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Constant-Rate Intravenous Indocyanine Green Infusion for Anatomical Segmentectomy: A Case Report of Enhanced Intersegmental Plane Visualization

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Abstract **Case Report**

Accurate identification of the intersegmental plane (ISP) is essential in pulmonary segmentectomy to ensure oncological adequacy while preserving lung function. Indocyanine green (ICG) fluorescence imaging has been increasingly used for this purpose; however, conventional bolus injection provides only transient visualization. Constant-rate intravenous infusion offers brighter and more sustained visualization, potentially improving surgical precision. A 66-year-old man with hypertension, dyslipidaemia, and a history of rectal adenocarcinoma was found to have a suspicious pulmonary nodule in the superior segment of the left lower lobe on a surveillance computed tomography (CT) scan. Despite a negative biopsy, surgical resection was performed. The patient underwent video-assisted thoracoscopic superior segmentectomy guided by constant-rate intravenous ICG infusion (12.5 mg/min). Near-infrared imaging demonstrated clear fluorescence of the perfused lung, with the target segment remaining non-fluorescent, enabling precise ISP delineation. The segment was successfully resected, and the patient had an uneventful recovery. Histopathology confirmed primary lung adenocarcinoma with clear margins. Constant-rate intravenous ICG infusion provides stable and enhanced visualization of the ISP compared to conventional bolus injection. This technique is feasible, safe, and may improve surgical precision in minimally invasive segmentectomy. Further studies are required to standardise protocols and evaluate long-term outcomes.

Keywords: Pulmonary segmentectomy, constant-rate intravenous infusion, indocyanine green infusion, intersegmental plane.

INTRODUCTION

In patients with small, early-stage non–small cell lung cancers or selected metastatic tumours, anatomical pulmonary segmentectomy and wedge resection are increasingly performed as parenchyma-sparing alternatives to lobectomy. These approaches preserve pulmonary function while maintaining oncological efficacy in carefully selected patients. However, identification of the intersegmental plane (ISP) remains challenging, particularly in minimally invasive approaches such as video-assisted thoracoscopic surgery (VATS) or robotic surgery, and even more so when the lesion is not visible on the visceral pleura.

Traditional methods, including the inflation–deflation [1] and high-frequency jet ventilation (HFJV) techniques [2], are limited by collateral ventilation, emphysematous changes, prolonged procedural times, and obstruction of the operative field in minimally invasive settings. As a result, near-infrared (NIR) fluorescence imaging with indocyanine green (ICG) has gained prominence as a reliable method for real-time delineation of intersegmental borders [1-6].

ICG is a water-soluble fluorescent dye that binds to plasma protein and lipoprotein [3]. It has traditionally been used to assess liver function and cardiac output and has more recently been applied in thoracic surgery to facilitate pulmonary resection. ICG can be administered preoperatively via percutaneous computed tomography (CT)-guided injection [4], or intraoperatively through transbronchial or intravenous routes [3,5,6].

Here, we report a case of primary lung cancer managed with anatomical segmentectomy using constant-rate intravenous infusion of ICG,

demonstrating its feasibility and potential advantages in minimally invasive thoracic surgery.

Case Presentation

A 66-year-old Malay man with a history of hypertension, dyslipidaemia, and rectal adenocarcinoma treated with neoadjuvant chemotherapy and low anterior resection was found on surveillance CT to have a 2 x 1.5cm solid pulmonary nodule with ground-glass changes with spiculated margins in the superior segment of the left lower lobe. A CT-guided biopsy showed no malignancy; however, given the suspicious radiological features, surgical resection was planned.

The patient underwent left VATS superior segmentectomy of the left lower lobe, guided by constant-rate intravenous ICG infusion. Under general anaesthesia with double-lumen endotracheal intubation, he was positioned in the right lateral decubitus position. A two-port VATS approach was employed: a 4-cm access port at the fourth intercostal space, 5 cm lateral to the nipple, and a 2-cm camera port at the seventh intercostal space along the anterior axillary line. Intraoperatively, a 2 x 2cm puckering lesion was noted over the superior segment. The pulmonary ligament was divided, and the segmental pulmonary artery branch (A6) was isolated [Figure 1] and stapled [Figure 2].

ICG was prepared by dissolving 25 mg of dry powder in 10 ml of sterile water and infused at a constant rate of 12.5 mg/min (5 ml/min) via the right internal jugular line using an infusion pump. Under NIR imaging, all segments of the left lung fluoresced green except the superior segment. The ISP was marked with diathermy [Figure 3], and the segment was resected with an Endo-GIA stapler and removed en bloc.

Postoperatively, the patient was extubated and transferred to the intensive care unit for monitoring. He recovered uneventfully and was discharged on postoperative day four. Histopathology examination confirmed primary lung adenocarcinoma with clear surgical margins.

