, which may be associated with postoperative complications.

Thus, non-intubated VATS techniques were progressively proposed and investigated.¹⁴⁻²¹ The term 'awake' was used as many patients remained fully alert during the procedure.¹⁵⁻¹⁸ Subsequently more technically demanding operations were faced in more sedated patients while conserving spontaneous ventilation, thus the definition of non-intubated or tubeless surgery.²² Thoracic epidural anaesthesia (TEA), intercostal nerve block, and paravertebral block are the most commonly employed techniques for non-intubated anaesthesia.²³⁻²⁹ Nowadays, a non-intubated technique has been shown to be a feasible approach for a number of procedures, even under uniportal access.²² It is particularly suitable for patients excluded from conventional surgery by elderly age, comorbidity, and respiratory disease.^{30,31}

In 2014 Rivas et al.²² published the first non-intubated single-port VATS lobectomy in a patient with middle lobe cancer. The patient was discharged 36 hours after with excellent postoperative outcome. To date, many groups have reported good results of major pulmonary resections.^{17,19,32}

EXPERIENCE OF RESEARCH GROUP AT TOR VERGATA UNIVERSITY

In the early 2000s, after a consolidate experience in multiport VATS with intubated GA, we started an investigational programme of thoracic operations performed without GA and one-lung ventilation. This programme was approved by our Institutional Review Board and encompassed the whole

body of thoracic pathologies treated by surgery. Within this project, a multidisciplinary group named the Awake Thoracic Surgery Research Group was founded by one of our members, Dr Tommaso Claudio Mineo, who remains co-ordinator of the group. This group included thoracic surgeons, anaesthesiologists, pneumologists, cardiologists, physiotherapists, infectologists, psychologists, and administrators.

Initially, non-intubated anaesthesia was successfully employed in non-oncologic conditions such as pneumothorax, emphysema, pleural infection, and interstitial lung disease. Oncologic conditions such as malignant pleural effusion, peripheral lung nodules, and mediastinal tumours were approached with TEA. As the familiarity with this surgical practice has increased, we progressively shifted from a multiportal to a uniportal approach and now the majority of operations are being performed in this way (Table 1).

THE EVOLUTION OF THE ANAESTHESIOLOGICAL SUPPORT

Initially, our standard anaesthetic protocol was based on TEA.²⁴ Nevertheless, in some operations the use of this form of regional anaesthesia looked exaggerated compared with the potential risks, which included severe hypotension, respiratory depression, bleeding, epidural haematoma, and intracranial hypertension. With this purpose, the paravertebral and the intercostal blocks were introduced for shorter and less elaborate operations.

However in some circumstances TEA appeared to be inadequate. This was the case for operations requiring a considerable amount of time and conducted in proximity of hilar structures, thus triggering the cough reflex. The most remarkable improvements in this field were the introduction of vagal blockade, the development of new opioids (sufentanil and remifentanil), and the employment of bispectral index monitoring for the regulation of sedation level during the operation. These techniques have consistently facilitated non-intubated major lung resections.²⁶⁻²⁸

THE EVOLUTION OF THE SURGICAL TECHNIQUE

When we began 15 years ago, the approach was typically through three ports placed according to the 'baseball diamond', with the camera port at the 'home base' pointing to the lesion sited at 'second

base'. The other two ports were placed at the 'first base' and 'third base' positions to allow the right and left-hand instruments to be placed and triangulated forwards towards the target. The use of these two ports was very useful at the beginning because they allowed for the introduction of gauze pad sticks to enable some control over the inevitable movements of a breathing lung.

Following the natural evolution of the VATS technique under GA, we progressively tried to omit the posterior port also in awake patients. In fact, it was possible to achieve adequate surgical retraction and manipulation using a wider utility port. The restriction of the number of access points proved effective in decreasing both intraoperative discomfort and postoperative pain.

The natural passage was the insertion of the camera port through the unique anterior port, thus carrying out the whole procedure through a single-port access protected by a plastic sleeve-shaped retractor to avoid instrument impingement. This further step of progress was possible with the development of the new anaesthesiological technique that allowed operations in nearly 'numb' patients with minimal respiratory movements. The initial difficulties in reaching the operatory field with the correct angle following a unique direction and the crowding problem created by a single port were resolved by the development of dedicated instruments.

