Review Article

Ultrasound for intraoperative localization of lung nodules during thoracoscopic surgery

Yu-Han Huang, Ke-Cheng Chen, Jin-Shing Chen

Department of Surgery, National Taiwan University Hospital and National Taiwan University, College of Medicine, Taipei, Taiwan

Contributions: (I) Conception and design: YH Huang, KC Chen; (II) Administrative support: JS Chen; (III) Provision of study materials or patients: YH Huang, KC Chen; (IV) Collection and assembly of data: KC Chen; (V) Data analysis and interpretation: KC Chen; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Ke-Cheng Chen, MD, PhD. Department of Surgery, National Taiwan University Hospital, No. 7, Chung Shan South Road, Taipei, Taiwan. Email: cskchen@gmail.com.

Abstract: In low-dose CT screening era, an ideal preoperative localization method is essential for resection of small and deep-seated pulmonary nodules by video-assisted thoracoscopic surgery (VATS). This article focuses on intraoperative ultrasonography localization method during thoracoscopy. Performing ultrasonography intraoperatively is a real-time and alternative approach to localize small, non-visible and non-palpable pulmonary lesions without injury to lung parenchyma. Its widespread usage has been limited due to the air in the lung parenchyma; however, its application can be useful in some conditions with guidance to find the lesion.

Keywords: Pulmonary nodules; ultrasonography; video-associated thoracoscopic surgery (VATS); localization; ground-glass opacity (GGO)

Submitted Jan 10, 2019. Accepted for publication Jan 17, 2019.
doi: 10.21037/atm.2019.01.41
View this article at: http://dx.doi.org/10.21037/atm.2019.01.41

Introduction

Lung cancer has been an important health issue worldwide and in Asian countries (1,2). For early lung cancer, video-assisted thoracoscopic surgery (VATS) has been adopted as an important tool in the treatment of this devastating disease through minimal invasive surgery. Low dose CT has been shown to be effective in the early detection of lung cancer, thus reducing mortality rates (3,4). However, the nodule requiring resection found out by screening is smaller and smaller. The difficulty of palpating makes VATS resection of deep-seated nodules or ground glass opacities hard. Successful VATS for the resection of pulmonary nodules depends on intraoperative nodule identifying by direct visualization or palpation in the past. With the increased use of low dose CT, greater numbers of small lung lesions were disclosed. Deep-seated solitary pulmonary nodules are difficult to palpate or to see during VATS. Ground-glass opacity (GGO) is the most difficult one among them (5,6). Not only size but also distance to the pleural surface can influence the nodule detection rate. Localization can lead to successful VATS lung resection, and it would be best if simultaneously during operation. CT-guided localization was once raised to be effective preoperatively (7-10). Nevertheless, it carries with some risks and suffering. Therefore, this report focuses on intraoperative ultrasonography localization method during operation.

Ultrasonography during video-assisted thoracic surgery

More and more solitary pulmonary nodules, either single or multiple, are needed to be confirmed. Compared with needle biopsy, video-assisted thoracic surgical resection of the entire lung tumor is possible, and it is allowed for pathological examination. The potential benefit of reduced morbidity can be diminished of video-assisted thoracic

