

Uniportal video-assisted thoracic surgery treatment of intra-operative complications

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Background: The uniportal video-assisted thoracic surgery (U-VATS) approach is rapidly gaining attention. Still there is lack of gross engagement to this technique, even within the VATS surgeons. We believe that the uniportal approach needs the same attention as any newly introduced skill; it would be a great mistake to be considered as a simple variation of the standardised multi-portal VATS.

Methods: We have evaluated personal and institutional experience, supported by international bibliography. Factors that could influence complications have been searched. Factors have been split to operator-related and patient-related.

Results: We have identified a series of preventable complications. The operator-related ones, need addressing prior to engagement to surgery. A well-structured team led by the surgeon functions in benefit of the patient. A wise and skilled surgeon in synergy with the surgical team can be prepared to resolve the most common presented challenges.

Conclusions: Our collected experience may be a guide to facilitate the U-VATS journey.

Keywords: Uniportal video-assisted thoracic surgery (U-VATS); lung surgery; complications; treatment

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Introduction

The first principle in addressing intra-operative complications, in surgery and particularly in uniportal video assisted thoracic surgery, is prevention.

Hence, prevention is supported by understanding the anatomic challenges of the individual case, study pre-operative images, discuss each patient in a multi-disciplinary team meeting, select appropriately and plan carefully each case which merits a uniportal approach.

Nevertheless, complications are still part of the operation; the surgeon should be prepared to identify them early and treat them adequately.

The authors aim to analyse the following factors as shown in *Table 1*, to help the reader to avoid and treat intraoperative complications.

Operator related factors influencing complications

Minimally invasive and uniportal approach skills

Every surgeon needs to recognise own limitations, more than strengths. A skillful traditional 3–4 port VATS surgeon is not necessarily equally capable in uniportal approach.

Education in uniportal VATS surgery should encompass:

- (I) A team learning approach including Anaesthetist, assistants and scrub nurses;
- (II) Attendance at an accredited uniportal video-assisted thoracic surgery (U-VATS) Institution with good experience followed by;
- (III) Production of standard Operating Procedures and Protocols at Home Institution;
- (IV) Provision of appropriate equipment and;
- (V) Proctorship to safeguard a comfortable learning

Table 1 Operator and patient related complications of U-VATS

Operator related
Inadequate minimally invasive surgical skills
Inappropriate, established, step wise technique
Tissue handling
Poor team communication at Operating Room leading to airway, vascular, nerve or hollow organ injuries
Patient related
Anatomic variations
Oncological reasons (unsuspected disease progression)
Patient characteristics

curve (1).

U-VATS technique

Access through a single incision renders the technique unique in multitasking. Most surgeons are able to handle more than one instrument on a single hand.

- (I) It is not uncommon that U-VATS requires the surgeon to address 3–4 instruments simultaneously (2).
- (II) Frequently the 0 or 30-degree camera (in U-VATS lobectomy, segmentectomy and pneumonectomy) is on the “roof” of the incision.
- (III) A suture around the camera, in a loop fashion, anchored at the posterior aspect of the skin incision maintains a stable position of the camera and helps the assistant.
- (IV) It should be noted that often it is difficult to assist a lengthy U-VATS major lung resection, as the position of the camera requires hyperextension of the assistant’s shoulder and forearm holding the camera in an anti-gravitational direction.

Tissue manipulation

Contrary to the multi-port VATS operations, U-VATS does not allow multiple angulations of the different endoscopic instruments. All instruments are pointing towards the anatomical structures from a similar direction in a way that often vessels or airways might not be presented at a favourable, familiar angle to the instruments.

- (I) On these occasions the operator needs to present the anatomical structure to the instrument, by retracting and manipulating lung tissue.
- (II) Reckless and excessive manipulation of the lung,

does lead to microtrauma of the parenchyma. Apart from the risk of an annoying postoperative air leak (3), more importantly the injury of the lung tissue can affect the lymphatic and venous drainage; acute lung injury or adult respiratory distress syndrome have been reported (4);

- (III) Injury to the distal bronchioles is contributing to postoperative atelectasis.
- (IV) Dedicated U-VATS instruments (elongated with various angulations) have been developed particularly for the above-mentioned reasons. The elegance of gentle tissue manipulation cannot be emphasized enough to prevent complications.

