Case Report

Utilization of intraoperative indocyanine green fluorescence imaging to identify vascular anatomy in severe pleural adhesions in uniportal video-assisted thoracoscopic surgery: a case report

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Background: Extensive and dense pleural adhesion is a serious challenge in video-assisted thoracoscopic surgery (VATS), in which identification of vessels and their anatomical spaces is difficult. Once critical vessel is damaged while dissecting adhesion in VATS, leading to fatal hemorrhage, the surgeon will have to switch to thoracotomy. This is the first report of a case in which intraoperative indocyanine green (ICG) fluorescence imaging was used to identify critical vessels in severe pleural adhesions in uniportal VATS.

Case Description: The patient (67-year-old male) with an 8-year history of tuberculosis and severe mixed ventilation dysfunction underwent a standardized wedge resection due to chest computed tomography (CT) scan that revealed a 2.6-cm nodule in the right upper lung. Intraoperatively, the superior vena cava and azygos vein were successfully identified and safely dissected using ICG fluorescence imaging in the presence of extensive and dense pleural adhesions. The chest drainage tube was removed on postoperative day (POD) 3, and patient was released from hospital on POD 5. The patient recovered well and no complication was observed in the follow-up.

Conclusions: The ICG fluorescence imaging is used to illustrate the vessels and help to dissect them safely, which is a feasible, visualizable, and user-friendly method in severe pleural adhesions in uniportal VATS.

Keywords: Fluorescence imaging; pleural adhesions; vascular anatomy; uniportal video-assisted thoracoscopic surgery (uniportal VATS); case report

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Introduction

Extensive and dense pleural adhesions are a significant challenge in thoracic surgery, especially in uniportal video-assisted thoracoscopic surgery (VATS), and are often the final outcome of an inflammatory reaction process (1). Due to severe pleural adhesions, the vascular structures, anatomical space, and pulmonary parenchyma are disorganized and unidentifiable, which can lead to a series of problems, including a poor operative field, lung parenchymal damage, intraoperative bleeding, and other morbidity risks. In particular, bleeding of critical vessels

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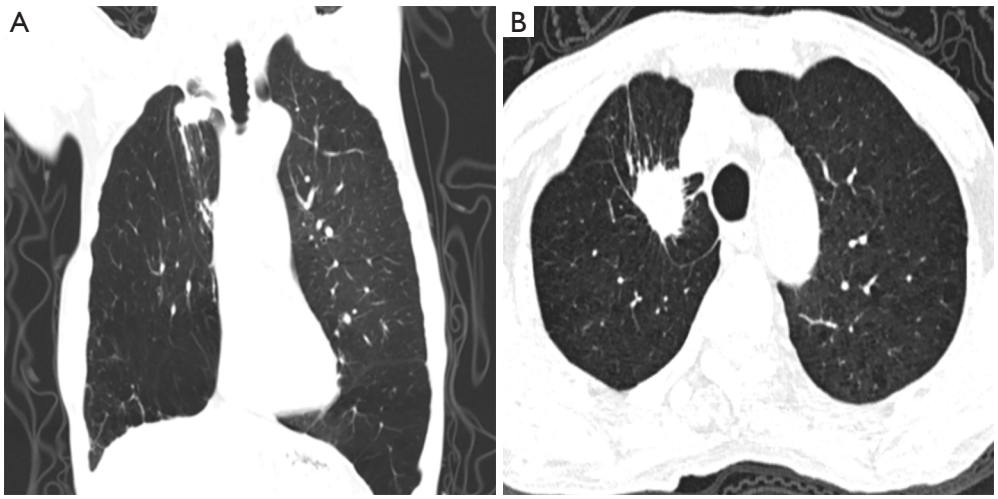


Figure 1 CT showed a well-defined irregular, lobulated nodule (25 mm × 26 mm) in the upper part of the remaining right lung with pleural traction. CT, computed tomography.

caused by adhesions may lead to fatal injuries when uniportal VATS is used, such that the operative approach may have to be changed by the thoracic surgeon to thoracotomy. Thus, the presence of extensive and dense pleural adhesions presents a significant challenge to thoracic surgeons and increases the rate of conversions to thoracotomy (2-4). We, therefore, report a case of a pulmonary lesion with massive pleural adhesion receiving uniportal VATS resection safely with the help of indocyanine green (ICG) fluorescence imaging. We present this case in accordance with the CARE reporting checklist (available at https://tcr.amegroups.com/article/view/10.21037/tcr-23-729/rc).

