Computer-aided Preoperative Pulmonary Segment Analysis for Segmentectomy Based on CT Images

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Abstract. We proposed a preoperative analysis of pulmonary segment for safer segmentectomy. With image processing functions including serial lung CT image segmentation and vessel extraction, a three-dimensional interactive lung model is reconstructed for further pulmonary segment analysis. By human-computer interaction, it is able to obtain vascular territory information which provides the key factor for determination of pulmonary segments and volumetric assessment of each segment. The result shows a promising application of preoperative pulmonary segment analysis in lung surgeries.

Introduction

Lung cancer is cancer that starts in the trachea, bronchus or the lung tissue, and it is the leading cause of cancer death. In 2012, 1.8 million people had been diagnosed with lung cancer and 1.6 million deaths occurred because of it globally [1]. Lung cancer is treated in several ways, including surgery, chemotherapy, radiation therapy, targeted therapy, or a combination of these treatments [2]. Lung surgery is an operation which generally involves removing a portion of the lung (lobotomy, segmentectomy, and wedge resection), the entire lung (pneumonectomy) or a sleeve resection for some cancers in the large airways in the lungs [3]. The type of operation depends on the size and place of the tumor and on the patient's lung function.

Studies have shown that segmentectomy is becoming a more effective treatment for certain small, early-stage lung cancer [4-6]. It is essential for the surgeons to understand the anatomic features of the pulmonary segments along with the vascular branches before performing safe and precise segmentectomy.

In this study, we present an easily accessible computer-aided preoperative pulmonary segment analysis for lung surgery mainly including three parts: 1) lung segmentation and vessel extraction; 2) vascular branch and territory calculations; and 3) pulmonary segment analysis.

Methods

The lungs are the main organs located on either side of the heart within the chest cavity. Left lung has two lobes divided into nine segments. The right lung is bigger than the left and it has three lobes divided into ten segments. The following
experiment results are using the right lung based on the CT images of a patient for example.

**Lung Segmentation and Vessel Extraction**

Lung segmentation and vessel extraction are the most fundamental step for reconstructing a 3D lung model for preoperative planning. In our study, a modified fast marching method (FMM) is used to perform the lung segmentation [7]. The procedure of lung segmentation is nearly fully automatic which only needs one seed point to begin with. The FMM mainly depends on the curve-fitting algorithm and takes the lung shape continuity as well as comparability into account. The FMM parameters are obtained from contiguous slice outcome to segment the pulmonary parenchyma from surrounding tissues.

The original CT image and the segmentation result marked in yellow are shown in Fig. 1(a) and Fig. 1(b). And the 3D reconstruction of the right lung is shown in Fig. 1(c) and Fig. 1(d).

A refined region growing algorithm is used for the extraction of pulmonary artery, pulmonary vein and bronchi. The extraction results are shown in Fig. 2(a), Fig.2(b), Fig. 2(c) and the Fig. 2(d) is the anatomic structure of these three parts.
The bronchi branch again and again into ever-small bronchioles which would be fading and undetected in the CT images. Therefore, we use the branches of pulmonary artery as the basis for distinguishing the pulmonary segments. By human-computer interaction, we proposed a method for surgeons could pick up certain nodes in the pulmonary artery to build a tree-like structure of vascular branches and territories [8]. Based on the information of vascular territory, the pulmonary segments of the right lung could be determined automatically with a multiple background distance transformation algorithm and the volumetric assessment of each segment could be further calculated. The Fig. 3(a) and Fig. 3(b) are the results of pulmonary segment determination. And Fig. 4(a) and Fig. 4(b) give each segment and corresponding volume.
Precise analysis of pulmonary segments is critical important to the success of segmentectomy of the lung. A series of steps including lung segmentation and vascular extraction along with 3D lung model reconstruction are conducted in our study for pulmonary segment determination and volumetric assessment. The method of preoperative pulmonary segment analysis is useful for planning lung surgery and has been used in clinical applications.

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