Appropriate pre-operative planning of each case

- (I) Correct studying and interpretation of pre-operative imaging is mandatory.
- (II) A dedicated discussion with a thoracic radiologist is a routine practice in our institution.
- (III) A contrast CT scan remains the gold-standard imaging to identify the vessels and airways in need of attention, their relationship and any anatomical variations necessitating the presence of all appropriate equipment, skill mix and team preparation.
- (IV) An inviting operating field at U-VATS is of paramount importance and such can only be presented by an appropriate Thoracic Anaesthetist. His presence in U-VATS is not desirable but mandatory.

Management of intraoperative airway complications

Airway injuries at VATS are very unusual but once they occur the consequences can be disastrous and lead to unacceptable and high morbidity. Injuries range from simple perforations as a result of extensive manipulation, tissue or instrument failure at stapling line with stump leaks to stapling and transection of the wrong bronchus (*Figures 1,2*).

The authors have provided a comprehensive table to manage airway injuries (*Table 2*).

In the unfortunate event of transection of the wrong bronchus, early identification and re-establishment of the anatomy is of paramount importance.

In general:

- (I) Air leaks should be addressed to avoid prolonged hospital stay and risks of pleural infection with all



Figure 1 Obvious tear of membranous part of left main bronchus stump following stapling. Blue arrow shows position of tear. (I) Reason for tear, possibly old patient with calcification of bronchus and dehiscence. (II) Added 'hard' manipulation of bronchus while stapling; repair should be performed with buttressed interrupted sutures (monofilament) and stump reinforced with viable surrounding tissue; procedure should be finished with a flexible endoscopy before patient is transferred out of Operating Room.

catastrophic sequel for patients and Health Care Systems.

- (II) Tissue is always favourable in buttressing airway injuries rather than commercially available sealants and 'plugs'.
- (III) The authors would also encourage any surgeon in doubt, to convert to a multi portal VATS or open



Figure 2 Main bronchus stapling line leak and suturing (5). Available online: <http://www.asvide.com/article/view/24314>

thoracotomy in case of concern. What matters most is the successful outcome and not the obsession to complete with one port.

- (IV) There is enough evidence in the medical literature to suggest that a primary repair, with or without a flap reduces significantly the incidence of bronchopleural fistula and empyema, compared to a delayed repair, once an intrapleural infection has been established.

Management of intraoperative bleeding

This remains the main concern shared by all surgical fraternity.

Table 2 Differences of approach to main versus lobar/sublobar bronchial injury

Basic principles

Expose adequately injury or leak before applying any bronchial repair

In most instances, simple suture and tissue approximation is adequate

Mono filament sutures are preferable to facilitate knot sliding through a single port

Inform anaesthetist and confirm no endobronchial device or catheter is at proximity to the site of repair

Lobar or sublobar bronchus or stump leak or injury

Tissue cover is advised if: vascular supply is questionable and repair remains exposed following lung re expansion

Main bronchial stump leak or injury

Tissue cover is advised always

Right main bronchus stump; cover with Azygos, mediastinal pleura or pericardial fat

Left main bronchus stump: cover with mediastinal pleura, pericardium or pericardial fat

Attention

Do not leave Operating Room without a bronchoscopy in order to evaluate endobronchial integrity and correct repair