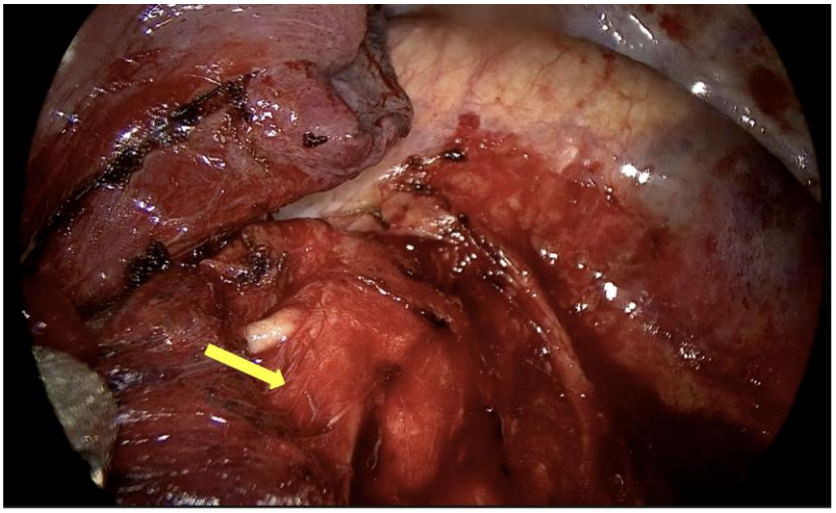

Figure 1: Arrow: A6 segmental artery

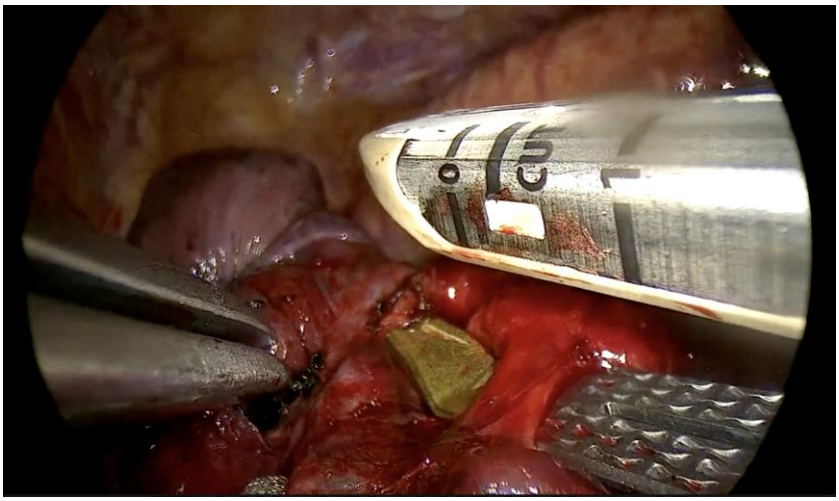

Figure 2: Ligation of A6 segmental artery

Figure 3: Delineation of intersegmental plane using diathermy

DISCUSSION

Accurate identification of the ISP is crucial in pulmonary segmentectomy to ensure adequate oncological margins while preserving functional lung parenchyma. NIR fluorescence imaging with ICG has increasingly been adopted to facilitate ISP delineation [2-5].

ICG can be administered preoperatively via CT-guided percutaneous injection [4], or intraoperatively through intravenous or transbronchial routes [3,5,6]. Intravenous ICG, administered either as a bolus or via constant-rate infusion is primarily used for ISP identification. Following ligation of the segmental artery, intravenous ICG allows the perfused lung to fluoresce while the target segment remains non-fluorescent, providing clear delineation for resection.

Bolus ICG injection produces only transient fluorescence and may result in uneven distribution, limiting the time available for accurate ISP marking. Yotsukura *et al.,* reported a median fluorescence duration of 40-90 seconds [2]. Large-cohort series have demonstrated good demarcation in approximately 88% of cases, compared to 78% with HFJV, with low complication rates and no ICG-related adverse events [2].

In contrast, constant-rate intravenous infusion maintains a steady circulating concentration of ICG, resulting in a more uniform and prolonged fluorescence. This allows greater flexibility in intraoperative decision-making and improves the accuracy of ISP delineation. Misaki et al demonstrated that constant infusion at 12.5mg/min achieved significantly higher fluorescence intensity and longer visualization compared to bolus injection, without increased dose or adverse effects [3]. A systematic review further supports that continuous infusion provides longer fluorescence duration (~170 seconds vs 90-140 seconds) and more consistent ISP delineation [5]. Patients receiving bolus ICG may also require repeated injections to maintain adequate visualization [5].

ICG administered via percutaneous CT-guided [5,6] and transbronchial approach [5,8] are primarily used for tumour localisation rather than ISP delineation. The percutaneous approach is effective for peripheral lesions but carries risks such as pneumothorax and requires coordination with radiology to minimize dye diffusion prior to surgery [7]. The transbronchial approach requires expertise in bronchoscopy and may be time-consuming, particularly if repeated injections are necessary [8]. Additionally, retrograde diffusion of dye from the target bronchus may occur, leading to dissemination within the bronchial tree and compromising accurate ISP identification.

Despite its advantages, constant-rate intravenous infusion is not yet widely adopted. Optimal dosing regime, infusion protocols, and timing require further standardisation. Our case highlights the practical advantages of this technique, including improved visualization, smoother operative workflow, and reliable ISP identification. We believe this technique has the potential to enhance precision of minimally invasive segmentectomy and warrants further investigation in larger studies.

CONCLUSION

Constant-rate intravenous infusion of ICG is a feasible and safe technique for intraoperative delineation of the ISP during minimally invasive pulmonary segmentectomy. Compared with conventional bolus injection, it provides more stable, uniform, and prolonged fluorescence, facilitating precise anatomical resection and improving intraoperative workflow. This technique may be particularly beneficial in challenging cases where accurate segmental identification is critical. Further prospective studies are warranted to establish optimal protocols and evaluate long-term oncological outcomes.

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