Highlight box

Key findings

- The indocyanine green (ICG) fluorescence imaging is used to illustrate the vessels and help to dissect them safely, which is a feasible, visualizable, and user-friendly method in severe pleural adhesions in uniportal video-assisted thoracoscopic surgery (VATS).

What is known and what is new?

- It is not uncommon to use intraoperative ICG fluorescence imaging to identify vascular anatomy in hepatobiliary surgery, gastrointestinal surgery, and urology.
- The identification of critical vascular anatomy in severe pleural adhesions was first reported in uniportal VATS by using the fluorescence imaging.

What is the implication, and what should change now?

- When severe pleural adhesions are encountered during VATS, which leads to difficulties in identifying vascular anatomy, the use of ICG fluorescence imaging is more conducive to safe and smooth operation, especially for young and inexperienced thoracic surgeons. In addition, more cases need to be included in further research.

Case presentation

The patient in question was a 67-year-old male, who presented to our hospital because of a nodule (2.6 cm in diameter) in the right upper lung. He had recently developed symptoms of cough, expectoration, and shortness of breath. His medical history included an 8-year history of tuberculosis and a right upper lobectomy for tuberculoma 8 years prior. The results of a pulmonary ventilation function test proved that he had severe mixed pulmonary ventilation dysfunction. Sputum testing for *Mycobacterium tuberculosis* was negative. A chest X-ray and computed tomography (CT) scan showed postoperative changes of the right lung, and a well-defined nodule 25 mm × 26 mm in size could be seen in the upper part of the remaining right lung (*Figure 1*). All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committees and with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the editorial office of this journal.

