Robotic segmentectomy using a lung base-flip approach

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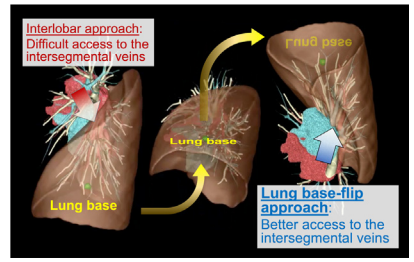


Depictions of the interlobar and lung base-flip approaches for the intersegmental veins.

CENTRAL MESSAGE

We developed a novel lung base-flip approach for robotic basilar segmentectomies using 3D-computed tomography images to overcome the difficulty in accessing the intersegmental planes.

Video clip is available online.

The use of robotic lung segmentectomies for early-stage lung cancer has been increasing.[1] Single segmentectomies of the lung base (single or combined basilar segments [or subsegments] such as S^9, S^{10}, S^{8-9}, S^{9-10}, S^9b, etc) are often more technically challenging than other lung segmentectomies because of anatomic complexity and difficulty in identifying the intersegmental planes.[2] Herein, we demonstrate a newly developed lung base-flip approach with 3D computed tomography (CT) image-based navigation for safe and secure robotic basilar segmentectomies.

SURGICAL TECHNIQUE

Institutional Review Board Approval and Informed Consent Statement

This single-center study was approved by the institutional review board of the Shinshu University Hospital (Project ID 5541). The patient provided written informed consent for the video presentation.

3D-CT Images-Based Lung Segmentectomy Planning and Intraoperative Navigation

For all patients who undergo lung segmentectomies at Shinshu University Hospital, thoracic surgeons routinely use a novel 3D-CT processing software (Revoras, Ziosoft) for segmentectomy planning.[2] Segmentectomy planning provides surgery-specific images, including the vascular/bronchial stumps and the intersegmental planes with corresponding intersegmental veins. These images are easily modified on the basis of the margin distance and target vessels/bronchi to be divided. The images can be generated and modified in multiple terminal computers in our hospital including computers in the operating rooms, outpatient clinic, surgical ward, and meeting rooms. The planning process can be performed by thoracic surgeons or trainees without help from radiologists or radiation technicians. In addition, the planning process is "semiautomated," meaning that the 3D-CT software can create 3D-CT images automatically except for simple intervening actions by surgeons such as selecting a series of CT scans being used for 3D reconstruction, pointing out a tumor to be resected, and selecting a segmental branch to be divided during segmentectomy. During the lung base-flip approach, 3D-CT images of the "flipped view" (180° rotation around the horizontal axis) are used for intraoperative navigation (Figure 1).

Port Placement and Instruments in Robotic Segmentectomy

At Shinshu University Hospital, we use the daVinci Si system for robotic lung resection. For segmentectomies at the middle and lower lobes on the right side and at the

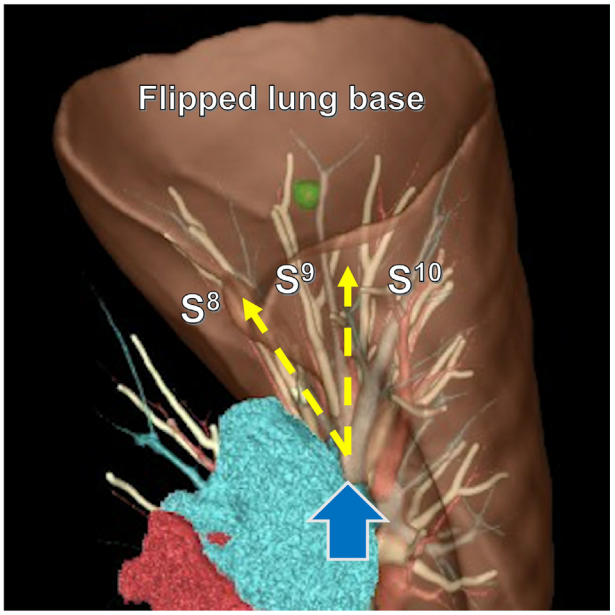


FIGURE 1. A schema of the lung base-flip approach. The lung base is retracted toward the "ceiling," or the lateral chest wall. The *blue arrow* represents the direction of hilar dissection. In this approach, the intersegmental veins can be easily accessed. Therefore, the central portion of the corresponding intersegmental planes (*yellow dotted lines*) can be easily identified and divided at the beginning of surgery.

lingular segment and lower lobe on the left side, we use the sixth to eighth intercostal spaces. Port placement in the present case is shown in Figure 2. We use Maryland bipolar forceps in the right arm (first arm), fenestrated bipolar forceps in the left arm (second arm), and Cadiere forceps in the assist arm (third arm). Using the lowest assistant port, a bedside surgeon manipulates a surgical stapler and energy device.

