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The capabilities of modern rapid prototyping tools for developing training of computed tomography 3-d models in phthisiology

Jiao Hankun*[a], Maksym Tymkovych[a], Oleg Avrunin[a], Olga Shevchenko[b], Irina Moroz[c], Olena Nanaka[d], Saule Smailova[e], Aida Uvaysova[f], Konrad Gromaszek[f]
[a]Kharkiv National University of Radio Electronics, Nauky Ave, 14, 61166, Kharkiv, Ukraine; [b]Kharkiv National Medical University, Nauky Ave, 4, 61000, Kharkiv, Ukraine; [c]Kharkiv National Automobile and Highway University, Yaroslava Mudrogo St. 25, 61002, Kharkiv, Ukraine; [d]Vinnytsia National Technical University, Ave. Khmelnytskeshose, 95 Vinnytsia, 21021, Ukraine; [e]D. Serikbayev East Kazakhstan Technical University, Ulitsa Serikbayeva 19, Ust'-Kamenogorsk 070000, Kazakhstan; [f]Lublin University of Technology, ul. Nadbystrzycka 38D, 20-618, Lublin, Poland

ABSTRACT

The development of such a model of the human lung allowed to master the technology of recreating anatomical structures based on personalized data of spiral computed tomography taking into account individual variability, which can be useful in determining the volume of pathologically altered areas and planning treatment. These approaches also make it possible to significantly improve the technology of training medical and bioengineering specialists.

Keywords: planning treatment, medical training, model, computed tomography

1. INTRODUCTION

The widespread introduction of rapid prototyping technology takes the development of medicine to a new level. 3D modeling technologies also make it possible to study the architectonics of anatomical areas on full-scale models and preoperative planning of surgical interventions on personalized phantoms[1, 2]. The development of 3D models and the creation of various organs from biocompatible materials, and in the short term, living tissues expand the possibilities of transplantology[3, 4]. Such systems are widely used, for example, in otorhinolaryngology for natural modeling of the upper respiratory tract[5, 6] and allow research on real aerodynamic models[7]. Therefore, when preparing specialists in biomedical engineering, it is advisable to widely introduce 3D printing into the learning process to familiarize students with the modern capabilities of rapid prototyping tools, 3D modeling programs, 3D printing principles, and 3D scanning [8, 9]. Due to the prevalence of respiratory diseases in phthisiology, there is the task of training specialists who can determine the presence of certain pathologies using intrascopic images[10,11,12]. In this, phantom modeling based on real tomographic images of lung patients can provide substantial assistance, allowing to obtain full-scale models not only in normal conditions but also taking into account individual variability and the presence of a specific pathology.

2. MATERIALS AND METHODS OF STUDYING

The aim of the work was to develop full-scale models of the human lung using rapid prototyping tools [18,19]. The initial data were spiral-computed tomographic sections of the lung area, presented in the DICOM format, which allowed the actual physical dimensions of the internal organs to be compared. Examples of coronary and frontal sections of the lung are shown in Figure 1a, and 1b, respectively.

The data were loaded into specialized software Slicer3D, which allows performing various operations on three-dimensional medical data, in particular on tomographic research. With the help of the image segmentation module, cut-off segmentation of the lung area was performed. Then, using the boundary selection method, only the areas of transition from low to high density were left. It should be noted that the thickness of the transition surface formed was chosen on the assumption that the volume of the model would be reduced by 5 times [13,14].

*e-mail: 1350829683@qq.com

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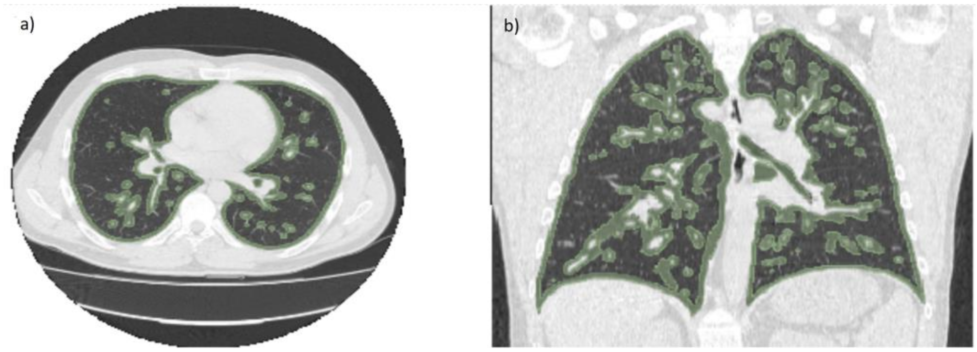

Figure 1. Visualization of the lungs according to spiral computed tomography: a) coronary section, b) frontal section.

3. RESULTS AND DISCUSSION

When constructing a too thin transition area, there is a probability of impossibility of its three-dimensional printing. As a result of segmentation, a three-dimensional model of the lungs was obtained in the STL format, shown in Figure 2, and its segmentation was carried out to eliminate visualization artifacts (Figure 2, b). Using the FreeCAD software, the bracket was modeled in real physical dimensions, which was later merged into one model with the lungs [15,16,17].

