Handling vascular bleeding without conversion during video-assisted thoracoscopic surgery major pulmonary resection

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Abstract: Bleeding due to vascular injury is the most troublesome and dangerous condition during video-assisted thoracoscopic surgery (VATS) major pulmonary resection. It is also the main reason for emergent conversion to open thoracotomy and remains a great challenge for thoracic surgeons. We designed the suction-compressing angiorrhaphy technique (SCAT) for troubleshooting this problem. Handling of the vascular injury under VATS was divided into three different situations. Herein, three typical videos were presented to elucidate the technical details for the management of vital vascular bleeding during VATS major pulmonary resection.

Keywords: Video-assisted thoracoscopic surgery (VATS); lobectomy; vascular bleeding; angiorrhaphy

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Introduction

Video-assisted thoracoscopic surgery (VATS) has been technically matured and is currently considered the preferred approach for surgical treatment of the malignant and benign lung diseases. The ratio of VATS lung resection to open lung surgery increased quickly in the past years (1,2). However, there are still several issues that should be considered during lung surgery, including dense hilar adhesion, bleeding due to major vascular injury, completely fused fissure, etc. Among these, bleeding caused by vascular injury is the most dangerous condition and the most difficult problem that should be solved.

The incidence of vascular injury during VATS lung resection is about 2.9–9.2%, while the conversion rate caused by vascular injury is 0.48–6.2% among all VATS major pulmonary resections (3). Sometimes intraoperative vascular injury may cause patient deaths during or after surgery (4). For this reason, vascular injury was once an obstruction to the performance and acceptance of VATS in lung surgery for those thoracic surgeons who dared to perform VATS lung resection (5). However, there was no effective solution for this problem before our first report of the suction-compressing angiorrhaphy technique (SCAT) for dealing with major vascular injury during VATS pulmonary resection (6). The solutions for this problem reported afterwards are still rare, except conversion to open thoracotomy. Herein, we presented three typical videos to elucidate the technical details of SCAT in handling three different situations of vascular bleeding during VATS lung surgery.

Operative techniques

Our routine VATS lobectomy was carried out with the "single-direction" technique, as previously described (7). The patient is placed in the lateral decubitus position, with the surgical table flexed to a 30-degree angle after general anesthesia with double-lumen endotracheal intubation. The operation can be performed through three or only one hole. During surgery, we recommend a metal endoscopic suction cooperating with energy devices like electrocautery

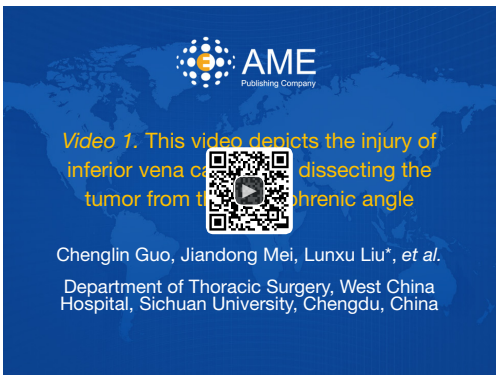

Figure 1 This video depicts the injury of inferior vena cava when dissecting the tumor from the costophrenic angle (8). The bleeding was firstly controlled by the suction-compressing maneuver, followed by rotating-suture angiorrhaphy using 5-0 Prolene stiches.
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Figure 2 This video shows a case of left pulmonary artery injury when dividing the oblique fissure (9). The bleeding was firstly controlled by the suction. A pair of Allis forceps was used to clamp the wound instead of the suction. Angiorrhaphy was accomplished using 5-0 Prolene stiches with an endoscopic needle-holder through the assistant incision.
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hook or harmonic scalpel to do tissue dissection. When accidental vascular injury is encountered, the first step is to stop the bleeding. Because the suction is usually in the chest during surgery, it is easy to control the bleeding with "suction-compressing", which means compressing the injured site through side compression with the suction tip (6). Sometimes, other devices can also be applied to compress the site of injury if the suction is not in the chest. It could be replaced by the suction later. The next step is to repair the injury. Vascular repair could be divided into three different situations according to the technical details of angiorrhaphy.

Situation I: rotating-suture angiorrhaphy

This method is typically applied when the vascular wound is relatively small, usually less than 5 mm, and the bleeding can be well controlled by the suction-compressing maneuver with the suction tip. *Figure 1* depicts a case of VATS right lower lobectomy for a patient with lung adenocarcinoma invading the diaphragm. The inferior vena cava was accidently injured when dissecting the tumor from the costophrenic angle using harmonic scalpel. The suction was applied to compress the site of injury immediately, with the suction-compressing maneuver. We were able to further dissect the surrounding soft tissue to achieve better exposure of the injured structures; continuous suction-compressing was used to improve exposure. The first suture was made after slightly rotating the suction tip to the distal side along the injured vessel using 5-0 Prolene stiches with an endoscopic needle-holder. Afterwards, the suction was rotated slightly against the proximal side to make space for another suturing. While the assistant was controlling the bleeding with suction, suture knots were placed.

