Case Report on Thoracic Surgery

Planning video-assisted thoracic surgery segmentectomy using three dimensional computed tomography angiography and bronchography with a virtual safety margin

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Abstract: In segmentectomy using video-assisted thoracic surgery (VATS), surgeons view the operative field on a 2-dimensional video monitor. The lack of ability to palpate organs directly frequently leads to difficulties in evaluating anatomic relations. Three-dimensional computed tomography angiography and bronchography (3D-CTAB) using a virtual 3D safety margin enables thoracic surgeons to recognize the distance and positional relation between the primary tumor and intersegmental veins. It also helps with surgical planning, allowing the surgeon to secure an adequate safety margin around the primary tumor. We report two patients with double primary lung cancer who underwent segmentectomy based on preoperative simulation 3D-CTAB with a virtual 3D safety margin.

Keywords: Non-small cell lung carcinoma; three-dimensional computed tomography (3D-CT); pulmonary angiography; bronchography; video-assisted thoracic surgery (VATS); segmentectomy

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Introduction

The use of video-assisted thoracic surgery (VATS) segmentectomy for early-stage lung cancer, including solid nodules and ground glass nodules (GGNs), has been increasing because the technique preserves pulmonary function better than lobectomy. Compared with open surgery, the VATS approach has a number of benefits in the immediate postoperative period, including fewer complications and a shorter length of hospital stay (1). However, VATS requires surgeons to view the operative field on a 2-dimensional video monitor, and because they cannot palpate the organs directly, this frequently creates difficulties in judging anatomic relations (2). It is important to identify the intersegmental pulmonary veins that divide the pulmonary segments, especially when performing segmentectomy. Therefore, preoperative anatomic imaging is important.

Many studies have reported the efficacy of 3-dimensional computed tomography angiography and bronchography (3D-CTAB) for preoperative assessment of the pulmonary vessels and bronchi (3-7). However, it is difficult for 3D-CTAB alone to recognize the recommended safety margins, which are currently 2 cm from the primary tumor. Therefore, we adopted a scheme that merges a virtual 3D safety margin with 3D-CTAB for patients with lung cancer (8,9). We report two patients with double primary lung cancer who underwent segmentectomy based on preoperative simulation 3D-CTAB with a virtual 3D safety margin.

Contrast enhanced CT

In our institution, 3D-CTAB data are obtained using a high-speed 64-channel or 128-channel multi-detector CT scanner (Aquilion 64, Toshiba Medical Systems, Tokyo, Japan; SOMATOM Definition Flash, Siemens Japan, Tokyo, Japan). Vascular access was obtained using a 20-gauge needle in the right median cubital vein. For