Current efforts are aimed at the development of non-intubated surgery through a subxiphoid approach^{33,34} that we pioneered for a long time under GA.³⁵⁻³⁸ This route proved safe and tolerable for the awake patient, reasonably pain free in the postoperative period, and easy for the surgeon as it allows the introduction of one entire hand in the chest cavity. Its location allows a superb exposure of the lower lobes and a more perpendicular direction of the stapling devices towards the structures of the hilum. Nowadays our group has employed this approach in non-intubated modality for lung metastasectomy, undetermined lung nodules, and pulmonary and mediastinal biopsies.³⁹ The development of new dedicated instruments and the increment of surgical skill in uniportal VATS may open new intriguing perspectives.

PRIMARY AND SECONDARY SPONTANEOUS PNEUMOTHORAX

Our attention was primarily directed to the treatment of primary and secondary pneumothorax

in awake VATS under sole TEA (Table 1). We assessed in a randomised study the technical feasibility, efficacy, and acceptance of the procedure.⁴⁰ Awake two or three-port VATS bullectomy and pleurodesis proved to be technically feasible. In this experience only one patient had recurrence within 12 months. Reduction of procedure-related costs are impressive.

Currently we prefer non-intubated single-port access that proved both safe and more acceptable. With this access we have not yet experienced surgical conversion or need of orotracheal intubation. The same technique was used for the treatment of secondary spontaneous pneumothorax which is often a challenging condition because of the underlying disease and deteriorated general status of the patients.⁴¹ Awake procedures were initially performed through a classic three-port and now through a uniport approach with better results in terms of postoperative pain and hospital stay. We did not find any difference in conversion rate between the two approaches.

EMPHYSEMATOUS BULLAE

We treated emphysematous bullae by awake multiportal (n=48) and uniportal (n=27) introflexive non-resection bulloplasty (Table 1), of which 27 were giant. According to our previous classification, we removed 44 Grade I, 28 Grade II, and 3 Grade III bullae.⁴² There was no mortality. A mini anterior thoracotomy was necessary in four patients without tracheal intubation. Severe and diffuse adhesions required GA in another four patients. In the uniport approach, conversion to GA was required in one patient only. No patient needed GA because of excessive hypercapnia or panic attack. This technique allowed a shorter air leakage period, and in all instances satisfaction of patients was excellent, especially in those with comorbidities.⁴³

EMPHYEMA THORACIS

Awake VATS procedures under TEA or paravertebral block were used for localised empyema, achieving an almost complete lung re-expansion in nearly all patients (Table 1).⁴⁴ We have now accomplished the procedure through a single port along the maximum diameter of the fluid collection. We experienced a shorter hospital stay compared with patients undergoing classic operation. Conversion was only due to surgical reasons, and no difference was found between multi and uniport groups.

Table 1: Awake Thoracic Surgery Research Group at Tor Vergata University of Rome. Cumulative experience with non-intubated video-assisted thoracic surgery from 2000–2016.

Non-intubated procedure	Multiport		Uniport	
	Number	Failures	Number	Failures
Primary pneumothorax	69	2	44	-
Secondary pneumothorax	31	7	20	3
Emphysematous bullae	48	4	27	1
Empyema thoracis	26	7	18	2
Interstitial lung disease	20	6	30	2*
LVRS	77	13	31	4
Redo LVRS	13	6	11	-
Malignant pleural effusion	16	-	451	-
Benign nodules	48	2	32	-
Malignant nodules	23	2	22	4
Lung metastases	14	4	55 (7 subxiphoid)	5*
Anterior mediastinal biopsies	68	-	126	-
Lung cancer anatomical resections	32	17	11 (4 subxiphoid)	5

*p<0.05 for failures multi versus uniport.

LVRS: Lung volume reduction surgery.

INTERSTITIAL LUNG DISEASE BIOPSY

The correct diagnosis of interstitial lung disease is considered the mainstay of the therapeutic approach. The non-intubated modality has become fundamental in all these forms since one-lung ventilation carries a mortality rate.⁴⁵ Initially, we operated under TEA. Ultimately the procedures are carried out under intercostal block through a unique access (Table 1).⁴⁶ Conversion rate was lower in this subset of patients (Table 1). These patients presented a lesser reduction of intraoperative oxygenation and postoperative respiratory function. We observed a shorter hospital stay and a reduction in costs without affecting diagnostic yield and pneumonologists' satisfaction.

