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Thoracoscopic Anatomical Lung Segmentectomy using Fluorescence Navigation with Indocyanine Green

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Abstract

Purpose: Detection of the intersegmental line during thoracoscopic segmentectomy is sometimes difficult. We describe a newly evolved technology using indocyanine green (ICG)-fluorescence navigation during this procedure.

Description: We performed thoracoscopic right segments 8 and 9 anatomical segmentectomy on a 48-year-old man with pulmonary metastasis of osteosarcoma. Preoperative three-dimensional computed tomography revealed the relationships of the pulmonary artery and vein and segmental bronchi, and revealed the surgical margin of the segmental plane to measure 10 mm. During surgery, we separated the pulmonary artery, and then injected ICG 0.25 mg/kg into a peripheral vein. Using the KARL STORZ ICG system (KARL STORZ Endoscopy, Tokyo, Japan), we could observe that the residual segments were light and S8 and S9 were dark. We cut along the border created by this contrast, the intersegmental line, using electrocautery.

Evaluation: This new technology allows easy detection of an intersegmental line and safe performance of thoracoscopic anatomical segmentectomy. Because this method does not require inflation of the lung, it is useful for thoracoscopic surgery.

Conclusion: Intraoperative ICG-fluorescence navigation is useful in thoracoscopic segmentectomy.

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Introduction

Correct diagnosis of peripheral small nodules, such as ground grass opacities (GGOs) and metastatic pulmonary tumors, is sometimes difficult preoperatively. However, most patients with these findings on multi detector-row computed tomography (MDCT) frequently undergo pulmonary resection to obtain pathological diagnosis and radical cure. Sub-lobar resection, such as segmentectomy or wedge resection must be performed in patients with small-sized peripheral lung tumors on preoperative MDCT.

Anatomical segmentectomy is a technically more complicated operative procedure than standard lobectomy because of anatomical variances. Our new methods may help to perform thoracoscopic (TS) anatomical segmentectomy. We report the successful segment (S) 8 + S9 TS segmentectomy in a patient with pulmonary metastasis of osteosarcoma.

Materials and Methods

A 48-year-old man underwent radical resection of the hip musculature for alveolar soft part sarcoma 4 years before being admitted to our hospital for treatment of a suspected pulmonary metastatic tumor in the right lung. Chest MDCT revealed a tumor measuring 5 mm located in S8, near to S9 (Figure 1A). Based on three-dimensional CT reconstruction using Synapse Vincent (Fujifilm Corp., Ltd., Tokyo, Japan), we clearly visualized the space enclosed by three intrapulmonary structures (pulmonary artery [A], veins [V], and bronchi [B]) that intersect in B8 and B9: A8 and A9 along with the bronchus, and V8 and V9 (Figure 1B). In addition, we were able to delineate the arterial dominant area (A8 and A9) and margin length from this nodule to an imaginary segmental boundary (10 mm) (Figure 1C). We decided to perform thoracoscopic anatomical S8+S9 segmentectomy for this patient. To identify segmental plane, we used the ICG fluorescence navigation after dividing segmental artery. After intra-venous injection, if infrared light is lighted, ICG fluorescence will be lighted clearly under the infrared thoracoscopy produced by KARL STORZ.

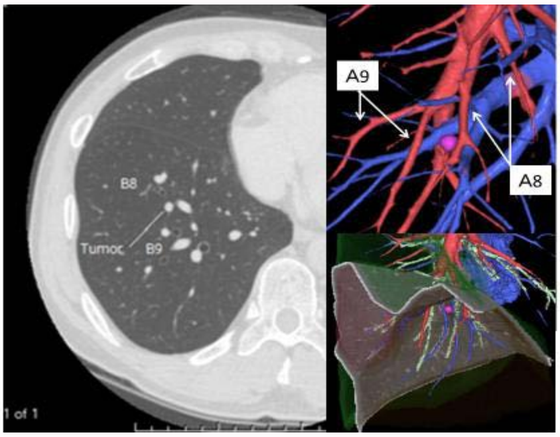

Figure 1: a) Chest CT identifies a small nodule in the right S8 segment, extremely close to the S9 segment. CT, computed tomography. **B)** Three-dimensional reconstruction image shows two tributaries of A9 arterial branches from peripheral A8. **(C)** Preoperative simulation of the arterial (A8 plus A9) dominant area.

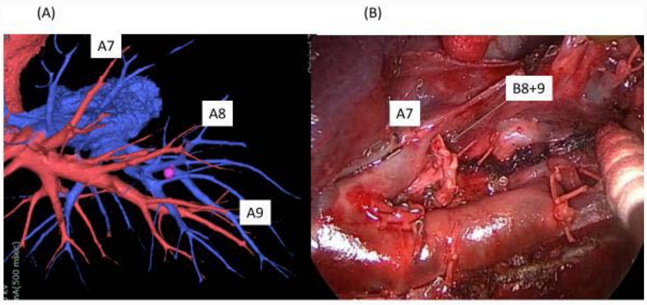

Figure 2: (A) Three-dimensional images compared to (B) thoracoscopic findings.

