# Three-dimensional printing of navigational template in localization of pulmonary nodule: A pilot study

Lei Zhang, MD, Mu Li, MD, Zeyao Li, MD, Xiermaimaiti Kedeer, MD, Long Wang, MD, Ziwen Fan, MD, and Chang Chen, PhD

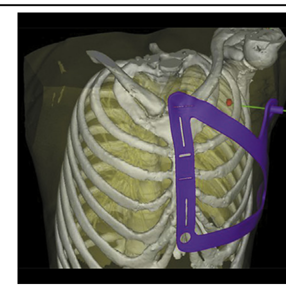
## ABSTRACT

**Background:** Small pulmonary nodules are a common problem, especially with the wide implementation of lung cancer–screening program. This poses a great challenge to thoracic surgeons because of the difficulty of nodule localization. We recently built an efficient, customized navigational template using 3-dimensional (3D) printing technology to facilitate the procedure of lung nodule localization. This study aims to investigate its feasibility in clinical application.

**Methods:** Patients with peripheral lung nodules (<2 cm) were enrolled. Preadmission computed tomography images were downloaded and reconstructed into a 3D model. A digital model of the navigational template was designed via computer-aided design software and then exported into 3D printer to produce physical template. The precision of the template-guided nodule localization and associated complications were evaluated.

**Results:** A total of 16 patients were enrolled, and 18 nodules were localized through template-guided localization. The success rate of lung nodule localization was 100%, and the median time of localization was 13 minutes (range 10-16 minutes). In our series, no significant complication occurred, except for 2 asymptomatic pneumothoraxes. The median deviation between the localizer and the center of the nodule was 10.0 mm, ranging from 5 to 20 mm.

**Conclusions:** This novel navigational template created by 3D printing technology is feasible, and it has acceptable accuracy for the application in lung nodule localization. The use of this navigational template could facilitate the procedure of lung nodule localization and may potentially break the dependence of percutaneous localization on computed tomography scanning. (J Thorac Cardiovasc Surg 2017;154:2113-9)



Lung nodule localization via a 3-dimensional printed navigational template.

**Central Message**

With 3-dimensional printing technology, a navigational template was designed and printed for small lung nodule localization and showed promising potential for clinical application.

**Perspective**

Localization of small lung nodules has become a real challenge to thoracic surgeons since the advancement of computed tomography technology used for lung cancer screening program. A 3-dimenstional printed navigational template in lung nodule localization could significantly facilitate the procedure of percutaneous lung nodule localization and may have the potential to alter the field of nodule localization.

See Editorial Commentary page 2120.



With the widespread availability of lung cancer–screening programs, small lung nodules have become much more prevalent in clinical scenarios. It is difficult to localize these nodules merely through palpation during video-assisted thoracoscopic surgery (VATS) because of their small volume and non-solid property.[1] Therefore, various preoperative localization methods have been developed to localize small lung nodule, allowing for wedge resection by VATS.[2-4] Among them, hookwire localization guided by computed tomography (CT) scan is currently the most commonly performed technique.[5] Despite its effectiveness,

Scanning this QR code will take you to the supplemental figures, video, and appendix for this article.

From the Department of Thoracic Surgery, Shanghai Pulmonary Hospital, Tongji University School of Medicine, Shanghai, People's Republic of China.

Supported by National Natural Science Foundation of China (NSFC 81570014).
Drs Zhang and Li equally contributed to this work.
Received for publication Jan 21, 2017; revisions received Aug 5, 2017; accepted for publication Aug 19, 2017; available ahead of print Oct 7, 2017.

Address for reprints: Chang Chen, PhD, Department of Thoracic Surgery, Shanghai Pulmonary Hospital, Tongji University School of Medicine, Shanghai 200443, China (E-mail: chenthoracic@163.com).

0022-5223/$36.00



http://dx.doi.org/10.1016/j.jtcvs.2017.08.065

**Abbreviations and Acronyms**
3D = 3-dimensional
BMI = body mass index
CT = computed tomography
VATS = video-assisted thoracoscopic surgery

it needs to be performed in CT room, like the other percutaneous localization methods, which to some extent increases the complexity of the procedure, burdens the radiology department, and exposes patients to extra radiation.

Hideo Kodama of Nagoya Municipal Industrial Research Institute[6] first described 3-dimensional (3D) printing technology in 1981. Since its invention, this technology has been used successfully for preoperative planning, intraoperative guidance, and medical education, showing promising potential in the medical field.[7-10] The application of 3D printing technology in medical field begins from designing 3D models, which usually are created by converting digitized medical images, such as magnetic resonance imaging or CT images, into computer-aided design software. Thus, it gives 3D printing the advantages of customizability and the ability to produce complex models.