surgery if missing the localization target lesion or spending a lot of time searching it. The spatial relationships of the nodule to landmarks are changed by intentional collapse of the lung during operation. It will increase the difficulty of operation, too. Intraoperative ultrasonography during VATS origins from laparoscopic surgery. Ultrasound is used to detect small, deep lesions in the lung or mediastinum and to stage lung lesions on the basis of the results obtained during laparoscopic procedures (11-13). Failure to detect a nodule may require conversion to thoracotomy (14). It ranged from 0.7% to 7.5% from the earlier literature (15). The percutaneous localization techniques consist of different materials injection or insertion, including methylene blue, colored collagen (16), fluorescent dye and hook wire localization. Nevertheless, they have the risks of pneumothorax, hemothorax and lung hemorrhage. Besides, hook wire dislodgment from the pulmonary parenchyma was noted from time to time. Also, it requires two different spaces including the computed tomographic facility and the operating room simultaneously (11-13). Intraoperative ultrasound was doubted in the lung for localization because the air in the parenchyma often inhibits proper ultrasound examination. However, high-frequency ultrasound probes can overcome the disadvantage and it is very accurate in small pulmonary nodules localization with the size of 20 mm or less (17). Generally, the inflated lung can prevent the use of intraoperative ultrasonography. The lesion can be visualized only when deflating the lung all the time. Moreover, careful suction of the airways can cause complete collapse of the lung which is useful for ultrasonography detection. Reducing residual air below the transducer by gently pressing on the lung surface with the ultrasound probe makes it possible to localize the lesion. In addition, multiplanar scanning of the area of interest can be allowed by the probe with a flexible tip (17). The target nodules with size more than 1 cm or large than 0.5 cm under the visceral pleura had a 63% detection failure rate during VATS (6). Another report (18) demonstrated that pulmonary lesions less than 1.5 cm in diameter if the distance from the pleural surface was large than 1 cm is also difficult to localize. Guiding both the linear stapler placement and the resection direction to complete surround the target tumor can be performed with aid of intraoperative ultrasound, too.

Small lung lesions can be found by intraoperative ultrasound when they are superficial, fixed in lung parenchyma, and solid. On the contrary, large but soft density tumor or GGO pattern could be more difficult to localize. Although complete collapse of the lung is essential to detect GGO by ultrasonography, detection is still hard in lung emphysema or poor pulmonary function patients. Ultrasonography during thoracoscopy to direct the resection of GGO was successful and can get good-quality ultrasound images in 56% of patients (19). Furthermore, GGO is similar to adjacent normal lung tissue in density and thus localizing them with ultrasonography is hard, even for experienced chest surgeons. Some pilot studies have measured the chance of detecting tiny pulmonary lesions including GGO with ultrasonography to define the limitation as well as to get the skills of chest surgeons better (20). Using the probe to press on the visceral pleura of the lung made us to eliminate the air around the tumor and to improve identification of GGO (21). Ultrasound disclosed pure GGO as hyperechoic lesion while part-solid GGO as mixed components with hyperechoic and hypoechoic lesion. It is particularly difficult to differentiate subtypes of adenocarcinoma of early lung cancer (21). Another new advancement evolves with robotic-assisted thoracoscopic surgery with da Vinci system. One China group showed intraoperative ultrasound equipped by robotic arm can achieve ultrasonographic localization for mixed ground-glass nodules with CT values of –500 to –100 Hounsfield units with an efficacy of 87.5% (22).

Intraoperative ultrasound with VATS has some disadvantages that could limit its widespread use. The application is a challenging procedure that requires a lot of training and experience, as well as the problems associated with the collapsed lung. However, with proper learning, surgeons are still able to precisely utilize the ultrasound examinations in the VATS, even combining with robotic-assisted thoracic surgery.

Conclusions

Thoracoscopy ultrasonography can localize invisible or nonpalpable lung tumors with great safety. However, it is particularly challenging for GGO lesions. It is an alternative one-step localization method and may assist in thoracoscopic lung surgery with increased accuracy.

Acknowledgements

Funding: This study was supported by Ministry of Science and Technology (MST 106-2314-B-002-241-MY2) and National Taiwan University Hospital and National Taiwan University College of Medicine (NTUH 107 FTN21) of the Republic of China.