LUNG VOLUME REDUCTION SURGERY

Lung volume reduction surgery (LVRS) implies anatomical resection of the most severely emphysematous target area. We originally performed the procedure under multiportal VATS with intubation GA. In properly selected patients, this technique allowed improvements in exercise capacity, respiratory function, survival, and quality of life.^{47,48}

In 2001, one of our members, Dr Mineo, introduced a novel personal technique of LVRS, entailing the plication of the most emphysematous lung regions (Figure 1). This technique was used under conventional awake TEA multiport VATS in a pilot study with faster recovery, minimal acute postoperative pain, and satisfactory 6-month functional outcomes (Table 1).⁴⁹⁻⁵¹

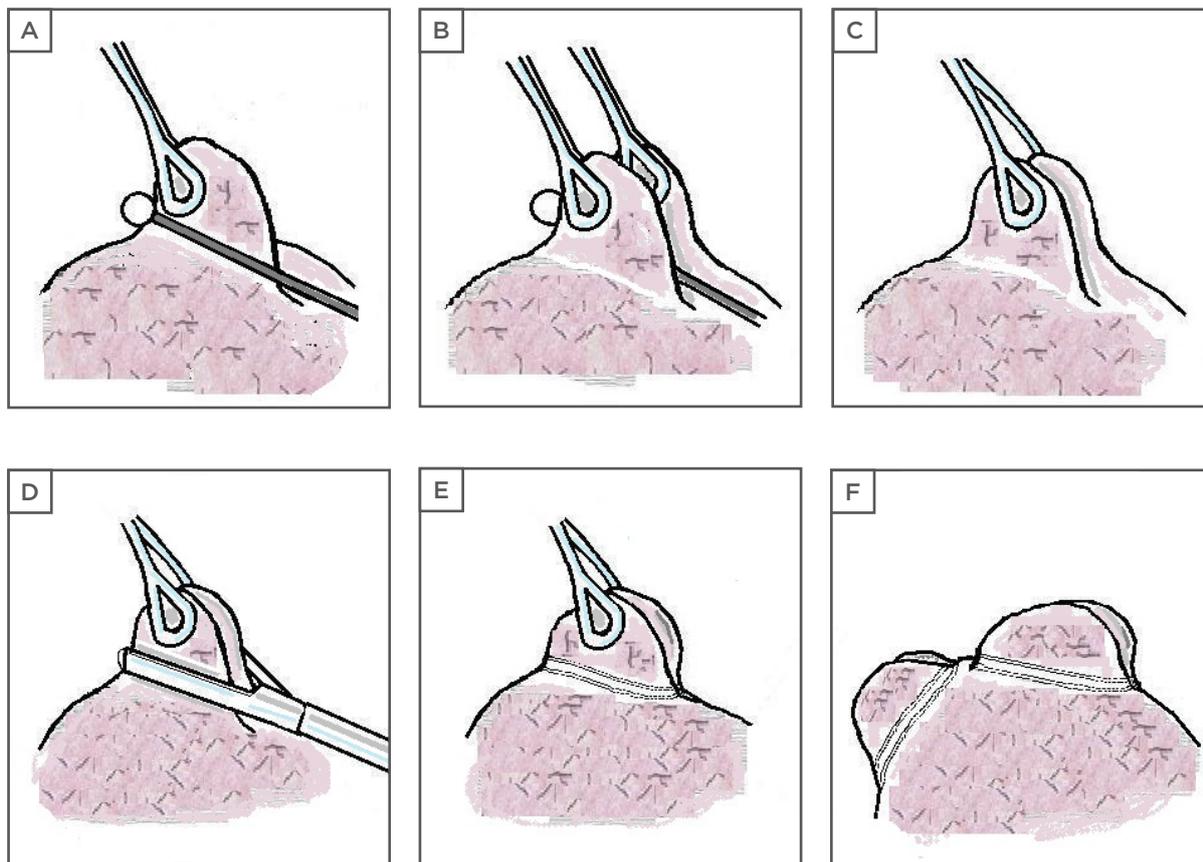


Figure 1: Surgical steps in non-resectional lung volume reduction.

A) A wide plication is created in the most emphysematous area of the upper lobe with the help of a sponge stick and ring forceps; B) a second plication is created adjacent to the previous one; C) the two plications are included in the same bite with unique ring forceps; D) a no-knife 45 mm stapler is positioned at the bases of the plicated areas; E and F) the stapler fires a unique triple-staple suture line, creating the lung volume reduction. This method respects the basic concept of resectional lung volume reduction surgery, including a reduction of 30% of the lung volume, thus favouring the immediate postoperative re-expansion and reducing the risk of prolonged air leaks.