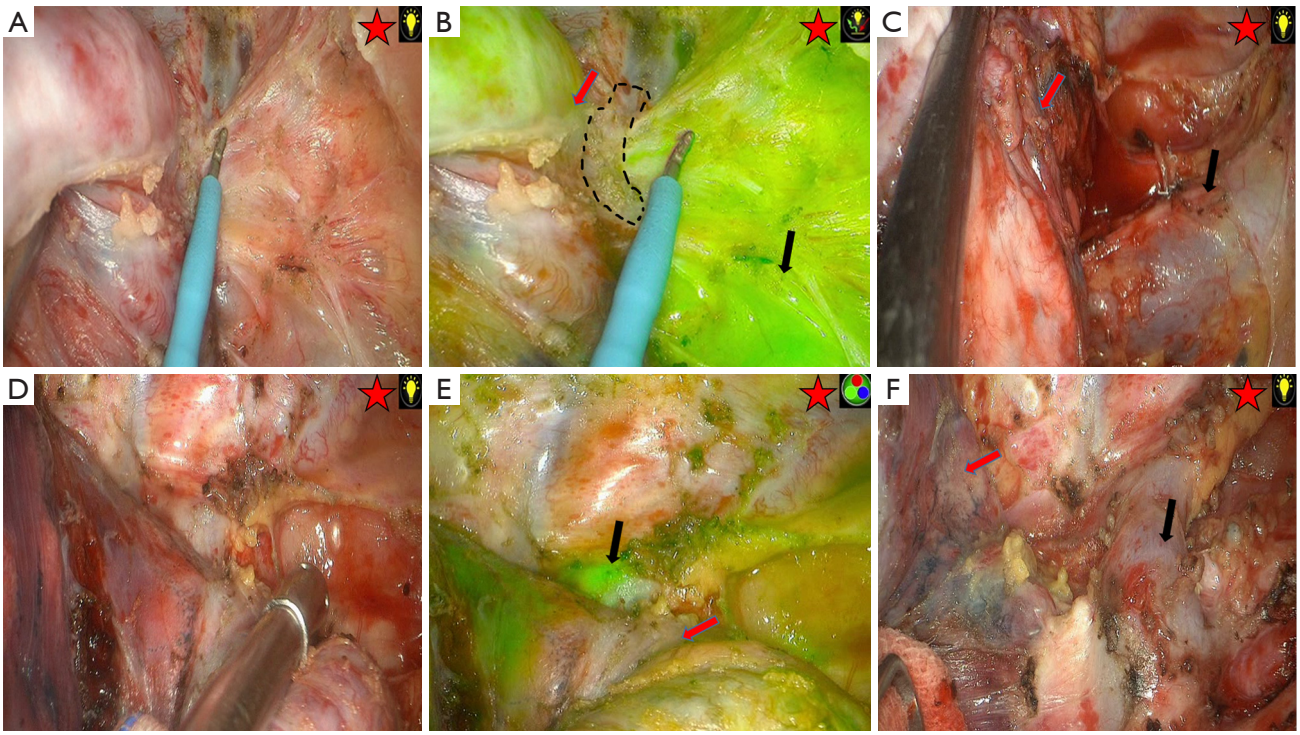
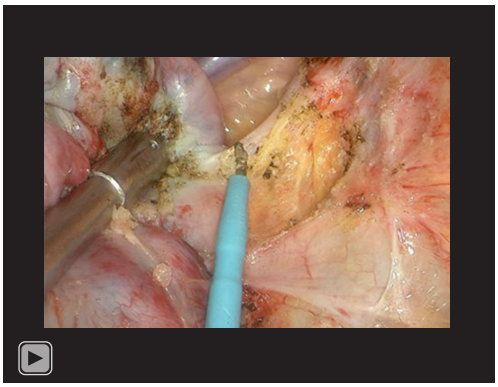


Figure 2 ICG fluorescence imaging showed the superior vena cava and the azygos vein (A-C: superior vena cava; D-F: azygos vein). The anatomical relationships and spaces were unclear among adhesions (A,D). The anatomical structures and spaces could be distinguished using fluorescence (B,E). The red arrows show the pulmonary parenchyma, the black arrows show the superior vena cava (B,C) and azygos vein (E,F), and the dotted line (B) indicates the space between the pulmonary parenchyma and the superior vena cava (C,F). The red pentagrams indicate the head side. ICG, indocyanine green.

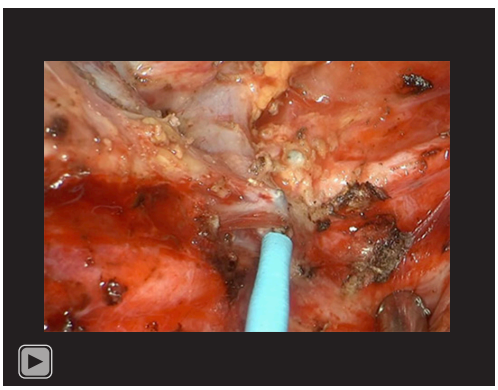
A standard right middle lobe wedge resection was performed using uniportal VATS 7 days following admission. During the surgical procedure, extensive and dense pleural adhesions were confirmed in the right thoracic cavity. The surgeon encountered some challenges, including highly calcified lymph nodes in the hilum and mediastinum. Due to severe adhesions, it was difficult to identify the critical vessels (the superior vena cava and the azygos vein) and to distinguish the anatomical gaps between vessels and surrounding structures using unassisted vision, and thus 3 mL of ICG (2.5 mg/mL; Dandong Medical Innovation Pharmaceutical Co., Ltd., Dandong, China) divided across 2 doses (0.19 mg of ICG per body weight) was administered through the peripheral vein.