Situation II: clamping angiorrhaphy

If the wound is larger than 5 mm but limited to one-third of the circumference of the injured vessel, it is risky to do suturing directly while compressing the site of injury with the suction tip. Additionally, the suction may sometimes retard the suturing. In this situation, the Allis forceps was used to gently clamp the wound to replace the compressing suction, and followed by suturing. In *Figure 2*, the left pulmonary artery (PA) was injured when firing the oblique fissure during the VATS left upper lobectomy. The endoscopic suction was immediately applied to control the bleeding. However, it was difficult to perform suturing from the anterior port with the suction in the chest. We then used the Allis forceps to carefully clamp the vascular wound and remove the suction afterwards. The suturing was carried out through the assistant port with an endoscopic needle-holder using 5-0 Prolene stiches from one side of the Allis. After making two sutures, the Allis was removed while the stitches were tightened. Finally, the knot was made with a knot pusher.

Figure 3 This video is a case of left pulmonary artery injury beneath the superior bronchial branch of the left upper lobe (10). The suction was applied to control the bleeding firstly, followed by applying gauze as an alternative. The left main pulmonary artery was mobilized and blocked using a releasable Bulldog clamp. After transecting the bronchus, the injured vessel was exposed and repaired.
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Situation III: blocking angiorrhaphy

In case of larger wounds which exceed one third of the vascular circumference or when the Allis clamping delay further suturing, the proximal main PA should be mobilized and blocked using a releasable Bulldog clamp (Aesculap, Inc., Center Valley, PA, USA). This is usually applied for the injuries of the PA. In *Figure 3*, a case of VATS trisegmentectomy was carried out with the single-direction technique (7). The apical and anterior branches of the superior pulmonary vein were transected first at the anterior of the hilum, followed by ligating the first branch of left PA. When dissecting the superior branch of the left upper bronchus, the PA beneath the bronchus was injured by the hook. The suction tip was applied to control the bleeding immediately, followed by compressing the injury with gauze. The left main PA was then mobilized and blocked using a Bulldog, which allowed dissection and further transection of the superior bronchial branch. The injured site was then exposed for angiorrhaphy. Running suture using 5-0 Prolene stiches was carried out with an endoscopic needle-holder. The injury was successfully sutured with blood loss of 300 mL, and no transfusion was required.

Comments

Massive bleeding due to vascular injury is still a great problem during VATS major pulmonary resection. Because of the complex anatomy and high rates of blood flow, the injury may sometimes result in life-threatening blood loss within a short period of time. It is important to keep calm when a vascular injury occurs and one should avoid clamping the vessels blindly. The bleeding should be controlled as soon as possible. A sponge stick is usually recommended to give pressure on the site of injury, adjacent hilar structures or even lung parenchyma to control bleeding (11).

When performing the single-direction thoracoscopic lobectomy, the surgeons usually use an endoscopic suction to guide tissue dissection with energy devices, like electrocautery hook or harmonic scalpel. The suction is usually in the chest and can be applied to compress the injured structures in time, which we named the "suction-compressing" maneuver. There are some other advantages for the use of the suction to control bleeding, including clearing pooled clot and the blood to expose the site of injury and making more space for further manipulation. When using gauze or sponge stick to compress the injuries, it is sometimes hard to insert it through the small incisions on the chest wall during emergent conditions. Moreover, it is impossible to expose vascular wound and do the suture with gauze covering on injured site. The use of suction prevented these shortages for the suction tip is small and can easily reach the injured site.

After controlling the bleeding, the mechanisms of vascular repair should be taken into account. There are different choices, such as the use of thrombostatic material, or converting to open thoracotomy (11). However, only using the thrombostatic material in case of an obvious vascular injury is unreliable and unsafe. We provided three technical strategies for further vascular repair under VATS. The strategies were designed based on the location and size of vascular injury. Only several additional devices were needed to repair the injuries, including a long or endoscopic needle-holder, a pair of long Allis forceps, and a releasable Bulldog clamp. It should be noticed that clamping an injured vessel with Allis must be done with great caution, and the ratchet should be avoided to lock too tightly because it may cause additional injuries to the vascular wall. With the SCAT, more than 88% of the vascular injuries were successfully solved without conversion to open thoracotomy (6). A few cases hard to deal with the SCAT are the injuries of the main PA, when there is not enough space to block the proximal artery. In addition, the surgeons should also consider their skills in manipulating the great

vessels through VATS approach. If lacking such skills, converting to open surgery is also an acceptable choice.

In summary, these videos show that bleeding due to vascular injury could be efficiently controlled with the "suction-compressing" maneuver. The injured vessels could be successfully repaired with suitable strategies in various situations without emergent conversion.

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Footnote

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

Informed Consent: Written informed consent was obtained from the patient for publication of this manuscript and any related images.

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