Thoracoscopic procedure

The surgical procedure was performed entirely under thoracoscopic visualization via four incisions measuring 25, 15, 7 and 7 mm.

Results

The preoperative simulation accurately predicted our intraoperative findings, including the locations of A7, A8, and two branches of A9 (Figure 2). Intersegmental veins V7b and V9b were preserved and intrasegmental (between S8 and S9) vein V8 and V9a draining S8 and S9 were ligated and divided. The intersegmental line was identified using the intersegmental veins near the hilum and the demarcation, which was completed ten seconds after systemic ICG injection (0.25 mg/kg) (Figure 3A), on the lung parenchyma. The ICG fluorescence was visible for four minutes after injection, so we marked the lung surface using electrocautery. The intersegmental plane of the parenchyma was divided using electrocautery at 70W and one endoscopic staple (Figure 3B). The patient's postoperative course was uneventful, and he was discharged on the postoperative day 8. The final pathological diagnosis was metastasis of osteosarcoma, and the surgical margin was 9 mm.

Discussion

Sub-lobar resection may be well adapted to small-sized peripheral lung tumors such as GGO lesions or metastatic lung tumors if surgical margins are sufficient. However, if it is difficult to keep sufficient surgical margin by wedge resection, we should sometimes perform anatomical segmentectomy. We emphasize four preoperative and intraoperative principles in our TS anatomical segmentectomy: (a) to map the pulmonary vessels accurately; (b) to detect the intersegmental veins; (c) to identify precisely the segmental plane, and (d) to obtain an adequate surgical margin.

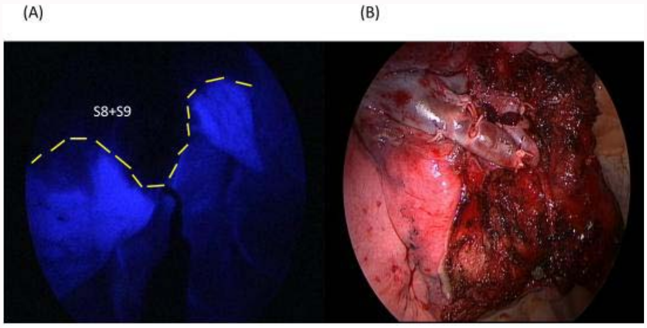

Figure 3: (A) Intraoperative ICG fluorescence and intersegmental line. Dark area is S8+S9. (B) Final aspect after segments S8+S9 anatomical segmentectomy. ICG, indocyanine green.

Some authors have reported preoperative prediction of pulmonary structures for video assisted thoracic surgery (VATS) or thoracotomy segmentectomy [1-3]. Understanding of the variations in individual anatomy of pulmonary vessels and bronchi is important for safety, especially when performing anatomical segmentectomy. Sagi et al. [3] reported that preoperative and intraoperative guidance by virtual segmentectomy using Synapse Vincent (Fujifilm Corp., Ltd.) could significantly assist surgeons in achieving the most appropriate anatomical and curative resection. To identify the inter-segmental line, the method of target-segment inflation by jet ventilation or needle insertion has been reported [4]. However, this method is sometimes difficult to employ with a severely emphysematous lung and when visualization is limited, such as with VATS. Previously we used needle insertion to the resected segmental bronchus to create an inflation-deflation line, but there are some reports of cerebellar air embolism after needle inflation method [5,6]. Therefore, another method should be used to detect the intersegmental line. Misaki et al. [7] conducted a clinical trial of segmentectomy using an infrared thoracoscopy system with ICG. Each bronchus is associated with a pulmonary artery. They have succeeded in visualizing the differential blood flow of the pulmonary artery in the lung using infrared thoracoscopy with injection of ICG (3 mg/kg). Detailed macroscopic and microscopic examination confirmed that the marking corresponded to the intersegmental line. In the present study, we visualized the intersegmental line quickly and clearly using the KARL STORZ ICG system with injection of a low dose of ICG (0.25 mg/kg). This method, which does not require lung inflation, may be useful for a severely emphysematous lung and for TS with deflated lung. Thus preoperative surgical-planning simulation evaluated by three-dimensional CT and intraoperative ICG navigation may be useful for anatomical segmentectomy during TS. The boundary created by using ICG and the identification of the intersegmental veins provide accurate delineation of the segmental plane and offset the disadvantages of a two-dimensional view.

Conclusion

We have described a new technology providing preoperative simulation based on three-dimensional CT and intraoperative ICG

-fluorescence navigation during TS. Intraoperative ICG-fluorescence navigation may contribute to the safety and accuracy of TS anatomical segmentectomy.

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