Intraoperative Computed Tomography Navigation During Thoracoscopic Segmentectomy for Small-sized Lung Tumors

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Performance of thoracoscopic pulmonary segmentectomy for primary lung cancer or pulmonary metastases has recently increased. In patients with emphysema, identification of the intersegmental line is often difficult. For nonpalpable lesions, securing a sufficient surgical margin is more likely to be uncertain. The purpose of this study was to evaluate the efficacy of intraoperative computed tomography (CT) scan during video-assisted thoracoscopic surgery (VATS) pulmonary segmentectomy. This study included 12 patients who underwent intraoperative CT-assisted VATS segmentectomy between January 2015 and August 2016. After dividing the corresponding vessels and bronchi, the intersegmental line was marked by clipping, and intraoperative CT scan was performed under bilateral lung ventilation. The intraoperative CT or 3-dimensional CT reconstruction images were used by the surgeons to confirm the correct anatomical segmental border and to secure a sufficient resection margin. In all patients, the location of the lesions to be resected, the intersegmental border, and the surgical margins could be confirmed while performing VATS segmentectomy. Complete resection was achieved in all patients. Although the pathologic margins tended to be shorter than the surgical margins on intraoperative CT images, there was a strong correlation between these 2 variables ($r = 0.963$, $P < 0.0001$). Intraoperative CT scan during VATS segmentectomy was useful for identifying the location of nonpalpable lesions, confirming anatomical intersegmental borders and securing the resection margins. Intraoperative CT navigation could enable a more definitive VATS segmentectomy for nonpalpable lesions.

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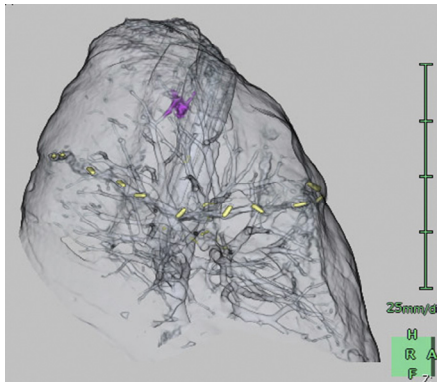

Three-dimensional images were reconstructed and colorized using Synapse Vincent from intraoperative computed tomography (CT) scan data.

Central Message

Intraoperative computed tomography (CT) scan during pulmonary segmentectomy was useful for identifying the location of lesions, confirming the anatomical intersegmental borders, and securing the resection margin.

Perspective Statement

When performing video-assisted thoracoscopic surgery (VATS) segmentectomy for patients with nonpalpable lesions, the presence of a lesion in the site of resection is often difficult to confirm. Intraoperative computed tomography (CT) scan could convince surgeons that the pulmonary parenchyma to be resected definitely contains lesions.

Several studies have reported the application of video-assisted thoracoscopic surgery (VATS) pulmonary segmentectomy for noninvasive lung cancer and pulmonary metastases. However, sufficient palpation of such lesions could be difficult by VATS. When performing segmentectomy for lung malignancy, maintaining a sufficient margin is the most important consideration, and the intersegmental line needs to be recognized. To identify intersegmental lines, several major methods have been reported; these include the classic inflate-deflate method, dividing the lung parenchyma along the intersegmental veins, and infrared thoracoscopy with indocyanine green. Although identification of the correct anatomical intersegmental line is important, establishment of a sufficient surgical margin takes priority.

In the cardiac, vascular, and neurosurgery fields, a hybrid operating room and intraoperative computed tomography (CT) scan are used mainly. Intraoperative CT navigation in a hybrid operating room is useful for identification of lung lesions that are difficult

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to palpate. We have developed a simple and effective method of using intraoperative CT to confirm the intersegmental line and to establish a sufficient surgical margin for lung lesions of this type.

MATERIALS AND METHODS

The study protocol was approved by the Research Ethics Board of Kochi Health Science Center, Japan. This study involved 12 consecutive patients who underwent intraoperative CT-assisted thoracoscopic segmentectomy between January 2015 and August 2016. Written informed consent was obtained from all patients.

Patient Selection

We had 3 basic selection criteria for CT-assisted thoracoscopic segmentectomy. The first criterion was lung segmentectomy for (1) intentional limited resection (eg, noninvasive or minimally invasive adenocarcinoma with no lymph node metastasis) and (2) compromised limited resection for lung cancer (eg, poor candidates for lobectomy because of limited cardiopulmonary reserve or other comorbidities) or metastases. The second was uncertain tumor location and expansion because of difficulty in palpation. The third was inappropriateness of wedge resection because of tumor size or location.

