A rule-based scheme for detection of accessory cardiac bronchus in chest computed tomography images

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Abstract. Accessory cardiac bronchus (ACB) is a rare bronchial anomaly. This anomaly often is left undetected due to its low frequency and no symptom in almost cases. ACB should be diagnosed because it sometimes causes infection and/or hemoptysis. In this paper, we presented a rule-based and 2D based scheme which detects ACB in chest multi-slice computed tomography volume data.

We have developed a computer aided detection scheme of ACB. This scheme performs extraction of bronchial tree structure, determination of trachea bifurcation, and detection of ACB on right bronchi.

Nine cases were obtained to evaluate this scheme on sensitivity and specificity. Three of them have ACB, another three of them have tracheal bronchus and no ACB, and the other three cases were normal cases. All of the cases were performed with MSCT scanners (LightSpeed Ultra 16 and LightSpeed Plus; GE Medical Systems, Milwaukee, WI, USA) using a contiguous slice thickness of 2.5 mm. We also measured time to perform the scheme to a case on a personal computer (CPU: 2.4 GHz Pentium4, Memory: 1 Gbyte and OS: Redhat linux 9).

The scheme could detect ACBs on two cases of the three ACB cases (Sensitivity: 66.7%), and all of the cases without ACB were identified as no ACB (Specificity: 100%). The mean processing time was 13.5 seconds (SD: 6.4) per a case. The time would not be too long to wait for finishing, so that this scheme can use before actual diagnosis.

Keywords: Accessory cardiac bronchus; bronchial anomaly; Computer aided detection; rule-based scheme

1. Introduction

Accessory cardiac bronchus (ACB) is a rare bronchial anomaly. It originates from the inner wall of right main bronchus or intermediate bronchus and progresses toward the pericardium. Presently, many chest examinations of multi-slice computed tomography (MSCT) have been performed, but this anomaly often is left undetected due to its low frequency and no symptom in most cases. Frequencies of 0.08-0.66% of ACB were reported in several papers [1-3]. ACB, of course, should be diagnosed because it sometimes causes infection and/or hemoptysis. Detecting ACB is not difficult task if its existence is known because the location of ACB is the almost same in any cases. Thus, a tool which checks existence of ACB and indicates a candidate before actual film reading will be useful.

Two papers described methods of anatomical labeling of bronchus [4, 5]. They used three dimensional (3D) center lines of thoracic airway tree to label the branches of the thoracic airway tree. Those methods were proposed for a navigation system of bronchoscopy and for morphology analysis. 3D processes, especially getting 3D center lines of objects, usually take long computational time, so that it is not suite for pre-checking before actual film reading.

In this paper, we presented a scheme to detect ACB in chest MSCT volume data. It's a rule based and two dimensional (2D) based method. The scheme indicates a slice including ACB if it exists.

2. Materials and Methods

Nine cases were retrospectively obtained to develop and evaluate a detection scheme of ACB. Three of them have ACB, another three of them have tracheal bronchus and no ACB, and the other three cases were normal cases about bronchial branching. Tracheal bronchus is another bronchial anomaly and has several type of branching. Two types of the tracheal bronchus originate from trachea [2]. We are also trying to develop a detection scheme of tracheal bronchus. All of the cases were performed with MSCT scanners (LightSpeed Ultra 16 and LightSpeed Plus; GE Medical Systems, Milwaukee, WI, USA) using a contiguous slice thickness of 2.5 mm. Cross sectional images of 99-143 slices on a case were obtained. These images were 512x512x16bit (pixel size: 0.586, 0.6836 or 0.781 mm) images

2.1 Detection scheme of ACB

A rule-based and 2D based scheme was developed to detect ACB. It informs operators a slice number of the slice showing ACB in MSCT volume data if an ACB exists in the case. The scheme is shown in Fig. 1.