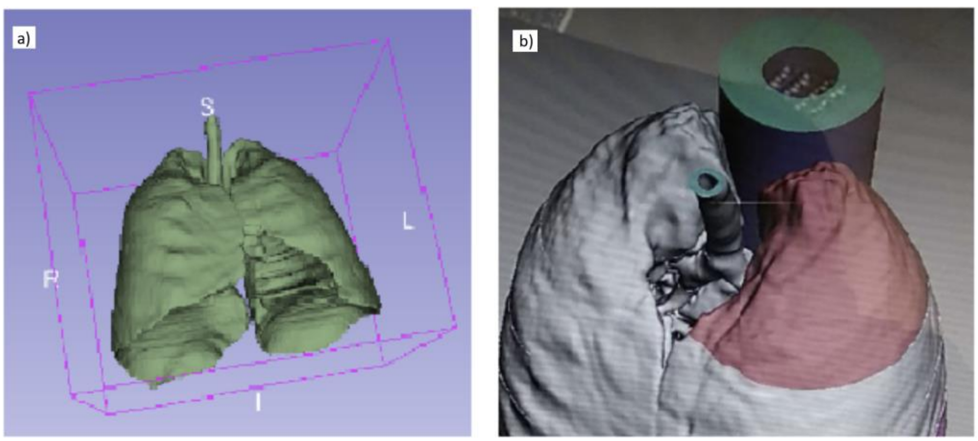

Figure 2. Visualization of a 3D model of human lung: a) a geometric volumetric model, b) a segmented model of the lung region before layering separation for printing.

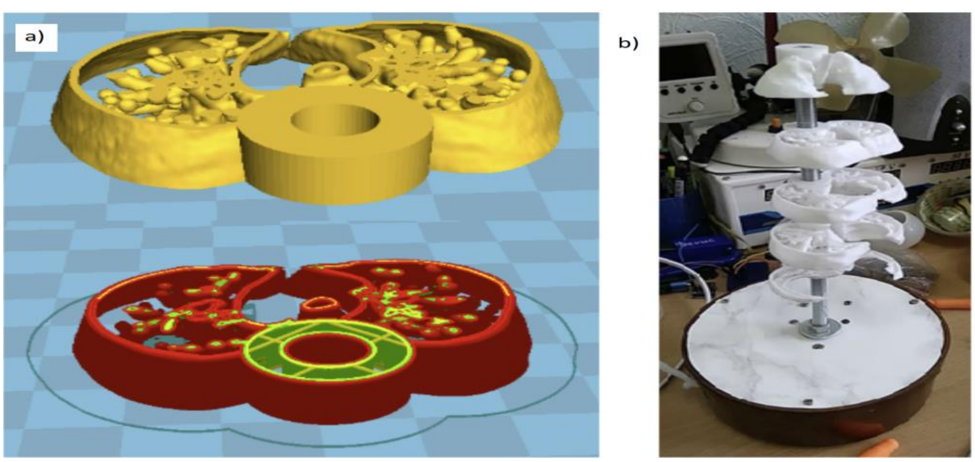

Figure 3. Stages of preparation of the lung model for printing: a) layered presentation of the model; b) ready-made full-scale model of the lungs.

Next, the resulting model was loaded into the specialized software MeshMixer[20,21], which allows you to perform various manipulations on the three-dimensional models before printing. With its use, the model was divided in the horizontal plane into five parts (see Figure 3, a), which are of the greatest interest. After that, each part was transformed into a G-code using a Cura slicer, and printed with PLA-type plastic on a three-dimensional Wanhao Duplicator i3 printer. Then the printed parts were combined together using a guide, the rotation of which is controlled by the microcontroller. The resulting model is presented in Figure 3b.

An illustration of prototyping a single slice of the lungs is shown in Figure 4, and Figure 4 shows a computer model of the lungs loaded into the 3D Slicer program, and Figure 4b shows a printed full-scale model.

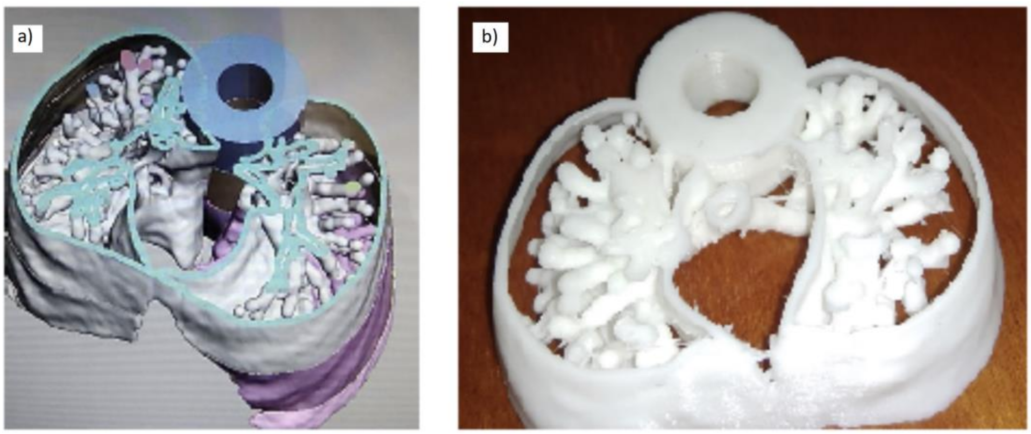

Figure 4. Illustration of prototyping a single slice of a full-scale lung model: a) computer model; b) printed full-scale model.

4. CONCLUSION

The development of such a model of the human lung allowed us to master the technology of recreating anatomical structures based on personalized data of spiral computed tomography taking into account individual variability, which can be useful in determining the volume of pathologically altered areas and planning treatment. These approaches also make it possible to significantly improve the technology of training medical and bioengineering specialists. The perspective of the work is the creation of a set of full-scale models of the lungs with typical pathologies and developmental abnormalities that can be used to teach diagnostics of respiratory diseases.

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