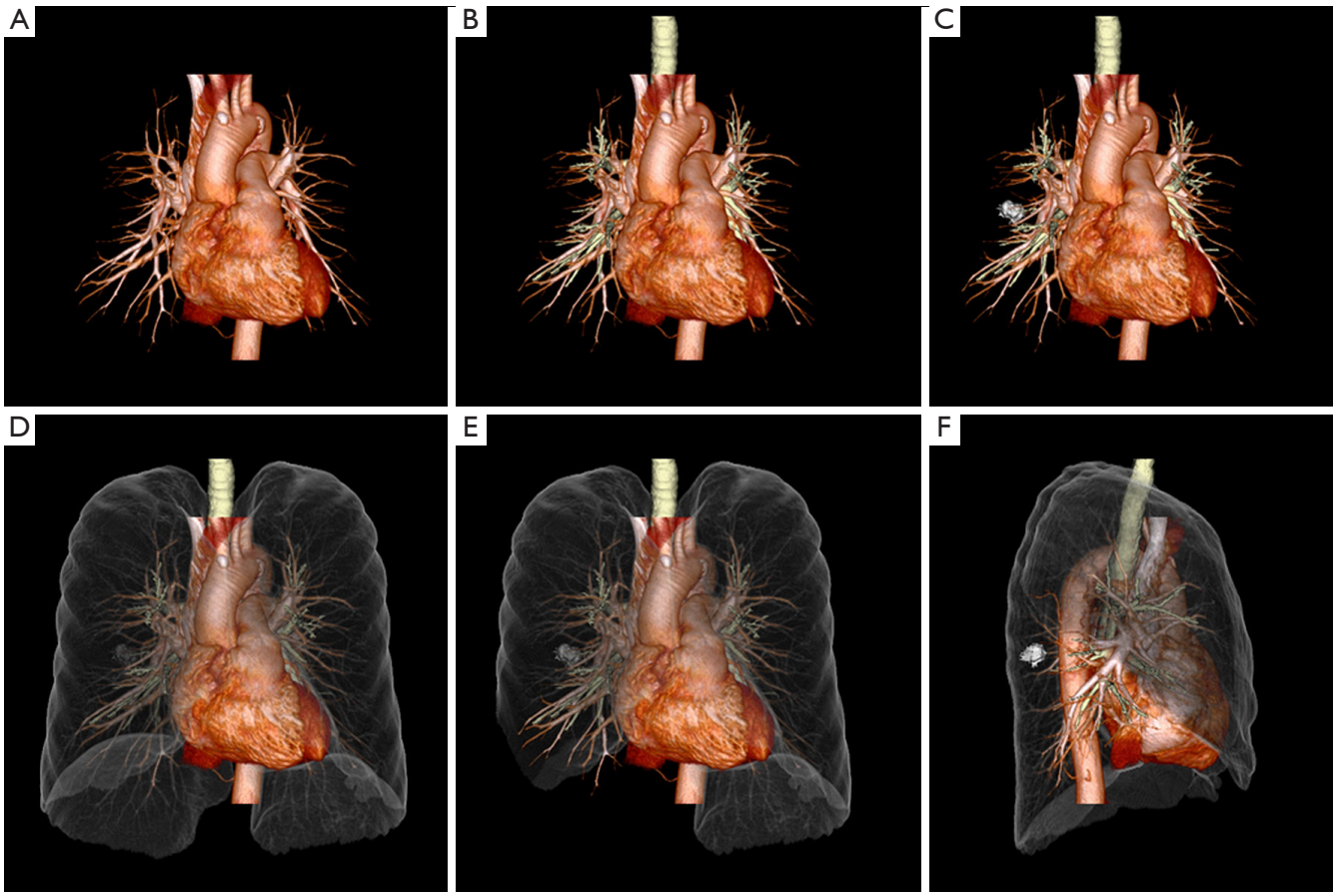

Figure 1 Reconstruction of 3D-CTAB. (A) Pulmonary vessels; (B) pulmonary vessels, trachea, and bronchi; (C) pulmonary vessels, trachea, bronchi, and the primary lesion in the right lower lobe; (D) pulmonary vessels, trachea, bronchi, primary lesion, and lung; (E) right lower lobe with the primary tumor removed from the image to improve visualization of the lobular distribution of bronchi and vessels; (F) right-sided 3D-CTAB view. 3D-CTAB, 3-dimensional computed tomography angiography and bronchography.

vessel enhancement, 96 mL of a nonionic contrast medium was used at a flow rate of 3.0 to 4.0 mL/s using a power injector (8,10). The injection of the contrast medium was immediately followed by 24 mL of saline at the same flow rate. To scan during the suitable arterial phase, the scan delay was decided using an automatic bolus-tracking system. Axial thin-section CT images of the whole lung were reconstructed using a slice thickness of 1 mm, a slice increment of 0.8–1 mm, and a standard algorithm.