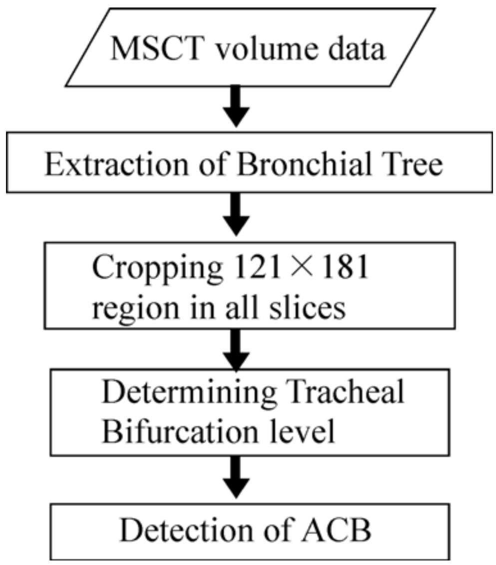

Fig. 1: Scheme of ACB detection

2.1.1 Extraction of Bronchial Tree

A bronchial tree is extracted from MSCT volume data with the region growing technique in 3D space, and then it is binarized. Only a seed point (a start point of the region growing process) has to be indicated by a operator. The seed point should be placed inside tracheal air way usually in the top of the volume data set. An upper threshold value is calculated from mean and standard deviation (SD) of pixel intensities around the seed point. We tried mean plus SD through mean plus five times SD, and determined use of mean plus three times SD as the threshold. The region growing process sometimes leaks at distal bronchi into lung. But the leak is not a problem for this detection scheme because this scheme tracks only a trachea and a right bronchus.

2.1.2 Cropping 121x181 region in all slices

A 121x181 region of interest based on the X and Y coordinates of the seed point is extracted in each slice to reduce processing time. Diameters of tracheas are generally about 20 mm, so that three times the diameter was chosen as the width of the cropping area including margins (we have pixel size of 0.5x0.5 mm^2, so 120 pixels). The 120 pixels plus a center pixel is equal to 121 pixels. Extra 60 pixels (30 mm) were added to the width to get the height of the cropping area because a tracheal region shifted downward up to 30 mm in volume data in our preliminary measurement. The 121x181 area is enough to include a trachea and also ACB.

2.1.3 Detection of Tracheal Bifurcation level

ACB originate from inner wall of a right main bronchus or an intermediate bronchus. To detect ACB, it is necessary to recognize the tracheal bifurcation in the extracted tracheal tree first.

To determine the slice level of tracheal bifurcation, a labeling procedure is applied to all of the 121x181 images and the trachea regions in the images are tracked from the top to the bottom. The tracking starts from the region including the seed point which was indicated for the extraction process and goes to the bottom along the trachea. Labels of the pixels in the same area as the tracheal region in a previous slice are checked, and then, if two kinds of labels are found, the slice may be the tracheal bifurcation level. When the tracheal region is divided into two regions, and if the area of the larger one of the divided regions is not exceeded four times the area of the other region, it determines that the slice is the tracheal bifurcation level. The criterion of area avoids identifying a tracheal bronchus as the bifurcation. The centers of mass of the divided regions are calculated to identify the right main bronchi after getting tracheal bifurcation level.

2.1.4 Detection of ACB

The right main bronchi region is tracked from the tracheal bifurcation slice as well as the tracking way for trachea to find a branch originating from the inner wall. This detection scheme of ACB keeps tracking until the end of the intermediate bronchus. When the tracking encounters a bifurcation (Fig. 2), a vector which goes from the center of mass of the larger region to that of the smaller region is calculated. If the vector and the X axis make an angle between -30 deg and 30 deg., i.e., heading for anatomical inside, this scheme determines that the smaller region is a part of ACB and informs that slice number. If not, this scheme recognizes the bifurcation as the end of the intermediate bronchus.

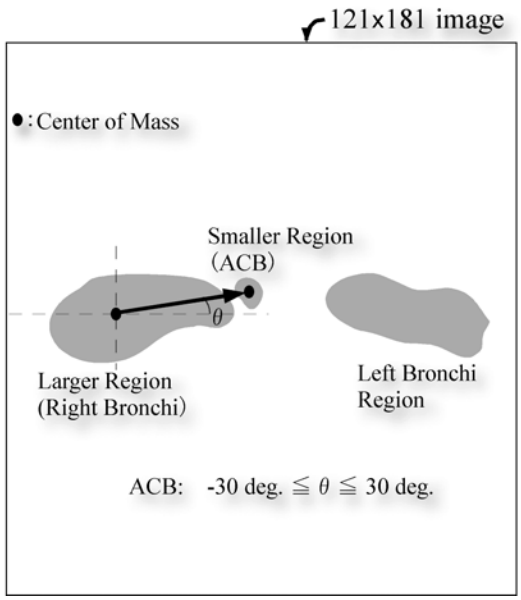

Fig. 2: Determination of ACB
The smaller region is determined as an ACB region if the θ, the angle between the vector and the Y axis, is between -30 deg. and 30 deg.