The first ICG injection was performed because there was an ambiguous anatomical relationship during the release of the superior vena cava and the pulmonary parenchyma. ICG was injected through the peripheral vein of the forearm, and after approximately 30 seconds of fluoroscopic thoracoscopy in fluorescence mode (Endoscopic Fluorescence Camera System, Stryker, Kalamazoo, MI, USA), a bright green fluorescence became apparent in the superior vena cava. In the fluorescence mode, a clear anatomical gap could be seen between the superior vena cava and the pulmonary parenchyma, which facilitated the safe release of adhesions (*Figure 2*; *Video 1*). The anatomical relationship was again unclear when the adhesions between the azygos vein and the pulmonary parenchyma were released, and a second ICG injection was performed as described above. As before, a distinct green fluorescence appeared in the superior vena cava and then also appeared in the azygos vein after the waiting time was increased by about 15 seconds. The anatomical gap being rendered visible by green fluorescence (*Figure 2*; *Video 2*) enabled the azygos vein to be further released from adhesions. The superior vena cava and the azygos vein were finally separated from the pulmonary parenchyma (*Figure 2*).

The chest drainage tube was removed on postoperative



Video 1 ICG fluorescence imaging identified the superior vena cava. ICG, indocyanine green.



Video 2 ICG fluorescence imaging identified the azygos vein. ICG, indocyanine green.

day (POD) 3, and the patient was released from hospital on POD 5. The follow-up chest X-ray on postoperative 14 was also normal. Overall, the patient recovered well with no notable findings, and the patients themselves expressed affirmation and satisfaction with the treatment.

Discussion

Severe pleural adhesions tend to cause a series of problems, especially the bleeding of critical blood vessels during operations, which presents significant challenges to surgeons. It is generally accepted that when surgeons encounter extensive and dense pleural adhesions when accessing the thoracic cavity, they must be prepared to perform a highly technically demanding and time-consuming surgical procedure. Severe pleural adhesions have been considered to be an absolute contraindication to complete VATS (3,5,6), mainly due to the fatal hemorrhage that occurs once critical blood vessels in the thoracic cavity are damaged, which makes conversion to thoracotomy necessary. Severe pleural adhesions are a key independent risk factor for conversion to thoracotomy during VATS and the most common cause of conversion is vascular injury (7).

With the advancement in operative instruments, techniques, and the minimally invasive surgery concept in modern thoracic surgery, uniportal VATS has become prevalent in minimally invasive thoracic surgery. Uniportal VATS causes less surgical damage, reduces the length of postoperative hospital stay and pain to patients, and facilitates faster recovery for patients by virtue of needing only a single incision. In addition to these advantages, it is able to provide outcomes that are almost comparable to those of traditional open or multiportal surgery (8). In the past, when encountering severe pleural adhesions during uniportal VATS, surgeons often had only 2 options: making 1 or 2 extra incisions or converting to thoracotomy (5). Most surgeons, even senior surgeons, convert to thoracotomy when they encounter severe adhesions.

The anatomical relationship between critical vessels and surrounding structures becomes very ambiguous if adhesions are present, and surgeons will inevitably damage critical vessels. Therefore, how to identify important structures among severe pleural adhesions and complete operation in uniportal VATS remain to be solved. Currently, there are several methods, including color 3-dimensional (3D) lung maps and transthoracic ultrasound (TUS), which can identify and visualize pleural adhesions preoperatively. Using a color 3D lung map and TUS, surgeons can perform an assessment to identify the presence of pleural adhesions (9,10). However, many limitations still exist for both methods. Disadvantages of a color 3D lung map are mainly low penetration, high doses of external radiation (9), and an inability to assess adhesions in the apical region and in patients with severe obstructive disease (11). Although TUS is a rapid, economical, and noninvasive method for detecting pleural adhesions, it has some drawbacks, including low accuracy in patients undergoing reoperation and those with chronic obstructive pulmonary disease (COPD) as well as the requirement of comprehensive ultrasound skills and systematic training of thoracic surgeons (10). Ultimately, color 3D lung mapping and TUS are preoperative approaches used to detect the presence or absence of adhesions and cannot substantially assist in identifying critical vessels or anatomical gaps between vessels and surrounding structures intraoperatively

during uniportal VATS. In recent years, the intraoperative application of ICG fluorescence imaging to identify critical vascular anatomy has aided in compensating for any limitations and achieved real-time visualization.

