Editorial

All things are created twice: the importance of planning and reproduction in sublobar lung resection

Masaaki Sato

Department of Thoracic Surgery, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan

Correspondence to: Masaaki Sato, MD, PhD. Department of Thoracic Surgery, The University of Tokyo Hospital, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan. Email: satom-sur@h.u-tokyo.ac.jp.

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Pulmonary lobectomy is an operation in which the anatomical resection is obviously defined by the common anatomy of pulmonary lobulation and hilar structures in most cases. Lobectomy has been the standard operation for lung cancer since the publication of the prospective, randomized, clinical trial by the Lung Cancer Study Group comparing lobectomy and sublobar pulmonary resections (including wedge resection and segmentectomy) in 1995 (1). However, accumulating data show no significant differences between lobectomy and sublobar lung resection in selected patient populations, such as those with nodules of ground glass opacity (2,3). Furthermore, the number of older and compromised patients, and patients with multicentric lesions is increasing, and so the clinical need for sublobar lung resection is increasing.

The technical challenge in sublobar lung resection is the ambiguity of anatomical definition of the resection area, and the resulting uncertainty in performing an appropriate resection with oncologically satisfactory resection margins, which affects local disease recurrence and patient survival (4,5). Unlike standardized lobectomy, the nature of sublobar resection entails difficulty in reproducibility. Although this critical issue is somewhat evident in wedge resection, especially in cases where the tumor is barely palpable, segmentectomies are also affected by issues with reproducibility (6). The pulmonary segments are not as obvious as the pulmonary lobes, and so there are many different methods proposed for the delineation of resection lines in anatomical segmentectomy (7-9). If the anatomical segments were as obvious as the lobes, segmentectomies would be better standardized and reproduced without such efforts.

Given the existence of such inherent uncertainty in sublobar lung resection, we have focused on how to make it more certain and reproducible. A recent article by Lachkar *et al.* entitled "Pleural dye marking using radial endobronchial ultrasound and virtual bronchoscopy before sublobar pulmonary resection for small peripheral nodules" described a novel technique with which to mark a pulmonary nodule that is anticipated to be barely palpable in thoracoscopic surgery (10). Their method is essentially an application of preoperative bronchoscopic localization (11,12), but uses both virtual bronchoscopy and radial endobronchial ultrasound (rEBUS). The procedure was conducted immediately before surgery after the induction of general anesthesia, and the time required for this procedure was generally short (10 minutes on average) (10). The marking was considered by surgeons to be indispensable for the performance of the surgery in most cases (84%) (10), suggesting that the surgeons had a high level of satisfaction with the technique and the outcome.

Stephen R. Covey stated that "*all things are created twice. There's a mental or first creation, and a physical or second creation to all things*" in the famous business book, "*The 7 Habits of Highly Effective People*" (13). The principle of this phrase also applies to surgery. I believe that the most important task

for surgeons to ensure that they achieve successful sublobar lung resection is preparation. Good preparation outside of the operation theater leads to high reproducibility of the surgery, which is essential for the operation to become standardized. In essence, the surgery is conducted twice: the first surgery outside of the operation theater (in our mind and on a computer/workstation), and the actual physical or second surgery. An important modality for such preparation is the recently developed virtual imaging technology. Three-dimensional imaging based on high-resolution CT images allows surgeons to preoperatively simulate the surgery. Visualization of the hilar anatomy, segments, and ideal resection lines in three-dimensional images enhances the quality of segmentectomy (14). Virtual bronchoscopy is a powerful tool with which to design bronchoscopic lung marking or mapping (12,15), and the resulting lung marking/mapping with dye (or any other method) is another level of preparation that bridges the first surgery in our mind and the second physical surgery by placing "physical preparation" on the patient.

Virtual bronchoscopy also has potential limitations in preparation for bronchoscopic lung marking. We previously demonstrated that bronchoscopic dye marks dislocate from the original planned positions by an average of 2–3 cm (16). Such dislocation seems to be more than a minor issue clinically. If a lesion measuring around 1 cm in diameter is targeted with a desired resection margin of 1 cm, dislocation of a dye mark of 2–3 cm may pose a substantial risk of acquiring insufficient resection margins. Such dislocation is primarily attributed to the limitation of virtual bronchoscopy that is based on the detection of a bronchial tree by a computer program. As far as I am aware, any currently available computer software or workstation can only recognize up to 7–12 generations of a bronchial tree, and the computer can barely distinguish the more peripheral bronchi from the surrounding lung tissue on CT images. In emphysematous lungs, this trend is further enhanced, resulting in a poorer depiction of the bronchus. However, in reality, the bronchial tree in humans branches up to 22–23 generations. This means that virtual bronchoscopy can give only a rough guidance if very peripheral lung tissue is targeted, as in bronchoscopic dye marking on the pleura. This issue may be overcome by the use of rEBUS in the method proposed by Lachkar *et al.* (10) by enabling actual visualization of the target lesion in the peripheral lung tissue. However, ultrasound imaging reportedly only identified half of the lesions (10). A balance must have been reached between the time required for tumor visualization and the accuracy of marking; if the authors had tried too hard to visualize the tumor by rEBUS, it would have taken a longer time to mark it. Alternatively, the main reason for using rEBUS might have been the use of the guide sheath for subsequent dye injection.

There are other methods that can potentially overcome the challenges facing the current virtual bronchoscope. Taking another CT image after bronchoscopic lung marking/mapping is probably the most reliable and straightforward way to confirm the actual location of marks and their relationship with the tumor (16). In the conventional method of virtual-assisted lung mapping, a bronchoscopic multi-spot lung marking method, we recommended post-mapping CT and three-dimensional reconstruction showing the relationship among multiple marks on the lung surface and the tumor (12,17). Although this strategy puts more emphasis on reproducibility than time consumption before surgery, this depends on where the intended target is. An alternative strategy is to use CT in the operation theater, if available (18). The use of an electromagnetic navigation bronchoscope might also enhance the accuracy of lung marking (19), even if CT was not performed.

At the very least, it is certain that some kind of marking/mapping technology makes a difference in sublobar lung resection compared with surgery without any such technology. There are multiple marking/mapping options available, and the choice depends on where the value is placed among the multiple parameters involved, such as time, cost, accuracy, and reproducibility. Further investigation and discussion are expected in this field.

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Footnote

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