Robotic Segmentectomy Using the Lung Base-Flip Approach

To obtain better access to the basilar segmental anatomy, particularly the intersegmental veins, we developed a lung base-flip approach in which the lung base is retracted cephalad or toward the "ceiling" (chest wall) using the third arm in the Si system after dividing the lung ligament (Figure 1, Video 1). In general, we subsequently complete a basilar segmentectomy using the following steps: (1) dissection of the central intersegmental planes and the corresponding intersegmental veins using Maryland bipolar forceps, (2) hilar dissection with division of segmental branches of pulmonary vessels and bronchi, and (3) stapling of the peripheral intersegmental planes after systemic indocyanine green administration. The procedure in a representative patient who underwent a 2-staged bilateral segmentectomy with the lung base-flip approach is shown in Videos 2 and 3.

DISCUSSION

We propose the lung base-flip approach for robotic basilar segmentectomy. Significant advantages of this approach are as follows: (1) this approach helps identify the basilar intersegmental veins at the beginning of hilar dissection, (2) the completeness of the interlobar fissure does not affect the difficulty of the surgery, and (3) this approach complements robotic-assisted thoracic surgery with a "look-up" view from the caudal side and a stable lung retraction by the third arm (Si system).

In our institute, we perform robotic lung segmentectomies with the 3-step strategy[3]: (1) identify and divide the central intersegmental plane on the basis of the corresponding intersegmental vein, (2) dissect the segmental structures in the deep hilum, and (3) identify and divide the peripheral intersegmental plane. The first step is crucial in lung segmentectomies to create a good operative field and to obtain

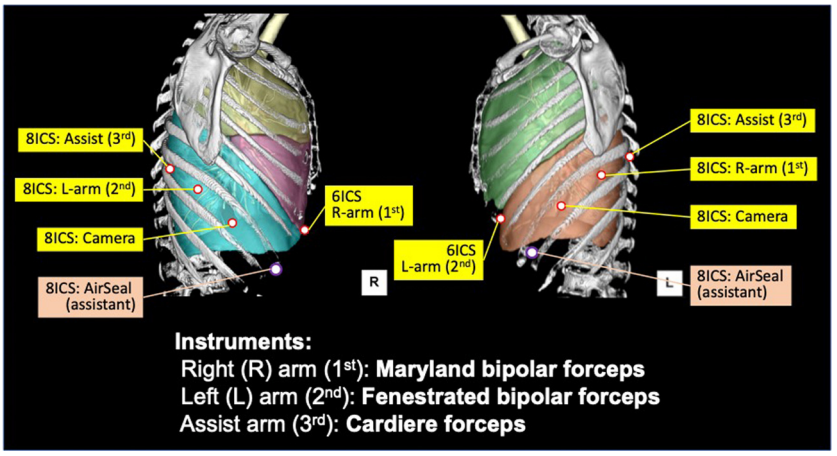
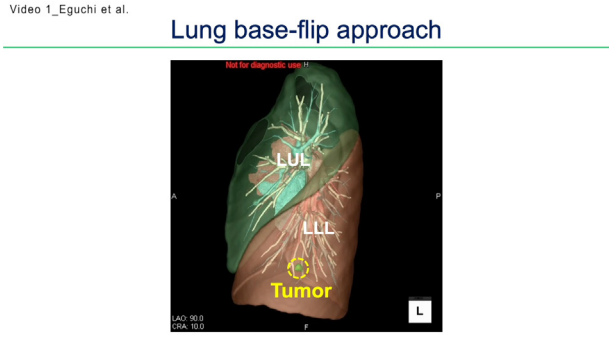


FIGURE 2. Port placement and instruments for left S^9b and right S^{10}b segmentectomies. *ICS*, Intercostal space; *L*, left; *R*, right.