3D-CTAB reconstruction

The thin-section CT images were transferred to a commercial 3D workstation (Ziostation, Amin Co. Ltd., Tokyo, Japan; Synapse Vincent, Fujifilm Medical, Tokyo, Japan), where a chest radiologist constructed the thoracic 3D-CTAB. The lung, primary tumor, pulmonary vessels, and the trachea and bronchi were separately segmented and color-coded by CT value, as defined by the tissue's Hounsfield units (*Figures 1*,*2*) (8,11).

Virtual 3D safety margin

The safety margin was defined as a sphere, extending 2 cm outside the primary tumor. For example, the margin was 5 cm in diameter for a primary tumor of 1 cm, and the margin was 6 cm in diameter for a primary tumor of 2 cm (8). We typically drew the sphere in blue (*Figures 3*,*4*) (12). The center of the virtual 3D safety margin was manually matched to the center of the tumor using the 3D workstation. The radiologists and surgeons interpreted the relation between the margin and the intersegmental veins. In cases where

the intersegmental veins ran through the safety margin, the veins were designated for removal.

Case presentation

Patient 1

A man in his 60s was referred to our hospital because of suspicion for a double primary lung cancer in the right lung. Examination with CT showed a pure GGN measuring 12 mm between right S4 and S5, and a single nodule measuring 15 mm in right S6 (*Figures 5A-C,6*) (13). As the patient had comorbid chronic obstructive pulmonary disease [forced expiratory volume in 1 second (FEV1) =1.76 L; FEV1 as a percentage of forced vital capacity =58.5%], we anticipated that bilobectomy of the right middle and lower lobe would be difficult. Therefore, we planned a right middle lobectomy and S6 segmentectomy based on the results of 3D-CTAB with a virtual 3D safety margin.

Figures 5D and *6* show that the results of 3D-CTAB were difficult to interpret in the right lower lobe, and for the distance between the tumor and the intersegmental vein V6c (between S6 and the basal segment). *Figures 5E,F* and 7 (14) show that the course of V6c was outside the virtual 3D safety margin, which was 5.5 cm in diameter. Therefore, in a preoperative conference with respiratory medicine, thoracic surgery, and radiology, we deemed it possible to secure a sufficient surgical margin with right S6 segmentectomy. After lobectomy of right middle lobe, the pulmonary artery and vein to the involved segment (A6, V6) were resected. Next, the right lower lobe was inflated and segmental bronchus (B6) was divided. After collapsed S6, the surgeons confirmed inflation-deflation line and removed S6 using stapling device. Pathologic findings confirmed the diagnosis of well-differentiated adenocarcinoma in the middle lobe and moderately differentiated squamous cell carcinoma in S6; the surgical margins were free of tumor. No recurrence was seen at last follow-up, 5 years after surgery.

Figure 2 The 3D-CTAB (11). Right lower lobe with the primary tumor removed from the image to improve visualization of the lobular distribution of bronchi and vessels. 3D-CTAB, 3-dimensional computed tomography angiography and bronchography.
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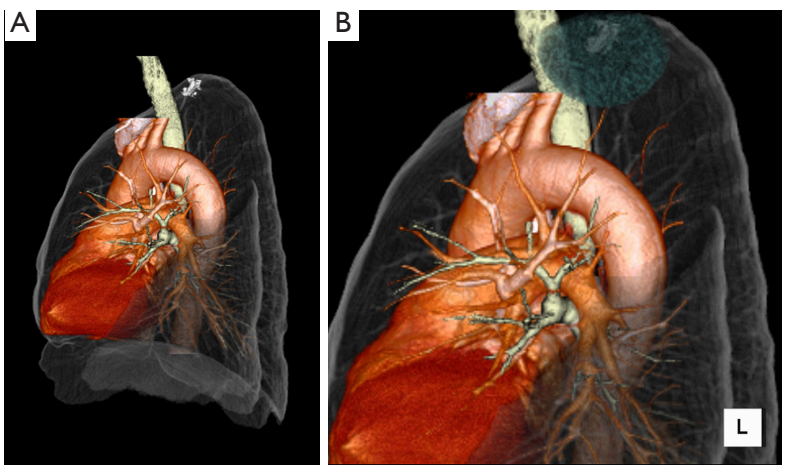

Figure 3 3D-CTAB with a virtual safety margin. (A) Primary lesion, 2 cm in diameter, in the apical portion of the left lung on 3D-CTAB; (B) virtual 3D safety margin (blue hemisphere) merged with the 3D-CTAB image. 3D-CTAB, 3-dimensional computed tomography angiography and bronchography.