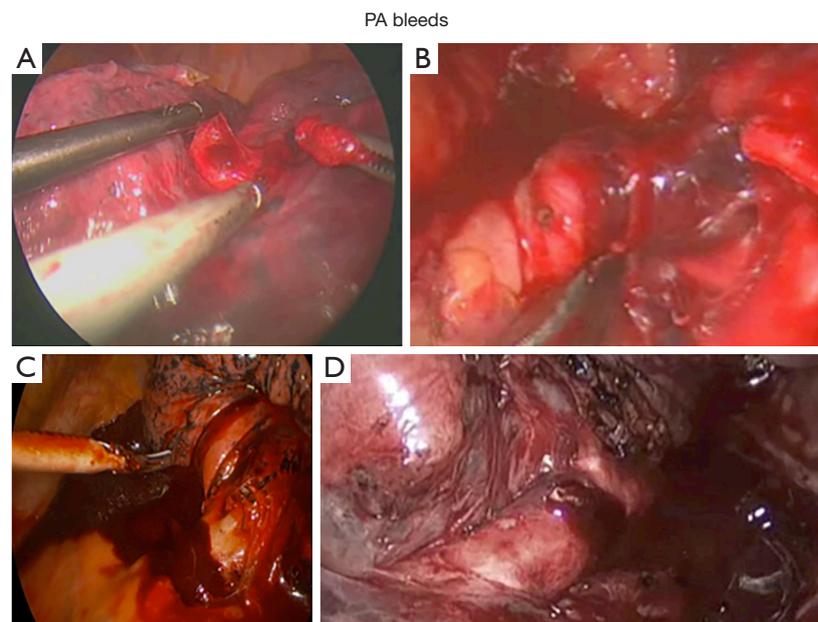


Figure 3 Intra-operative pictures of pulmonary artery injuries. (A) Small injury at left oblique fissure. This injury can be managed conservatively. If dissection of the pulmonary artery is required for a lung resection it should be performed after a good period of rest to allow coagulation at the point of injury. Do not attempt to repair and injury immediately after the injury. (B) Dissection and haematoma following manipulation of left main artery. Possible risks: (I) further proximal dissection; (II) rupture of artery with catastrophic bleed. In this situation attempt to repair or continue the resection depends on the experience of the surgeon. Proximal control is necessary. (C) Spontaneous rupture of truncus branch of pulmonary artery (PA) at dissection for left upper lobe lobectomy. The most important points for further action here are: (I) degree of prior dissection of surrounding tissues; (II) adequate length of main PA to clamp; (III) quality of tissue and surrounding parenchyma; (IV) PA pressures. In this situation conversion was necessary as injury took place early after initial dissection in a patient with high PA pressures. (D) Bleed for posterior PA branch of left upper lobe following stapling. Points to consider here: (I) is there enough remaining PA branch stump to work on? (II) what is the size of the defect? (III) what type of defect? i.e., leak through staplers, tear in wall, crashed wall with surrounding haematoma? (IV) dissection of surrounding tissues and possible control of PA proximally? In this situation we have the following: (I) small bleed; (II) good PA wall; (III) good prior dissection. Therefore compression for a few minutes and clipping or suturing should be possible.



Figure 4 Left pa dissection following manipulation (6).
Available online: <http://www.asvide.com/article/view/24315>

Pulmonary artery bleeding (Figures 3,4)

General comments:

- (I) The pulmonary artery (PA) and its branches, unless the patient has established pulmonary hypertension, are part of a low-pressure system. The PA-related bleedings can be controlled by applied gentle pressure.
- (II) The classic “swab on a stick” (small gauze wrapped in a Rampley sponge holding forceps) is adequate to control most PA bleeds. This should be available and ready for use in all procedures. We advise constant gentle pressure for at least 5 consecutive minutes, prior to re-evaluation of the injury. During this period a full team brief is established with a plan. Long vascular clamps, vascular tapes and fine sutures should

Table 3 Step-wise approach to pulmonary artery (PA) related injuries

PA stump bleed following stapling

Clean, blood leak without surrounding vessel involvement: apply haemostatic agent or apply gently a clip if length of stump healthy or a 5/0 prolene with a long needle if bleeding in a favourable to suture position

Bleeding with surrounding haematoma: apply haemostatic agent/patch and compress for 5-10 minutes. Do not attempt sutures

PA stump dehiscence following stapling

Apply pressure with haemostatic agent or simple sponge and re-evaluate in 5–10 minutes. If bleeding perfuse and not pin point, proximal control is advisable. Conversion at this point depends on surgeon experience, team experience and patient overall general condition

PA injury at dissection

Simple small Haemorrhage compress and then treat as for A1

Large injury with detachment of PA branch from main shaft; apply pressure and treat as for B1

Injury of main PA without prior dissection of surrounding tissues; apply pressure and convert

Injury of main PA with prior dissection of surrounding tissues, apply pressure and encircle PA to obtain proximal control. Re-evaluate and if salvaged apply sutures. If not convert

In all situations where uniportal VATS repair is required the PA pressure can be lowered for 5–10 minutes by IV injection of glyceryl trinitrate (GTN). Discuss with the anaesthetist

be available as well as haemostatic patches.