Preoperative Computed Tomography

The 3-dimensional (3D) image analysis system that we used employed the Synapse Vincent image processing software (Fujifilm Medical Co., Tokyo, Japan) (Fig. 1). This allowed 3D reconstruction of previously captured CT images of organs and vessels to allow the surgeon to simulate various patterns of planned lung segmentectomy. This particular process comprised the following steps. Preoperative enhanced multidetector row CT scan was obtained to evaluate patients scheduled to undergo lung segmentectomy. Data were transmitted to the workstation for 3D reconstruction of the tumor, pulmonary vessels, tracheobronchial tree, and lung parenchyma; to define the segmental bronchi based on the location of the tumor; and to determine the sites of resection of the pulmonary vessels, bronchi, and intersegmental veins. After selection of the segmental bronchi that supplied the planned resection area, surgical simulations were displayed.

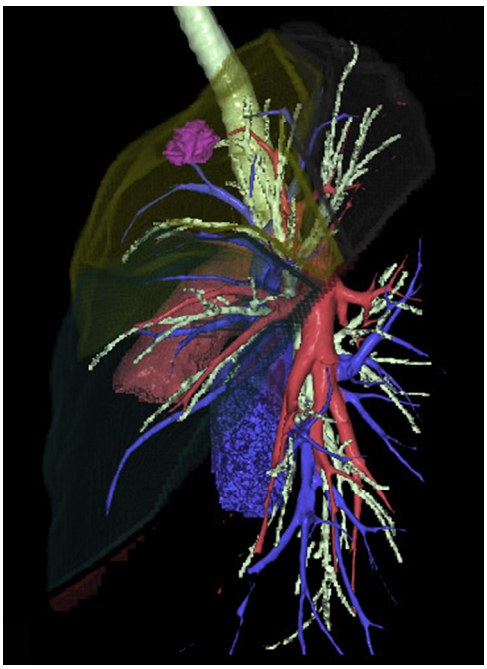

Figure 1. Case 11, a patient who underwent S^3 segmentectomy. Preoperative reconstructed 3D-CT images show the location of the lesion and the extent of lung parenchyma to be resected. (Color version of figure is available online.)

Intraoperative CT-assisted Segmentectomy

Intraoperative CT images were obtained using an angiographic system (Artis Q; Siemens Healthcare, Germany) in the hybrid operating room. Under single-lung ventilation, the patient was placed in the lateral decubitus position, with the affected side facing upward. An axillary roll was placed under the thorax because the bed in the hybrid operation room could not be flexed. For C-arm rotation, both arms were placed on the side of the head and were secured by a side panel and some small pillows. The C-arm was placed at the caudal side of the operative field. For obese patients who could not fit into the C-arm, intraoperative CT scan was not performed.

A 3- to 4-cm thoracotomy incision was made over the fourth rib without the use of a rib retractor, followed by complete thoracoscopic surgery with 2 ports. The surgeon individually ligated and dissected the segmental arteries and veins based on the preoperative CT images. Intersegmental veins were ligated and cut, whereas segmental bronchi were divided using surgical staplers. The intersegmental border on the visceral pleura was confirmed mainly by the ventilation and collapse method. However, this method was difficult in cases with emphysematous lungs; in such situations, the surgeon estimated the position of the intersegmental border based on preoperative 3D-CT images or the position of the vessel on the visceral pleura.

After marking the surface of the visceral pleura using the SOFT COAG of a modern electrosurgical unit (VIO300D, ERBE Elektromedizin GmbH, Germany), which could briefly draw a line on the visceral pleura without air leak, several points on the intersegmental line were marked by clipping (Ligaclip MCA Medium, Ethicon Endo-surgery, Cincinnati, OH) (Figs. 2C and 3B). Intraoperative CT scan during bilateral lung ventilation and 3D-CT imaging allowed the surgeon to confirm that a sufficient resection margin had been secured and that the anatomical segmental border was correct (Figs. 2D and 3C). Specifically, the surgical margin was calculated from the CT or 3D-CT reconstruction images by a radiologic technologist for a few minutes in the operating room (Fig. 4). If the calculated surgical margin was insufficient, the surgeon resets the resection line and marks it by clipping. In some cases, the surgeons considered performing combined resection of the adjacent segment. The intersegmental border was divided using surgical staplers without removal of the clips. The surgeon confirmed that a sufficient surgical margin had been secured, whereas the pathologist measured the actual surgical margin in the inflated and fixed lung specimen.