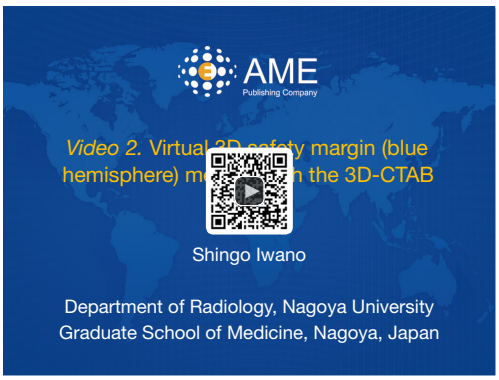

Figure 4 Virtual 3D safety margin (blue hemisphere) merged with the 3D-CTAB image (12). Primary lesion is observed in the apical portion of the left lung. 3D-CTAB, 3-dimensional computed tomography angiography and bronchography.
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Patient 2

A man in his 70s was referred to our hospital because of a high suspicion for primary lung cancer in the left lung. The results of CT showed a pure GGN measuring 20 mm in left S1+2 (*Figure 8A,B*). The patient had a history of a right upper lobectomy for large cell lung carcinoma 8 years prior. Therefore, we planned a left upper-division segmentectomy based on the results of 3D-CTAB with a virtual 3D safety margin. *Figure 8C* shows the results of 3D-CTAB in the left upper lobe. *Figures 8D* and *9* (15) show that the course of the intersegmental vein V1+2c between the upper division and the lingula was outside the virtual 3D safety margin, which was 6 cm in diameter. Therefore, we deemed it possible at the preoperative conference to secure a sufficient surgical margin using left upper division segmentectomy. The pulmonary artery and vein to the involved segment