It is not uncommon to use intraoperative ICG fluorescence imaging to identify vascular anatomy in hepatobiliary surgery, gastrointestinal surgery, and urology. ICG is nontoxic and nonradioactive, and has an extremely high safety index (adverse reaction rate: 1:300,000; maximum recommended dose: 2 mg/kg) (12-15). DeLong *et al.* (16) reported 4 patients with adrenal tumors who underwent laparoscopic adrenalectomy with ICG fluorescence imaging, confirming that ICG fluorescence imaging can clearly identify vascular structures, enhance tumor boundaries, and potentially improve surgical safety. Diana *et al.* (17) have asserted that intraoperative use of ICG fluorescence imaging is a viable tool in situations where vascular anatomy is challenging, which could broaden the application of robotic-assisted partial nephrectomy (RAPN). Yang *et al.* (18) reported a case in which the vascular anatomy was confirmed intraoperatively through ICG fluorescence imaging, which showed that the right branch of the middle colonic artery had traversed a malignant deposit on the residual mesocolic membrane.

However, ICG fluorescence imaging has not previously been reported in the identification of critical vascular anatomy in severe pleural adhesions during VATS, especially in uniportal VATS. Our team is thus likely the first to have attempted to use intraoperative ICG imaging to identify the critical vascular anatomy in severe pleural adhesions during uniportal VATS. ICG fluorescence imaging enables real-time visualization of critical vessels and anatomical gaps between critical vessels and surrounding structures, especially when severe pleural adhesions are present during uniportal VATS, thus significantly reducing the risk of accidental vascular injury, shortening the operative time, and facilitating the dissection. Even in cases where critical anatomical structures are normal, surgeons' confidence can be greatly enhanced, in particular that of junior surgeons with limited experience. Additionally, the cost of ICG is lower compared to that of 3D lung maps and TUS. To a certain extent, ICG fluorescence imaging can reduce the rate of conversion to thoracotomy during uniportal VATS. However, this method has several unavoidable drawbacks. The main situation that is difficult to identify is that there is extensive blood oozing in the pleural cavity when dissecting adhesions, because ICG will be distributed everywhere with the blood flow, so that the entire surgical field will appear green fluorescence. In this case, it is necessary for the surgeon to operate delicately, stop the bleeding timely and accurately, and clean up the contaminated surgical field. In addition, it is difficult to accurately identify blood vessels with collateral circulation, and color overlap after multiple injections. Sometimes, an overlap of fluorescence may occur between the mediastinal fat tissue, vessels and lung parenchyma leading to a difficult differentiation among them. In our experience, the solution is to use the fluorescence intensity display mode of the Stryker camera system. In this mode, ICG will display different colors according to the concentration. The more ICG is concentrated, it will appear yellow, and the less it will appear light blue, so as to help us identify blood vessels.

Conclusions

We showed that ICG fluorescence imaging is a feasible, rapid, economical, safe, and easy-to-operate means of identifying critical vascular anatomy in the presence of severe adhesions in uniportal VATS. In our experience, the surgical risk and operating time associated with severe adhesions are significantly reduced. More cases are warranted to verify its feasibility, efficacy, and safety.

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Footnote

Reporting Checklist: The authors have completed the CARE reporting checklist. Available at https://tcr.amegroups.com/article/view/10.21037/tcr-23-729/rc

Peer Review File: Available at https://tcr.amegroups.com/article/view/10.21037/tcr-23-729/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tcr.amegroups.com/article/view/10.21037/tcr-23-729/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All procedures performed in this study were in accordance with the ethical

standards of the institutional and/or national research committees and with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the editorial office of this journal.

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