PERSONALIZED 3D ANATOMICAL MODEL FOR PULMONARY SURGERY

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Introduction

Lung cancer is the most common type of tumour and the leading cause of cancer death worldwide [1]. Patients with early-stage non-small cell lung cancer should be treated with minimally invasive techniques, whenever possible [2]. The most used technics are segmentectomy (excision of a section of a lung lobe) and lobectomy (removal of an entire lobe). Both techniques require isolation and resection of hilar structures including pulmonary arteries, pulmonary veins and bronchi [3]. Vascular and bronchial anatomical variations are common, thus knowledge of them could aid in planning and performing interventional procedures [4]. 3D printing and cast moulding technologies are rapidly growing and transforming the medical industry and they could be useful in developing models for surgical planning and training in lung procedures [5].
This work introduces a personalized 3D anatomical model for planning lung lobectomy surgical interventions. The objective is to provide surgeons with a 3D representation of the lung anatomy and pulmonary vascular structures involved in lung lobectomy. This model could be used by surgeons to understand and study the patient anatomy and the possible anatomical variations prior to the surgical operation. In addition, the model could be used for educational purposes, and for training and retraining on specific surgical skills, such as pulmonary vessel isolation and resection, which are commonly done during pulmonary surgery procedures.

Methods

Figure 1 summarises the steps to create the patient's personalized 3D model. Starting from the segmentation of the anatomical structures by using a high-resolution CT scan, the 3D Slicer software, along with the available *CTACardio* CT scan, was utilized for obtaining the patient's anatomical model. The images were segmented using the *Paint* and *Grow from seed* functions. The first one allowed to select the anatomical regions of interest, the second one to reconstruct the 3D anatomical model. The obtained meshes were imported in Fusion 360 (Autodesk, USA) for 3D design. The meshes were refined to obtain *high* resolution to identify the smallest structures (diameter of 2 mm) and assure printability. Being vascular structures prone to anatomical variations, we focused on those structures. The model can be made both of rigid and soft materials. The rigid version accurately replicates the patient's anatomy, while the soft one allows to create high-fidelity replicas in terms of biomechanical properties. The rigid model is 3D printed without any additional step, obtaining a complete model of the anatomy (blue part of Figure 1). For the soft replica, a mould of the model must be first fabricated for silicone injection. To choose the right silicone, biomechanical data from porcine samples were used as reference [6]. The soft replica, alone or combined with anatomical rigid components, could be also used as a smart training platform for residents and young surgeons. However, once the isolation and resection tasks are performed on the model, it becomes single-used. This is explained in the light blue part of Figure 1.

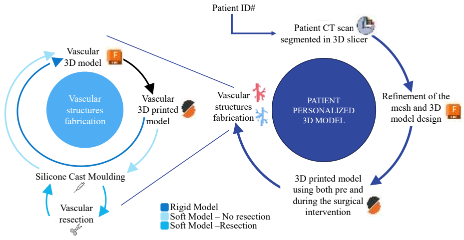

Figure 1: Schematic representation of the procedure to realize the patient personalized 3D model.

Results

In Figure 2, the printed patient-specific model - in scale 1:2 - is depicted along with the 3D representation of the rigid components. The mould for the soft replica was also realized and 3D printed using Polylactic acid for further silicone injection. Considering the mechanical properties of porcine vein and artery, Smooth On Silicones, e.g. Ecoflex 00-30, were chosen providing a good compromise in terms of flexibility and biomechanical properties.

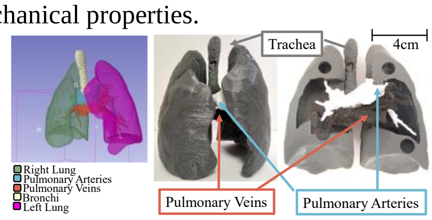

Figure 2: Segmentation of the lungs and vascular structures in 3D Slicer and 3D printed representation.

Discussion

The presented work introduces a patient-specific 3D model of lungs and hilar structures. The model can be proposed both for surgical intervention planning and surgical training.

References

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