(III) The first main task is to assess the injury by asking the following questions:

- (i) Type of injury, i.e., minor bleed on a vessel, moderate wall dissection with haematoma formation, full large thickness split of a PA branch or main shaft.
- (ii) Extent of injury and topography, i.e., small branch, lobar branch, main PA.
- (iii) Extent of prior dissection and ability to get proximal and distal control as well as encircle safely the vessel.

A suggested algorithm for management of PA bleeds is shown in *Table 3*.

Pulmonary veins (PV)

The PV and their tributaries, can tolerate more handling compared to their artery counterparts.

General comments:

- (I) The same principles of repair apply as in the previous paragraph with arterial bleeds.
- (II) It's advisable to allow adequate vein stump when stapling the pulmonary veins (photo). In this manner any bleeds can be addressed with proximal control and sutures.
- (III) PV bleeding close to pericardium raises concern as the left atrium is in close proximity and has a thin

muscular wall.

(IV) If such situation is suspected the pericardium should be opened without disturbing the stapling line and proximal control applied before any attempt to suture is commenced.

Other uncommon intra operative bleeding

- (I) The subclavian vessels can be traumatised not only in operations of the superior sulcus, but in bullectomies or lung volume reduction surgery (LVRS) because of frequent presence of vascular adhesions to the area. It may become challenging to visualise the area of bleeding with the uniportal approach. Compression is the first step, but large tears can only be managed with conversion and appropriate vascular control. In desperate situations ligation of the vessel might prove life-saving.
- (II) Blood flow to the upper limb can be re-established with vertebral or carotid to distal subclavian bypass and in some environments the assistance of the vascular team will be necessary.
- (III) The internal thoracic vein and artery might be injured during dissection of an anterior lesion or detachment of an adherent lung area. In case of injury compression followed by simple ligation of the vessels with sutures is enough to arrest the bleed.
- (IV) Caution should be applied in cases of a U-VATS

approach where the patient has received a prior CABG with internal mammary artery dissection and anastomosis. Quite often the lung is adherent in the groove between the anterior chest wall and the pericardium. A bleed can be avoided if an extremely adherent lung gets detached by the use of staplers. The retained lung tissue on the chest wall has enough vascular supply and will not necrose. Adventurous dissection in this area can cause a serious bleed. In this situation conversion will be necessary and on the balance of probabilities, if the arterial graft is lost the patient will require assistance from a Cardiac Surgeon to address the internal mammary artery conduit injury.

- (V) Intra operative bleeds from an azygos vein injury are managed easily either by simple suturing or stapling of the vessel.
- (VI) Similar bleeds from the superior vena cava should be addressed with initial pressure. Small injuries can be sutured, although bigger injuries will require control with a vascular clamp. Please note that in the presence of a central line:
 - (i) The vascular clamp might not arrest the bleeding completely and
 - (ii) Special care should be taken to avoid incorporating the central line within the repaired injury by the suture line.

Management of intraoperative diaphragmatic injuries

Diaphragmatic perforations can result from an inadequately paralysed patient or inappropriate port incision placement in cases of pleural sepsis as the diaphragm can be in an unusually high position.

It is advised in such pathology to perform an intra-operative ultrasound scan of the chest which marks the correct position of the diaphragm.

Diaphragmatic injuries can be simply repaired with sutures and no conversion is necessary. The surgeon should always take care to avoid abdominal organ injury during repair.

Management of intraoperative esophageal injuries

The oesophagus can be potentially injured in both pleural cavities. The most frequent injuries occur during dissection of the sub carinal nodes.

It is recommended that diathermy should be used with caution in the vicinity of the esophageal lumen. Any minor bleeding can be attended with simple packing for a few minutes and conscious use of haemostatic agents.

In cases where identification of the esophagus is challenging an oesophageal bougie or nasogastric tube should be inserted to facilitate recognition.