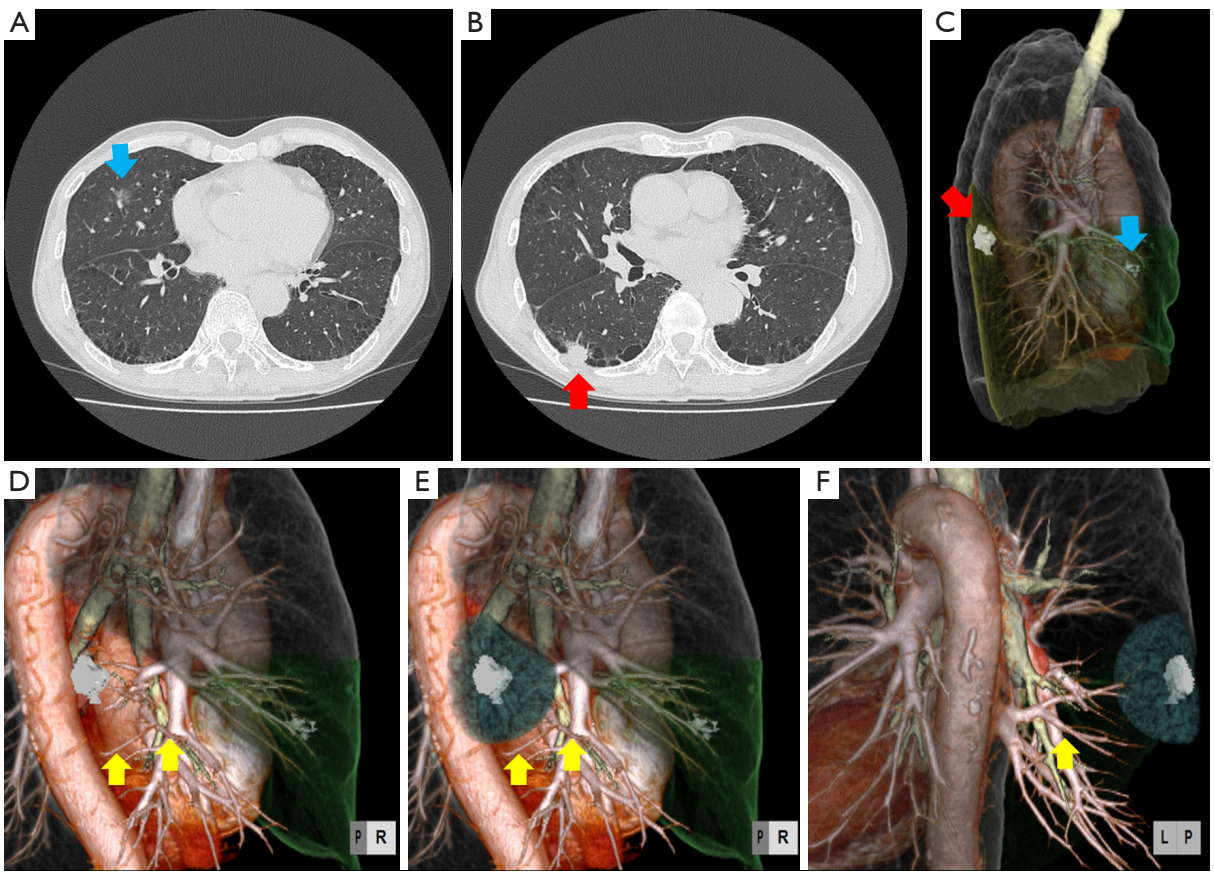

Figure 5 Patient 1. (A) Pure GGN, 12 mm in diameter, in the right middle lobe (blue arrow); (B) solid nodule, 15 mm in diameter, in the right lower lobe (red arrow); (C) right-sided 3D-CTAB view; (D) right lower lobe removed from 3D-CTAB; yellow arrows indicate the intersegmental vein (V6c); (E,F) 3D-CTAB with virtual 3D safety margin (blue hemisphere); yellow arrows indicate V6c. 3D-CTAB, 3-dimensional computed tomography angiography and bronchography; GGN, ground-glass nodule.

Figure 6 3D-CTAB view of patient 1 (13). Pure GGN is observed in the right middle lobe and solid nodule is observed in the right lower lobe. 3D-CTAB, 3-dimensional computed tomography angiography and bronchography; GGN, ground-glass nodule. Available online: http://www.asvide.com/articles/1556

