Robust Automated Lobe-Based Airway Analysis in MDCT Images

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Rationale

The pulmonary lobes are relatively independent functional units within the lungs. In chronic obstructive pulmonary disease (COPD) or cystic fibrosis (CF), changes in lung parenchyma are associated with an increase in airway wall thickness. Because this increase is not equally distributed over the whole tracheobronchial tree a robust and automated lobe-based analysis of the airway tree is of great importance. Depending on anatomical variations and pathological changes labeling of a previously segmented airway tree in MDCT images can be a demanding task. This work assesses the labeling accuracy of an automatic lobe-based airway analysis procedure.

Methods

Our developed automatic procedure for lobe-based airway measurement consists of following five main steps: (a) airway segmentation with a self-adapting region growing process (method described in [1]), (b) skeletonization of the segmentation result by a sequential topology-preserving 3-D thinning algorithm (more details in [2]), (c) transformation of the skeleton to an acyclic graph representation, (d) labeling of the airways by a rule-based method with special rules for anatomical variations and (e) airway measurement, which can be performed by the widely used full-width at half-maximum (FWHM) method, the integral based method (IBM, see [2,3]) and a new modified version of the IBM called parameter-free IBM (IBMpf). We applied the procedure in a batch mode without any user interaction to 36 thorax MDCT datasets from different scanners. The labeled airway trees were visually checked for correctness.

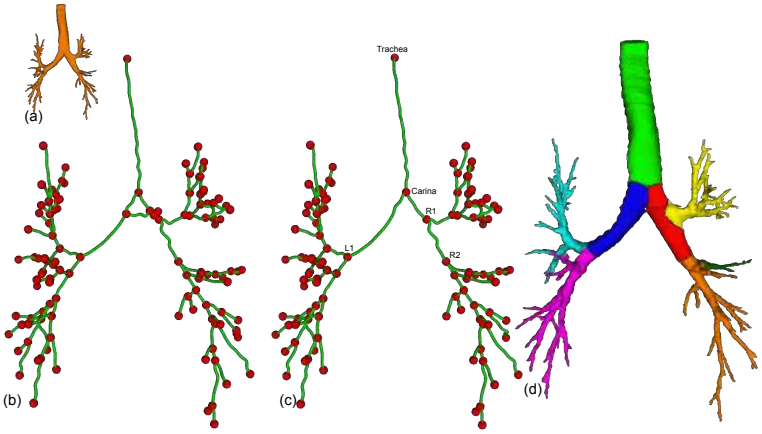

Fig. 1. (a) Segmentation result after 25 iterations and after application of different morphologic operations. (b) Graph representation of the skeletonization output. (c) Graph representation after erasing wrong nodes and edges. The five most importend nodes are labeld at this stage. (d) Colored lobe based rendering of tracheabronchialtree.

Rule Based Labeling

Our new developed airway labeling procedure is based on the method introduced in [4]. We modified the procedure in order to gain more robustness and added additional rules, e.g. a pig bronchus rule.

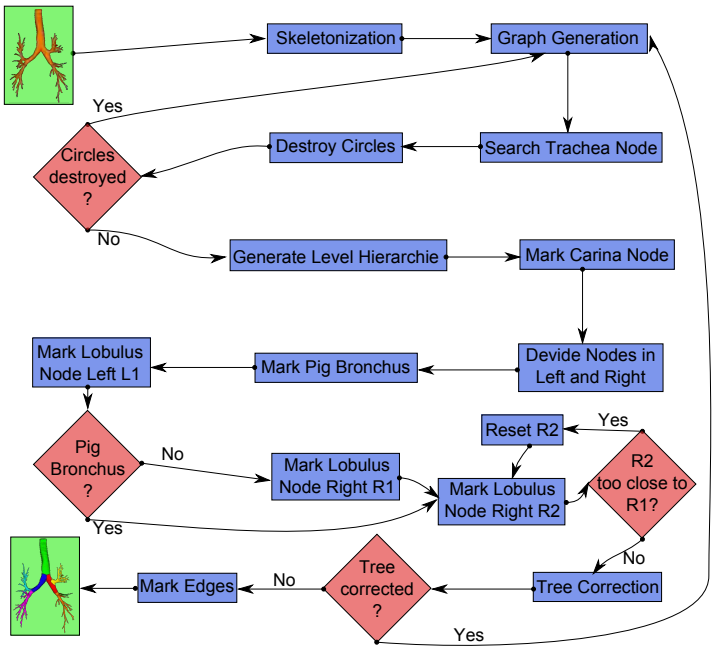

Fig. 2. Flowchart showing the main steps of the newly developed airway labeling algorithm.