Esophageal perforations need primary repair, preferably with 2 layers of sutures and an adjoining viable tissue flap to prevent subsequent leak and pleural sepsis.

Management of intraoperative thoracic duct injuries

The thoracic duct can be traumatised while sampling stations R9 and 8. Prevention is of paramount importance as such injuries become evident during the post-operative period.

Our recommendation is aggressive management with fat free diet and if the leak continues ligation of the duct without delay.

Patient related factors influencing complications

Extra care should be paid by the surgeon to identify those patient-related factors which can lead to intraoperative complications.

Anatomical variations

There are several recognised anatomical variations of the hilar anatomy (7). Such, dictate surgical approach and require pre-operative identification and understanding. We cannot emphasize enough the need to obtain appropriate imaging studies, discuss them with a dedicated radiologist and have these available in the operating room for consultation.

Disease progression

International guidelines dictate that no patient with lung cancer should undergo an operation with CT images older than 4 weeks from the date of surgery (8). The importance of a recent CT is multifaceted as (I) it provides accurate staging; (II) allows appropriate surgical planning, type of access and position of uniportal incision; and (III) guides the surgeon safely around the hilar structures preventing complications

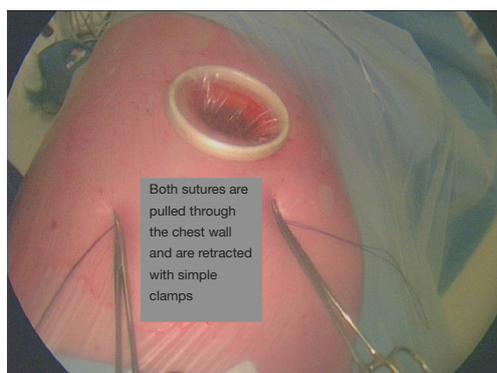


Figure 5 In this patient, the diaphragm was raised and 2 traction sutures were placed for retraction. (I) Large sutures should be used to avoid injury to muscle fibers; (II) Care should be exercised to avoid injury to intra-abdominal organs; (III) The sutures can be looped and delivered through the chest wall with a hook.

Patient characteristics

These provide important pivot points to prepare and prevent intra operative complications.

- (I) The chest wall contour dictates the position and size of the uniportal incision in combination with the intended procedure in a severely kyphotic or scoliotic patient.
- (II) The access and instrument selection is influenced by the presence of a severely emphysematous lung with minimum deflation or a severely obese patient with high hemi diaphragm and generous hilar fat. Loss of the operating field can be compensated by traction sutures to the diaphragm in order to increase the volume of the pleural cavity (*Figures 5,6*).
- (III) Similar concerns apply to a patient with significant pulmonary hypertension where a full hilar dissection is necessary.

Discussion

U-VATS approach brings new challenges. We feel the need to repeat that the uniportal surgery is not a variation of the multi-portal one. It requires specific skills, instruments and team mentality to succeed; equally it will present its own patient related challenges.

Nowadays, the VATS approach is dominating. In our institution, Leeds Teaching Hospitals, we have reported VATS lobectomies compared to open approach up to 100%



Figure 6 Diaphragmatic retraction (9).

Available online: <http://www.asvide.com/article/view/24316>

in certain months, while our average is well above 75%. Within the European Society of Thoracic Surgeons (ESTS) database (10) of approximately 40,000 lobectomies, in the last 5 years the VATS percentage in lobectomies alone is 31.9; this same percentage was only 5.3, just 5 years earlier.

In other words, it required a decade for the dedicated thoracic surgeon to change the surgical practice and increase to six-fold the percentage of VATS lobectomies.

At present, the ESTS Silverbook has no data on whether the VATS approach includes the uniportal procedure.

Undoubtedly, the uniportal approach needs time before it increases to large percentages at an international level. The involved surgeons ought to share their experience.

Conclusions

We presented several factors that can help and improve the understanding and safety of the U-VATS procedure. The differentiation of the contributing factors in operator and patient-related can help to have a better insight on the new adaptations that are required in the future.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Informed Consent: All participants gave informed consent

before taking part in this study.

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