Figure 7 3D-CTAB with virtual 3D safety margin (blue hemisphere) on the solid nodule in the right lower lobe (14). 3D-CTAB, 3-dimensional computed tomography angiography and bronchography.
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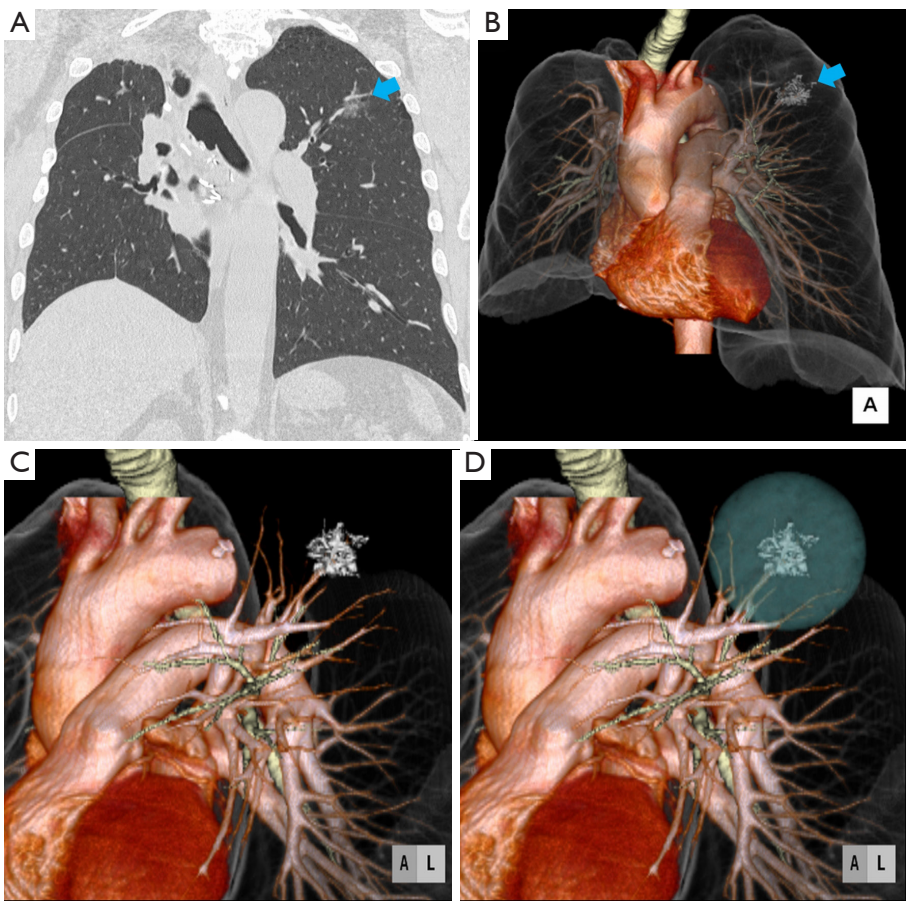

Figure 8 Patient 2. (A) Pure GGN, 20 mm in diameter, in the left upper lobe (blue arrow); (B) 3D-CTAB; the right lung volume is small due to a previous right upper lobectomy; (C) left anterior 3D-CTAB view; yellow arrow indicates the intersegmental vein (V1+2c); (D) 3D-CTAB with virtual 3D safety margin (blue sphere); yellow arrow indicates V1+2c. 3D-CTAB, 3-dimensional computed tomography angiography and bronchography; GGN, ground-glass nodule.

Figure 9 3D-CTAB with virtual 3D safety margin of patient 2 (15). 3D-CTAB, 3-dimensional computed tomography angiography and bronchography.
Available online: http://www.asvide.com/articles/1558

(V1+2, V3c, A3a, A1+2c, A1+2a+b+A3b) were resected first. Next, the surgeons identified inflation-deflation line after inflate left upper division and removed using stapling device. Pathologic findings confirmed the diagnosis of well-differentiated adenocarcinoma, and the surgical margin was free of tumor. No recurrence was seen at last follow-up, 4.5 years after surgery.

Discussion

Patients with lung cancer often have respiratory complications such as chronic obstructive pulmonary disease and interstitial lung disease. Furthermore, synchronous or metachronous multiple lung cancers often occur. There are a lot of patients whom limited to surgery have to be selected in order to preserve their respiratory function as shown in this report. For such patients, pulmonary segmentectomy preserves pulmonary function to a greater degree than lobectomy, but the smaller procedure could increase the risk of locoregional recurrence at the resection line (16,17). Therefore, preoperative planning is essential to secure a substantial margin from the primary tumor, especially for VATS segmentectomy. The use of 3D-CTAB with a virtual 3D safety margin helps the thoracic surgeon recognize accurate distances and positional relations between the primary tumor and the intersegmental veins. Most 3D workstations can create a virtual 3D safety margin; it requires only basic workstation functions.

Acknowledgements

None.

Footnote

Conflicts of Interest: The author has no conflicts of interest to declare.

Informed Consent: The IRB in our institution waived the requirement for written informed consent from patient.

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