Results

The whole procedure could be applied successfully to all 36 datasets. Accuracy for the labeling with labels trachea, main right bronchus, main left bronchus, right upper lobe, right middle lobe, right lower lobe, left upper lobe, and left lower lobe was 100%, 100%, 100%, 100%, 94.5%, 97.2%, 100%, and 97.2%, respectively. Runtime for the whole airway analysis procedure for one tree was about 30 seconds.

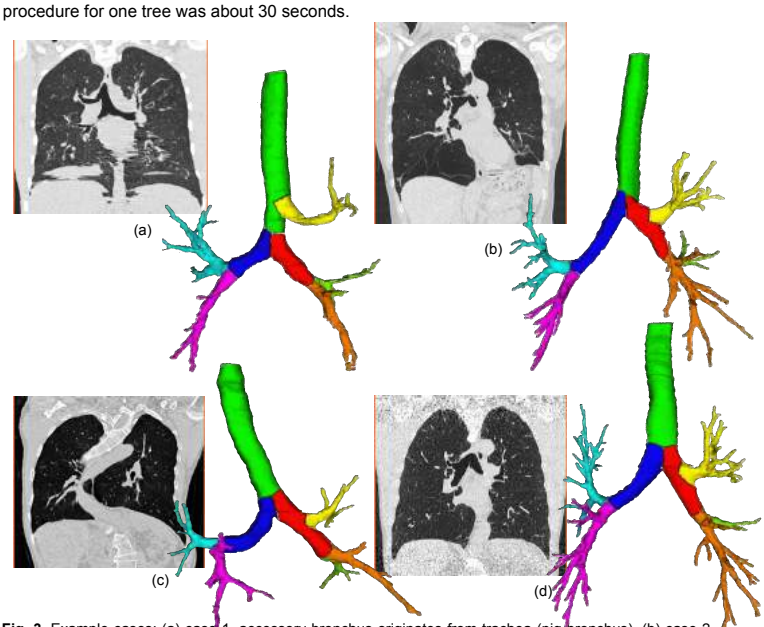

Fig. 3. Example cases: (a) case 1, accessory bronchus originates from trachea (pig bronchus). (b) case 2, lung with extreme low density. (c) case 33, deformed body and (d) case 21, low dose MDCT with a lot of noise.

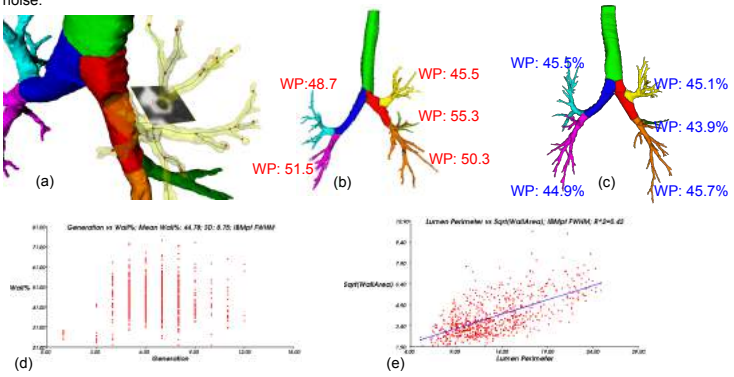

Fig. 4. Examples for the final output of the airway analysis tool. (a) Visualization of 3D airway measurement. (b) Average wall percentage (WP) values for the airways in the five lobes for case 2. (c) Average WP values for case 21. (d) Plot Generation vs WP, case 21. (e) Plot Lumen Perimeter vs Sqrt(Wall Area), case 21.

Conclusion

We developed a procedure for lobe-based airway analysis and showed that it works robustly and accurately. Lobe-based airway analysis can be an important tool for rating patients with airway diseases in the future.

Literature

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Further Information - Acknowledgements - Contact

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Supported by BMBF (82DZL00401, 82DZL00402, 82DZL00404).