More recently, the same change to process was accomplished by uniport technique with satisfactory early clinical results, costs, and nursing patient care. Four patients required intubation for adhesions (n=2) and panic (n=2). Open surgery was necessary in two patients due to firm adhesions. We also use uniportal non-intubated VATS in redo LVRS. In some cases, a second port is utilised when tenacious adhesions are present. Early results were impressive especially regarding the postoperative recovery and functional improvement (unpublished data). No patient required intubation due to panic attack.

MALIGNANT PLEURAL EFFUSION

Patients with recurrent malignant pleural effusion and scheduled for VATS represent an optimal group for non-intubated anaesthesia (Table 1). From the

beginning we perform a single-port access under intercostal block and sedation during incidental pleural biopsy and talc pleurodesis. To evaluate the efficacy of the non-intubated procedure we recently presented a case-matched study (intercostal versus GA) in which patients were paired by computer according to their clinical features.⁵² In this series, the procedure was safe and effective in relieving dyspnoea. The success rate for non-intubated VATS talc pleurodesis was 85.7%, which is similar to the rates observed in operations performed under GA. No intubation was necessary, and shorter operative theatre and hospital stay were consistently observed. In selected patients we accomplish this procedure in a one-stop day ambulatory setting. With the exception of explicit request from the patient, we now treat pleural effusion with a non-intubated approach on a routine basis.

RESECTION OF NODULES

In 2004 Dr Mineo began a randomised study concerning the feasibility of awake VATS resection of solitary pulmonary nodules. Awake TEA multiport VATS resection proved safe and feasible.⁵³⁻⁵⁶ Single-port access has now been employed (Table 1). We detected 58 early-stage unexpected lung cancers because of their shape and low uptake at positron emission tomography. Better patient satisfaction was associated with faster recovery and less nursing care.^{57,58} No surgical conversion was observed and intubation was required in two patients with benign tumour for cardiac impairment, and in six patients with malignant tumour for surgical reasons.

LUNG METASTASES

We dedicated specific attention to the awake resection of lung metastases. Awake multiport thoroscopic resection under sole TEA proved feasible and safe with a significant reduction of global operating theatre time and hospital stay.⁵⁹ We treated 45 patients using the uniportal local anaesthesia approach. These patients had comparable long-term survival to those performed under GA but with lower postoperative morbidity and reduced cost. A significant lower failure rate was found in the uniportal subset (Table 1). We have begun a programme of non-intubated lung metastasectomy through a subxiphoid approach, which was our preferred route for many years.^{35-38,60} We accrued a total of seven patients, who manifested significantly lesser postoperative pain and greater satisfaction compared with any transthoracic approach (Table 1). We identified some limitations, such as difficulties in performing a complete lymphnode dissection and controlling major bleeding. However, this approach provides significant advantages such as minimal pain and good cosmesis.

ANTERIOR MEDIASTINAL MASSES BIOPSY

Our group boasts a long experience with the acute diagnosis of bulky mediastinal masses provoking a superior vena cava syndrome.⁶¹ VATS or mediastinotomy under non-intubated anaesthesia were performed and achieved a diagnostic accuracy of 96%.⁶² The majority of these procedures were performed in supine patients with single-port anterior access under intercostal block (Table 1). No failure was experienced.

LUNG CANCER

We were able to carry out an increasing number of major thoracic operations under non-intubated modality for lung cancer. Inclusion criteria for patient selection are technical feasibility, staging, age, and comorbidity.^{30,31,63} These operations started in 2002 with anatomical segmentectomy using multiport access. At present we accrued a total of 36 segmentectomies, six of which were recently carried out using a uniportal approach (Table 1).⁶⁴ The ability acquired with VATS lobectomies under GA improved our confidence in performing these operations under non-intubated conditions. We accomplished non-intubated lobectomy in seven patients through three-port (n=2), uniport (n=3), and subxiphoid (n=2) approaches. In another two patients, conversion to an open approach was necessary for technical difficulties. The control of pain without opioids provides faster recovery with a prompt return to daily activity as well as lesser immuno-depression, with a potential impact on neoplastic recurrence.