With this knowledge in mind, we conceived using 3D printing technology to design a navigational template to mark the puncture site and angle of the localizer before lung nodule localization. If it were practical, we would be able to facilitate the process of lung nodule localization and may even localize the lung nodule outside the CT room. To test this idea, we designed and printed a novel navigational template for peripheral lung nodule localization using 3D printing technology. This article aims to demonstrate this novel template-guided nodule localization method and examine its feasibility in clinical application.

## PATIENTS AND METHODS

### Template Design and Printing

The design of 3D template model begins with the procurement of the patients' thoracic CT images. After obtaining patient's consent to participate in the study, we downloaded patient's CT images from Picture Archiving and Communication Systems. The CT scan with slice thickness of 1.5 mm was taken routinely for patients with small lung nodules in our hospital. We then used Bio3D software (Black Ship Technology, Co, Ltd; Shanghai, China) to process the obtained CT data and eventually reconstructed patient's thoracic 3D digital model, which was exported as stereolithography file. To process the patients' CT data, we integrated the spatial information of the target lung nodule into the digital model. Based on this thoracic 3D model, we developed the digital model of the navigational template.

Subsequently, we used computer-aided design software to mark the anatomical landmarks on the template to ensure its correct placement of this template on patient's thoracic wall (Figure 1). Detailed steps about the design of this customized template are described in Figures E1 to E6. After we finished the design of this 3D template model, the model was then printed by FS251P printer (Farsoon, Changsha City, China) with nylon (PA3200). The cost of creating 3D template per patient ranged from 80 to 100 US dollars. It usually took about 1 hour to develop the digital model of the customized template and 4 to 6 hours to print the physical copy depending on the size of the template. The physical copy of this template is shown in Figure 2, *A*.

### Study Population

Both the radiologist and the referring surgeon assessed the eligibility of the patients with peripheral lung nodule who required diagnostic pulmonary wedge resection by VATS between July 1, 2016, and September 30, 2016. The inclusion criteria were as follows: (1) the maximum diameter of the target lung nodule was less than 20 mm; (2) the minimum distance from the outer edge of the nodule to the nearest pleural surface was greater than 10 mm if the target nodule was solid but not subsolid (mixed nodule or pure ground glass opacity); (3) the target nodule was not located in the regions of the scapula where the bone structure impeded the percutaneous localizer; and (4) the inner edge of the target nodule was at least 2 cm away from major pulmonary arteries and veins to allow secure lesion excision.

If the inclusion criteria were met, a trained research assistant approached the patient, as a potential study participant, at least 2 days before the scheduled surgery. The patient was then informed about the risks and benefits of the procedure, and written informed consent was obtained. Once the patient consented to participate in the study, we started the process of template design and production, which took about 1 day to complete. The Institutional Review Board (IRB No. K16-302) at Shanghai pulmonary hospital approved the study.

### Localization Procedure

An interventional radiologist and surgeon performed preoperative localization in radiology department on the day of the surgery. After positioning the patient, the navigational template was placed on the patient's thoracic wall (Figure 2, *B*). During this step, the practitioner needed to carefully identify patient's anatomical landmarks to guarantee the correct placement of the navigational template. In the next step, we immobilized the navigational template to patient's thoracic wall by using medical adhesive tape in case of incidental deviation.

Subsequently, an initial CT scan was performed and the practitioner pre-evaluated the precision of template-guided localization by drawing an imaginary line from the puncture point toward the lung. Subsequently, the deviation between the imaginary line and the center of the target nodule was measured (Figure 3, *A*). Based on our previous experience of CT-guided localization, deviation of less than 2 cm was considered precise enough to allow for safe nodule localization. Afterward, we administered local anesthesia and inserted the hookwire after patient's deep inspiration. However, if deviation of more than 2 cm was found on the initial CT scan, it was recorded as the failure of the template-guided method; hence, routine CT-guided hookwire localization was used to localize the target lung nodule.

After the completion of nodule localization, a second CT scan was performed to confirm the correct insertion of the localizing needle, check for pneumothorax and hemorrhage, and evaluate the precision of nodule localization by measuring the deviation from the localizer to the center of the target lung nodule (Figure 3, *B*). The length of procedural time was measured from the time a patient was lying on the examining bed of the CT scanner to the time he/she received the second CT scan to confirm the localizer placement. Detailed information about the procedure of template-guided nodule localization was presented in both Appendix E1 and Video 1.

### Statistical Analysis

Continuous data were expressed as the median with interquartile ranges and analyzed with the Mann-Whitney *U* test. Categorical variables were analyzed with the Fischer exact test. All statistical analyses were 2-tailed