

## What is the most appropriate procedure for intraoperative localization of small pulmonary nodules?

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Ciriaco and colleagues described some methods and advantages concerning the intraoperative localization for pulmonary nodules. The researchers previously reported the preoperative computed tomography (CT)-guided hook-wire localization method of pulmonary nodules (1). We thank them for mentioning our manuscript as an alternative method of resection for small nodules that require intraoperative localization.

To date, the hook-wire method has been widely used, and has become a more traditionally-used method. Similar to our institution, other institutions have also performed this method in patients who underwent wedge resections for a small non-palpable and non-visualized pulmonary nodule, because the method is very simple, easy, and highly accurate. However, though the incidence is rare, the hook-wire method may lead to complications, such as hematoma, pneumothorax, and air embolisms. Therefore, various methods have been developed to identify the tumor location, and the accuracy and safety of these methods were recently reported. For example, Zaman and colleagues reviewed previous reports regarding tumor marking (2), and concluded that radio-guided surgery is preferable to other methods, such as dye methods and ultrasonography. However, the accuracy of the hook-wire method is different in each institution, ranging from 58.0% to 97.6%, due to dislocation of the hook-wire. Furthermore, some complications occasionally occurred. Therefore, as

practitioners, we have to make every effort to avoid these complications and precisely resect the targeted tumors during the surgery preparation process.

Recently, a hybrid operating room was introduced at some institutions with a focus on intravascular therapy, such as endovascular aortic repair. Gill and colleagues reported the usefulness of findings from a prospective clinical trial of image-guided video-assisted thoracoscopic surgery (iVATS), which creates percutaneous markings with two T-bars via intraoperative C-arm CT (3). In this report, the accuracy was very high, and there were no complications; hence, it is expected that iVATS will become a highly utilized method in the future.

On the other hand, we recently proposed an alternative method, called anatomical segmentectomy, without any tumor markings (4). Once we accurately understood the anatomy of the pulmonary vasculature and bronchi using the three-dimensional (3D) CT simulation, tumor markings were deemed unnecessary, even when tumors could not be identified during the surgery. Specifically, the pulmonary artery and vein themselves may become alternative tumor markings, similar to the hook-wire. The precise understanding of each pulmonary vasculature has been identified both before and during surgery using this recent 3D reconstruction tool. As a result, we reported that both simple and complex segmentectomies were achievable (5).

Limited resection has been considered acceptable for

small pulmonary nodules in recent years. Among the small pulmonary tumors, nodules containing ground glass opacity (GGO) have been increasingly detected on high-resolution CT. These GGO-dominant nodules are believed to have a good prognosis. Noguchi *et al.* concurrently reported that wedge resection for small-sized non-small cell lung cancers with GGO have been associated with good outcomes (6). Moreover, in recent years, most GGO-dominant nodules have been shown to be adenocarcinoma *in situ* or minimally invasive adenocarcinoma, both of which have good pathological prognoses (7,8). Therefore, the procedure for small nodules may change from lobectomy to limited resection.

Limited resection procedures are mainly comprised of wedge resection and segmentectomy. Wedge resection has been widely performed to diagnose indeterminate nodules or cure small GGO-dominant tumors, because the procedure is simple and easy. However, some tumor markings are necessary to ensure the inclusion of the lesion in wedge resection when identifying the tumor location is difficult. Further, if a tumor is located in the deep parenchyma, the surgical margin might be insufficient in wedge resection.

Compared to wedge resection, segmentectomy tends to secure sufficient surgical margin, but is an obviously more complex procedure. When the tumor is located in the deep parenchyma, securing the surgical margin is sometimes difficult with wedge resection because the cutting depth cannot be identified during surgery. Therefore, we have indicated anatomical segmentectomy for the tumor located in deep parenchyma. Another merit of segmentectomy is less troublesome than wedge resection, because segmentectomy does not require the additional step of using a CT room before surgery. In segmentectomy, targeted vessels can be easily identified using 3D CT simulation. Concerning 3D CT simulation, Ciriaco and colleagues stated that the coordination between surgeons and radiologists is very important. However, we believe that 3D CT simulation should be performed by the surgeon, because the surgeon's view during surgery is different from a radiologist's. We emphasize that the surgeon should make the vascular reconstruction individually, and not the radiologist.

Moreover, a thoracoscopic approach is highly desirable as a minimally invasive option, especially in limited resection, because an invasive surgery, such as a thoracotomy, leads to unfavorable patient clinical outcomes. The thoracoscopic approach has better outcomes than thoracotomy with

regard to patient quality of life and complications, and is preferred over thoracotomy for its advantages of decreased postoperative pain, shortened chest-tube duration, shortened length of hospital stay, faster return to preoperative activity levels, and preserved pulmonary function (9). Therefore, the combination of limited resection and thoracoscopic surgery is in great demand.

When we perform a limited resection for small tumors, which procedure is better—wedge resection or segmentectomy? Currently, the selection of these procedures remains unclear. Demmy and colleagues proposed that tumor size and distance from the pleural surface were important parameters for successful identification of small nodules in thoracoscopic surgery (10). There is the possibility that wedge resection or segmentectomy will be selected based on the tumor size and distance from the pleural surface in the future. However, we presently select one of these procedures at a glance according to where the tumor is located, tumor size, and tumor properties. Accurate measurement of the distance from the pleural surface will also be necessary for selecting the appropriate procedure in the future.

In conclusion, it is important for a surgeon to independently plan and perform the limited resection. With the selection of procedures according to the tumor size and distance from the pleural surface, 3D CT simulation and iVATS will be helpful for segmentectomy and wedge resection, respectively.

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## Footnote

*Conflicts of Interest:* The authors have no conflicts of interest to declare.

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