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3D PRINTING REALISTIC ENDOBRONCHIAL MODELS FOR SURGICAL PLANNING AND SIMULATION

Zhuo Zhao
School of Electrical and Computer Engineering,
The University of Georgia.
Athens, GA, USA

Javier Coronel Baracaldo
Department of Informatics, Technische Universität
München, Germany

Juliana Palacio Varona
Universidad de los Andes School
of Medicine
Bogotá, Colombia

Roberto Rueda-Esteban
Universidad de los Andes School
of Medicine
Bogotá, Colombia

Zion Tsz Ho Tse
School of Electrical and
Computer Engineering, The
University of Georgia;3T
Technologies LLC
Athens, GA, USA

BACKGROUND

Lung cancer is the second most common cancer in both men and women globally. More than one million lung cancer cases are diagnosed worldwide each year. The leading cause of cancer death is lung cancer in the United States and worldwide [1]. According to the American Cancer Society, there were an estimated 222,500 new cases of lung cancer and 155,870 deaths from lung cancer in the United States in 2017. Early detection and diagnosis, as well as accurate localization in lung intervention, are the keys to reducing the death rate from lung cancer [1].

Computer-assisted interventions (CAI) have been on the rise for lung interventions in recent years since they offer many advantages, such as increased accuracy, reduction of complications and decreased intervention time. Within the field of CAI, freehand navigation or guidance for localization of medical devices can be achieved through image-guided therapy (IGT) [2]. Fluoroscopy, ultrasound (US) images, magnetic resonance (MR) images, and computed tomography (CT) images are traditional methods used in lung interventions for position and orientation of medical tools. Nevertheless, these methods can be imprecise and inaccurate, since they cannot provide real-time position and orientation feedback without continually imaging the patient [3]. To improve the accuracy of lung interventions, real-time tracking medical tools have been developed, such as electromagnetic tracking catheters. Due to the complex structure of the airway and lack of experience of using these tools, it is necessary for doctors to practice operating these tools before using these tools in clinical applications.

In this study, it was hypothesized that inexpensive and patient specific lung airways phantom could be rapid-prototyped using 3D UV resin printing for pulmonologists to plan and simulate endochonchial interventions.

METHODS

To reduce the cost and ensure the fabrication process is easily repeatable for patient specific lung models, 3D printers were used to print our lung airways phantom.

1 Model Design

To achieve high quality 3D printing, lung airways were first segmented. Two lung airways models were acquired for comparison. One was from the database of the National Institutes of Health (NIH) medical images, and the other was from Coronel *et al*. [4]. Since the lung airways in both model was solid, an STL editor software, Meshmixer, was used to recreate the inner walls of the airways. The final models and its dimension are shown in Fig 1.

2 3D Print

Form 2 3D printer (Formlabs, Cambridge, MA) was used to print the revised Coronel's lung airways model. As a comparison, a Lulzbot 3D printer (Aleph Objects, Inc, Loveland, CO) was selected to print the NIH model.

3 Flexibility Test

After comparing two phantoms, a clear acrylic enclosure was used to fix the lung phantom. A steerable ablation catheter with diameter of 2.5 mm was used to evaluate the usability of the phantom for endobronchial procedures.

RESULTS

The final printed phantoms are shown in Fig. 2 (a) and (b). Fig. 2 (c) shows the selected lung airways phantom with the steerable catheter inside. Characteristics of two phantoms printed by two 3D printers are compared in Table. 1.

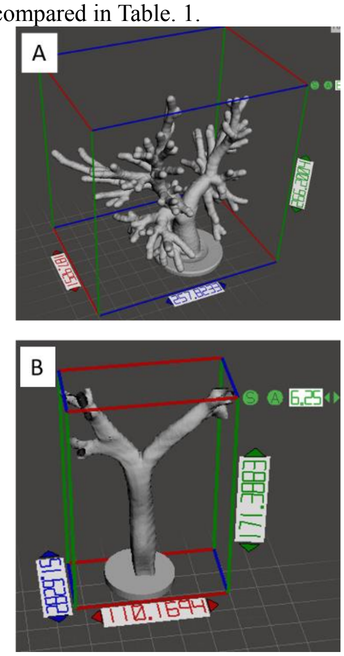

Fig. 1. Revised lung airways models (unit: mm): (a) based on NIH model, (b) based on the work of Coronel *et al*. [4].

INTERPRETATION

Table 1 shows the comparison of the two airways models. For Coronel's model clear resin in the FormLabs 3D printer could provide a smooth surface, high resolution, and completely transparent phantom. This method could provide direct visualization of the catheter position and orientation relative to the targeted region of interest in the airways when compared with the NIH model (Fig. 2 (c)).

Table. 1 Characteristic comparison between two phantoms

Characteristics	NIH model	Coronel's model
Dimension (mm)	256×266×187	110×171×52
Printing Time	53 hours	10 hours
Cost of material / money	350 g / $18.2	25.73 mL / $3.83
Resolution	0.2 mm	0.05 mm
Surface	Rough	Smooth
Transparency	Opaque	Completely transparent

The catheter was able to go through all airways in this phantom. The position and orientation of the tip of the catheter could be clearly seen even without image-guided software (Fig. 2 (c)). Therefore, pulmonologists could feasibly plan and simulate the procedure with their medical tools using the presented airways phantom.

This study has developed an inexpensive, and patient-specific lung airways phantom for clinical procedure planning and simulation. In the future, CT images of this phantom will be acquired. Then image-guided software will be combined with the developed lung airways phantom to provide a more realistic medium for practicing invasive lung interventions with real-time tracking medical tools. In addition, this can provide a convenient way for researchers to calibrate and evaluate new medical tools for invasive lung interventions.

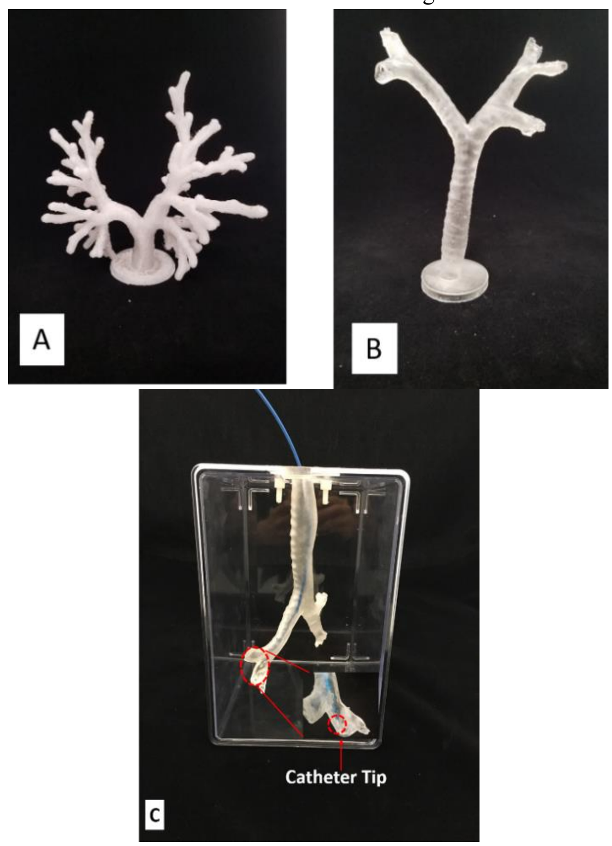

Fig. 2 3D printing lung airways phantoms. (a) Based on revised NIH model, (b) based on revised Coronel's model, (c) fixed lung airways phantom and evaluating process.

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