THE BIOLOGICAL IMPLICATIONS

We focussed much attention on the numerous and intriguing biological implications of non-intubated VATS. Many of these positive effects originated from the avoidance of GA and above all from the rejection of one-lung ventilation.¹³ We have shown that the operation performed in spontaneously ventilating patients can result in a remarkable reduction of perioperative stress response, as suggested by a lesser increase in several biomarkers of surgical trauma including cortisol, interleukin-6, and C-reactive protein.⁶⁵ We also experienced a stability of perioperative lymphocytes pool, thus suggesting a potential role for regional anaesthesia protocol in preventing perioperative immuno-depression and limiting postoperative morbidity.⁶⁶

We are also investigating whether the employment of the non-intubated technique influences the biological behaviour of cancer cells. It is a common finding that surgical manipulation and GA favours the escape of tumour cells from their dormancy condition. This mechanism is generally explained as a kind of incompletely understood postoperative immuno-depression, affecting natural killers, T helper cells, and pro-inflammatory cytokines.³⁹ All these derangements are mainly due to response to surgical trauma, mechanical one-lung ventilation, and pharmacologic supports to sustain GA.

When compared with conventional surgery, both lymphocyte populations and cytokines were less altered and showed a faster recovery in the non-intubated VATS.⁶⁶ The impact on overall and disease-free survivals is expected but not yet proved in our series, most probably due to the limited sample size and the short time-span of follow-up.

RELEVANCE OF PSYCHOLOGICAL PROFILE

The clinical observation of patients undergoing non-intubated operations evidenced an emerging and underestimated problem: the different degree of patients' psychological tolerance to the procedure. Fully informed consent is one of the mainstays of ethical behaviour in modern surgery, but in the case of non-intubated modality it becomes essential for the positive outcome of the procedure itself. We expected that patients apparently more motivated to bear the non-intubated operation should be those who better tolerate it. However, we experienced that some of these patients did not tolerate the procedure very well. We have recently developed an investigational programme based on a series of self-administered psychological tests targeted to this purpose. Every patient scheduled for non-intubated surgery is now processed with newly developed questionnaires⁶⁷⁻⁷⁰ that require 30 minutes to complete. Intraoperative evaluation of the tolerance and state of consciousness was conducted using the Richmond Agitation-Sedation scale.⁷¹ Preliminary data from the study are now available and we found that a combination of Profile of Mood States and Mini Mental State Examination questionnaires provided a better prediction of the non-intubated procedure tolerance. No panic has been found in patients with low combined scores in these two questionnaires.

COMMENT

In 1987, Dr Rush and Dr Mountain described the first thoracoscopic procedures under regional anaesthesia,⁷² and in 1997 Nezu et al.⁷³ presented the first lung resection in local anaesthesia; nobody could have foreseen what progress these new

techniques would make. At present non-intubated uniportal lung resections represent the most advanced frontier in the evolution of conventional VATS. This technique meets all the requirements desired by the surgeons, asked by the patients, expected by the physicians, and wanted by the administrators.¹⁰ Theoretically, indications for preferring a uniportal approach instead of a multiportal one do not exist. With adequate anaesthesiological knowledge and surgical practice, nearly all VATS operations can be accomplished under non-intubated modality through unique access. We only find useful the execution of a second access in the case of firm and dense adhesions. There is no doubt that our series show an unquestionable preponderance of minor operations. However, from these procedures we gained a remarkable amount of data that allowed us to approach the more major operations in a safer manner.

We are perfectly aware that operating with a breathing lung is a conceptual obstacle for many thoracic surgeons. To avoid serious complications and conversion, it is vital that these procedures are performed by experienced individuals. The Rivas group reduced conversion index from 6% to 3%.¹⁸ However, we have found that the learning curve for surgeons well trained in non-intubated VATS is no longer than that required for any other new endoscopic procedure, and we perceived that young surgeons were increasingly attracted by this approach. Accordingly, it is not unreasonable to hypothesise that in high volume VATS centres, a new highly-specialised generation of thoracic surgeons as well as anaesthesiologists can be moulded.

In conclusion, uniportal non-intubated VATS is an effective technique that can be safely carried out in a variety of thoracic pathologies. This kind of thoracic surgery is projected towards the future and still represents an unexplored and potentially fruitful field. Can we consider non-intubated uniportal VATS the final stage in the evolution of minimally invasive surgery? If we answer yes, we would create an inappropriate hindrance to its technological development as surgery is a constantly evolving speciality.

Footnotes

More recently, data from the Official Awake Thoracic Surgery Research Group, Policlinico Tor Vergata have been manipulated and published by an unexisting group of awake thoracic surgery of University of Rome Tor Vergata that has neither beds nor operative sessions in theatre. We thank all colleagues that co-operate for the development of the group, and those who share with us their patients.

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