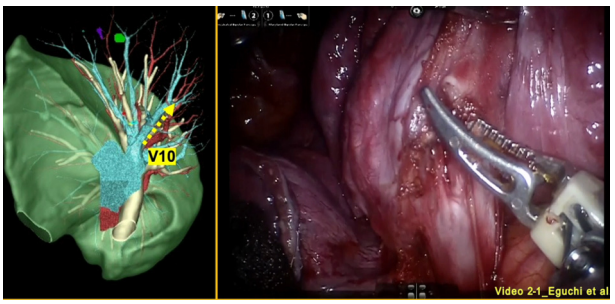


VIDEO 1. A schematic demonstration of the lung base-flip approach. Video available at: https://www.jtcvs.org/article/S2666-2507(22)00424-2/fulltext.

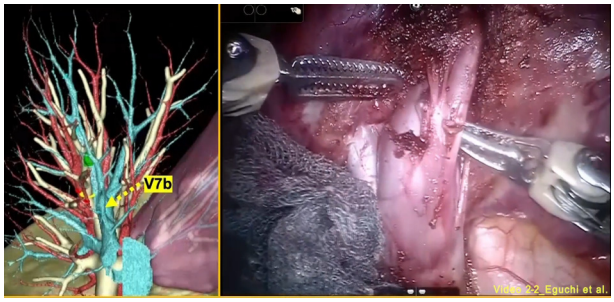
better access to the segmental anatomy that generally exists in the deep hilum.[4] However, intraoperative access to the basilar intersegmental veins from the interlobar area is challenging because the inferior pulmonary vein exists on the opposite side of the interlobar area.

The lung base-flip approach helps identify the basilar intersegmental veins at the beginning of hilar dissection, thus helping precisely identify and dissect the central intersegmental planes. This guides surgeons to an appropriate segment for hilar dissection to achieve a successful complex basilar segmentectomy.

We use 3D-CT image-based segmentectomy planning, in which surgeon-oriented intraoperative images are created with specific procedure-simulated angles of view.[2] Specifically, in the lung base-flip approach, flipped 3D-CT images are beneficial for preoperative simulations and intraoperative navigation.



VIDEO 2. A female patient in her 50s with bilateral lung metastases who underwent a 2-staged bilateral metastasectomy (left side followed by the right) is shown (the right-side surgery is shown in the Video 3). The surgical findings are shown on the right side of the screen, while corresponding 3D-CT images are shown on the left side. In the 3D-CT images, the green nodules represent the tumors. On the left side, we performed intraoperative tumor localization using radiofrequency identification technology and placed a marker via bronchoscopy.[2,5] The marker is shown as the purple point in the 3D-CT images. The patient's postoperative course was uneventful. Pathological examination revealed a metastatic lung tumor of uterine origin with a negative surgical margin. The patient underwent adjuvant chemotherapy after the 2-stage lung metastasectomy. A robotic left S^9b (the caudal subsegment of the lateral-basilar segment) subsegmentectomy was successfully completed with the following steps: (1) division of the lung ligaments, (2) dissection of the central intersegmental planes (S^8-S^9 and S^9-S^{10}) along with the corresponding intersegmental veins (V^8 and V^9, respectively), (3) hilar dissection with division of V^9, B^9b, and A^9b, and (4) stapling of the peripheral intersegmental planes after systemic ICG administration. Video available at: https://www.jtcvs.org/article/S2666-2507(22)00424-2/fulltext.



VIDEO 3. A robotic right S^{10}b (the caudal subsegment of the posterior-basilar segment) subsegmentectomy was successfully completed in the following manner: (1) division of the lung ligament, (2) dissection of the central intersegmental planes (S^6-S^{10} and S^7-S^{10}) along with the corresponding intersegmental veins (V^6 and V^7b, respectively), (3) hilar dissection with division of V^7b, B^{10}b, and A^{10}b, and (4) stapling of the peripheral intersegmental planes after systemic ICG administration. Video available at: https://www.jtcvs.org/article/S2666-2507(22)00424-2/fulltext.

CONCLUSIONS

The lung base-flip approach aids in safe and secure complex robotic segmentectomies of the lung base by providing better access to the intersegmental veins. Intraoperative navigation using "flipped" 3D-CT images is beneficial for enhanced anatomical understanding and intraoperative navigation.

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