Hybrid Theater and Uniportal Video-Assisted Thoracic Surgery

The Perfect Match for Lung Nodule Localization

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KEYWORDS

• Image-guided • Hybrid theater • Localization • Uniportal • Video-assisted thoracic surgery • Hook wire • Electromagnetic navigation bronchoscopy

KEY POINTS

- Uniportal thoracoscopic surgery is a minimally invasive option for managing small pulmonary nodules and is gaining in popularity globally.
- Intraoperative nodule localization can be problematic, increasing the necessity for adjuvant localizing techniques.
- Cone-beam computed tomography has the promising ability to visualize the target lesion and its surrounding critical anatomy with an error of less than 2 mm.
- Real-time imaging helps to increase the procedural accuracy of electromagnetic navigation bronchoscopy by identifying misplacement of and guiding biopsy tools deployment.
- Centralization of the hook wire placement with simultaneous resection inside the hybrid theater may reduce wire-associated complications and provide a promising, cost-effective solution.

Video content accompanies this article at http://www.thoracic.theclinics.com.

RATIONALE FOR LUNG NODULE MANAGEMENT IN THE HYBRID THEATER

For most of the pulmonary nodules discovered incidentally by thoracic imaging, the likelihood of them becoming malignant varies according to their size.[1] Despite the fact that small nodules tend to be benign rather than malignant, histologic diagnosis is strongly recommended for nodules that have a solid component greater than 5 mm or show enlargement on follow-up.[1] These nodules may require more invasive interventions regarding diagnosis and excision because of the low accuracy rate and false-negative biopsy samples via conventional percutaneous and bronchoscopic approaches. Furthermore, identification and excision of these small lung tumors, even by limited sublobar resections, can provide excellent prognosis.[2,3]

Disclosure: Z. Zhao and R.W.H. Lau declare no conflict of interest. C.S.H. Ng has an electromagnetic navigational bronchoscopy system SuperDimension Version 7 on loan from Medtronic.

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Thorac Surg Clin 27 (2017) 347–355
http://dx.doi.org/10.1016/j.thorsurg.2017.06.003

Single-port, or uniportal, video-assisted thoracic surgery (VATS), which is gaining popularity worldwide,[4–8] may be even more problematic for localizing pulmonary lesions. The single intercostal access not only causes instrument fencing[9] but could also significantly limit surgeons from effectively palpating lesions, especially when lesions are located away from the single incision, at a distance from the pleural surface or those presenting as part-solid lesions with high ground-glass opacity (GGO).[10] Therefore, preoperative adjunctive localization techniques such as hook-wire/microcoil placement or dye labeling conducted under computed tomography (CT) guidance have been widely used for identifying pulmonary lesions.

Nevertheless, these approaches inevitably increase the cost, complication, and complexity of care, all of which lead to a considerable logistic burden. The use of a hybrid operating room (OR) that can localize and manage an undetermined nodule in one suite would save time and cost, for example, by reducing hospital admissions, as well as reduce the rate of pneumothorax, marker dislodgement, and dye diffusion. Thus, a less invasive diagnostic and therapeutic option for patients could be provided.

PERFORMANCE OF INTRAOPERATIVE COMPUTED TOMOGRAPHY

When compared with conventional gantry-sized multidetector CT (MDCT), cone-beam CT (CBCT) has the advantage of multiaxis scanning, which is vital when off-plane access paths are required (eg, decubitus, semisupine).[11] The CBCT has been shown to offer equivalent accuracy to that of MDCT guidance for the transthoracic needle biopsy of lung nodules (96% vs 94%),[12] while maintaining similar effective dose, overall procedural time, and acceptable number of needle corrections.[13]

Modern mobile CBCT can provide submillimeter spatial resolution combined with soft tissue visibility even at a low radiation dose (~4.3 mGy per scan) for thoracic spine surgery.[14] However, the residual air in the collapsed lungs can make the visibility of pulmonary nodules in CBCT quite challenging. In 2013, Uneri and colleagues[15] proposed the 2-step deformable image registration for intraoperative CBCT to guide the targeting of small lesions in 12 porcine specimens under VATS. This study provided new insights into centralizing the localization, diagnosis, and treatment procedures in a hybrid OR. In detail, a robust model-driven method was used to match the pleural surface and bronchial structures between lung inflation and deflation, achieving a coarse localization of the target wedge with an associated error of less than 3 to 5 mm. Subsequently, a finer image-driven stage that used an intensity-corrected algorithm was used to decrease the registration error to 1 to 2 mm for both the target and surrounding critical structures.

The geometric accuracy quantified by the target registration error in the anatomic targets was 1.9 mm (95% confidence interval [CI] maximum = 5.0 mm) for the initial stage, and 0.6 mm (95% CI maximum = 4.1 mm) for the subsequent stage. Moreover, with a slightly increased dose (~4.6–11.1 mGy), the scan protocol demonstrated good visibility in deflated lung tissue. Therefore, clinicians would be confident in identifying a lesion regardless of its radiological density (eg, GGO) and could evaluate potential handicaps in the hybrid OR; for instance, whether there is a bronchus sign that indicates a direct route for biopsy via bronchoscopy, or if there are any adjacent vascular structures one should be aware of during percutaneous puncture.

Preoperative CT imaging could also be incorporated into the intraoperative CBCT, which may potentially provide intraoperative segmentation anatomy for a target lesion by aligning preoperative planning with on-table data.[16]

SETTING UP A HYBRID THEATER

The integration of real-time on-table image guidance technology into clinical practice is well established in other specialties, including cardiovascular and orthopedic surgery. Anecdotal reports of the use of a portable CBCT device to detect pulmonary lesions[17] have helped to inform the use of the hybrid technique in the field of thoracic surgery, although the technique may have shortcomings in that it lacks a predetermined scanning field, which may potentially lead to an increase in intraoperative radiation exposure.[10] The idea has also been tested in pediatric surgery.[18] The first comprehensive hybrid suite and procedural flow for thoracic surgery were introduced by the Brigham and Women's Hospital group in 2013, with the Advanced Multimodal Image-Guided Operating (AMIGO) suite[19] for image-guided VATS (iVATS). The 5700-square-feet AMIGO suite has 3 separate but integrated rooms that incorporate CT, MRI, near-infrared imaging, and PET, offering great assistance in the multidisciplinary treatment of a variety of diseases.

A relatively smaller suite (approximately 760 square feet) was established in the authors' hospital.[20,21] This OR also implemented a multidisciplinary design and had proven capable of