Footnote

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

References

1. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2017. CA Cancer J Clin 2017;67:7-30.
2. RF Yen, KC Chen, JM Lee, et al. 18 F-FDG PET for the lymph node staging of non-small cell lung cancer in a tuberculosis-endemic country: Is dual time point imaging worth the effort? Eur J Nucl Med Mol Imaging 2008;35:1305-15.
3. Chen KC, Lee JM. Photodynamic therapeutic ablation for peripheral pulmonary malignancy via electromagnetic navigation bronchoscopy localization in a hybrid operating room (OR): a pioneering study. J Thorac Dis 2018;10:S725-30.
4. National Lung Screening Trial Research Team, Aberle DR, Adams AM, et al. Reduced lung-cancer mortality with low-dose computed tomographic screening. N Engl J Med 2011;365:395-409.
5. Reck M, Heigener DF, Mok T, Management of non-small-cell lung cancer: recent developments. Lancet 2013;382:709-19.
6. Suzuki K, Nagai K, Yoshida J, et al. Video-assisted thoracoscopic surgery for small indeterminate pulmonary nodules: indications for preoperative marking. Chest 1999;115: 563-8.
7. Tseng YH, Lee YF, Hsieh MS, et al. Preoperative computed tomography-guided dye injection to localize multiple lung nodules for video-assisted thoracoscopic surgery. J Thorac Dis 2016;8:S666-71.
8. Toba H, Kondo K, Miyoshi T, et al. Fluoroscopy-assisted thoracoscopic resection after computed tomography-guided bronchoscopic metallic coil marking for small peripheral pulmonary lesions. Eur J Cardiothorac Surg 2013;44:e126-32.
9. Chella A, Lucchi M, Ambrogi MC, et al. A pilot study of the role of TC-99 radionuclide in localization of pulmonary nodular lesions for thoracoscopic resection. Eur J Cardiothorac Surg 2000;18:17-21.
10. Sancheti MS, Lee R, Ahmed SU, et al. Percutaneous fiducial localization for thoracoscopic wedge resection of small pulmonary nodules. Ann Thorac Surg 2014;97:1914-8; discussion 1919.
11. John TG, Greig JD, Crosbie JL, Superior staging of liver tumors with laparoscopy and laparoscopic ultrasound. Ann Surg 1994;220:711-9.
12. Machi J, Sigel B, Zaren A, et al. Technique of ultrasound examination during laparoscopic cholecystectomy. Surg Endosc 1993;7:544-9.
13. Santambrogio R, Bianchi P, Opocher E, et al. Intraoperative ultrasonography (IOUS) during laparoscopic cholecystectomy. Surg Endosc 1996;10:622-7.
14. McKenna RJ Jr, Houck W, Fuller CB. Video-assisted thoracic surgery lobectomy: experience with 1,100 cases. Ann Thorac Surg 2006;81:421-5; discussion 425-6.
15. Mack MJ, Hazelrigg SR, Landreneau RJ, et al. Thoracoscopy for the diagnosis of the indeterminate solitary pulmonary nodule. Ann Thorac Surg 1993;56:825-30; discussion 830-2.
16. Nomori H, Horio H. Colored collagen is a long-lasting point marker for small pulmonary nodules in thoracoscopic operations. Ann Thorac Surg 1996;61:1070-3.
17. Santambrogio R, Montorsi M, Bianchi P, et al. Intraoperative ultrasound during thoracoscopic procedures for solitary pulmonary nodules. Ann Thorac Surg 1999;68:218-22.
18. Tamura M, Oda M, Fujimori H, et al. New indication for preoperative marking of small peripheral pulmonary nodules in thoracoscopic surgery. Interact CardioVasc Thorac Surg 2010;11:590-3.
19. Kondo R, Yoshida K, Hamanaka K, et al. Intraoperative ultrasonographic localization of pulmonary ground-glass opacities. J Thorac Cardiovasc Surg 2009;138:837-42.
20. Daddi N, Sagrini E, Lugaresi M, et al. Ex vivo pulmonary nodule detection with miniaturized ultrasound convex probes. J Surg Res 2016;202:49-57.
21. Fiorelli A, Messina G, Frongillo E, et al. The use of ultrasound in detecting and defining ground-glass opacities: results of an ex vivo evaluation. Interact Cardiovasc Thorac Surg 2018;26:551-8.
22. Zhou Z, Wang Z, Zheng Z, et al. An “alternative finger” in robotic-assisted thoracic surgery: intraoperative ultrasound localization of pulmonary nodules. Med Ultrason 2017;19:374-9.

Cite this article as: Huang YH, Chen KC, Chen JS. Ultrasound for intraoperative localization of lung nodules during thoracoscopic surgery. Ann Transl Med 2019;7(2):37. doi: 10.21037/atm.2019.01.41