2.2 Evaluation

We applied this scheme to the nine cases, and sensitivity and specificity were measured to evaluate accuracy of this scheme. We also measured computation time to apply this scheme to a case on a personal computer (CPU: 2.4 GHz Pentium4, Memory: 1 Gbyte and OS: Redhat linux 9)

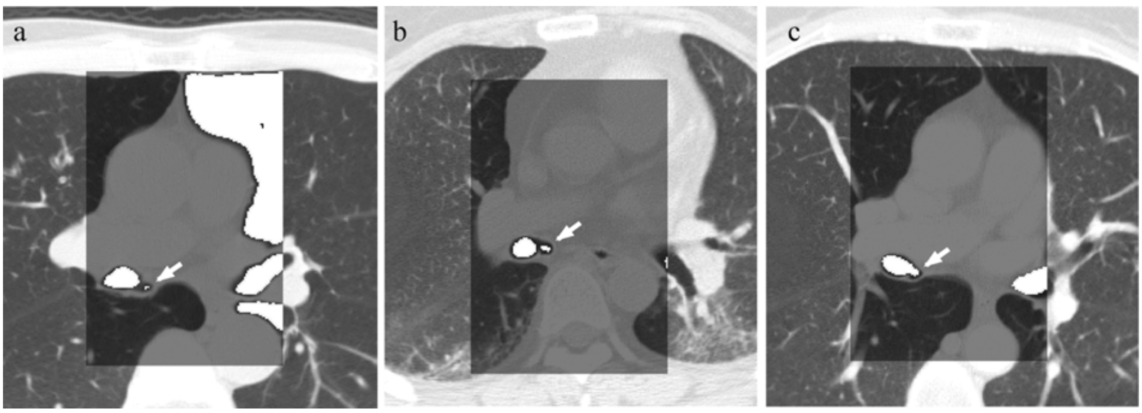

Fig. 3: Results for ACB cases

Darker rectangular regions in the images are the 121x181 cropped regions. White regions in the darker regions are extracted bronchial airway regions and the white arrows indicate ACBs. Image (a) and (b) is successful cases and image (c) is a failed case. Small regions are branching from the right intermediate bronchus in the successful cases. In the failed case, the ACB region is protruding but not branching.

3. Results

The scheme could detect ACB on two cases of the three ACB cases (Sensitivity: 66.7%), and all of the six cases without ACB were identified as no ACB (Specificity: 100%). The scheme failed to identify ACB in only one case. Two successful indicated ACB slices and a slice including the ACB of the undetected ACB case are shown in Fig. 3. The images were superimposed with regions of the extracted bronchial trees.

The mean computing time was 13.5 seconds (SD: 6.5) per a case. The extraction of bronchial tree took 11.7 sec (SD: 6.1) of the time and the other processes took 1.75 sec (SD: 0.26).

4. Discussions

We can say that the sensitivity of 66.7 % and specificity of 100 % are good results. However, only three cases of ACB were used to measure sensitivity because of its low frequency. We should obtain more ACB cases and should evaluate sensitivity again.

The extraction resulted in a protruding ACB from the inner wall of the right main bronchi in the failed case, but not a branch. Thus, improvement of the extraction might improve the sensitivity result.

The mean computing time would be short enough to wait for finishing, so that this scheme could be used before actual diagnosis.

5. Conclusions

We have developed a scheme to detect accessory cardiac bronchus in MSCT images. The sensitivity and specificity of the scheme were 66.7% and 100%, respectively. The mean computing time was 13.5 seconds (SD: 6.5) per a case. We think that this scheme has potential to be used in clinical situation. We need to obtain more ACB cases and evaluate the scheme again to prove the potential in the future.

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