MRI lung lobe segmentation in pediatric cystic fibrosis patients using a recurrent neural network trained with publicly accessible CT datasets

Authors: Orso Pusterla[1,2,3], Rahel Heule[4,5], Francesco Santini[1,3,6], Thomas Weikert[6], Corin Willers[2], Simon Andermatt[3], Robin Sandkühler[3], Sylvia Nyilas[7], Philipp Latzin[2], Oliver Bieri[1,3], and Grzegorz Bauman[1,3]

Author Affiliations

[1]*Department of Radiology, Division of Radiological Physics, University Hospital Basel, University of Basel, Basel, Switzerland*

[2]*Division of Pediatric Respiratory Medicine and Allergology, Department of Pediatrics, Inselspital, Bern University Hospital, University of Bern, Switzerland*

[3]*Department of Biomedical Engineering, University of Basel, Basel, Switzerland*

[4]*High Field Magnetic Resonance, Max Planck Institute for Biological Cybernetics, Tübingen, Germany*

[5]*Department of Biomedical Magnetic Resonance, University of Tübingen, Tübingen, Germany*

[6]*Department of Radiology, University Hospital Basel, University of Basel, Basel, Switzerland*

[7]*Department of Diagnostic, Interventional and Pediatric Radiology, Inselspital, Bern University Hospital, University of Bern, Switzerland*

Corresponding author:

Orso Pusterla, PhD

Division of Radiological Physics, University Hospital Basel, Petersgraben 4, 4031 Basel, Switzerland

E-mail: orso.pusterla@unibas.ch ; Phone: +41.76.693.02.20

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ABSTRACT

Purpose

To introduce a widely applicable workflow for pulmonary lobe segmentation of MR images using a recurrent neural network (RNN) trained with chest computed tomography (CT) datasets. The feasibility is demonstrated for 2D coronal ultra-fast balanced steady-state free precession (ufSSFP) MRI.

Methods

Lung lobes of 250 publicly accessible CT datasets of adults were segmented with an open-source CT-specific algorithm. To match 2D ufSSFP MRI data of pediatric patients, both CT data and segmentations were translated into pseudo-MR images, masked to suppress anatomy outside the lung.

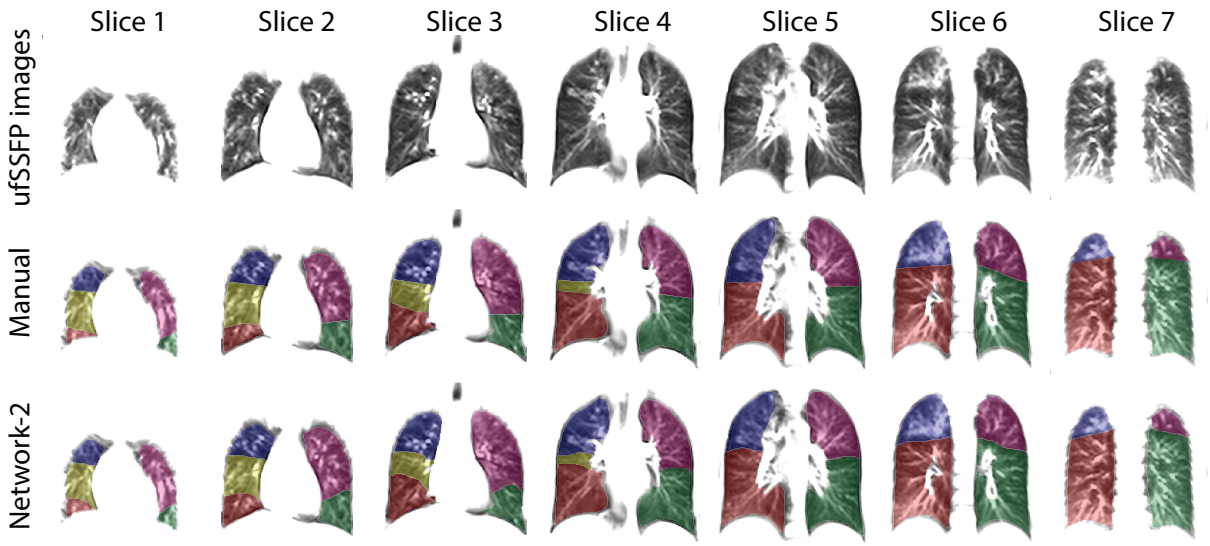
Network-1 was trained with pseudo-MR images and lobe segmentations, and applied to 1000 masked ufSSFP images to predict lobe segmentations. These outputs were directly used as targets to train Network-2 and Network-3 with non-masked ufSSFP data as inputs, and an additional whole-lung mask as input for Network-2. Network predictions were compared to reference manual lobe segmentations of ufSSFP data in twenty pediatric cystic fibrosis patients. Manual lobe segmentations were performed by splitting available whole-lung segmentations into lobes.

Results

Network-1 was able to segment the lobes of ufSSFP images, and Network-2 and Network-3 further increased segmentation accuracy and robustness. The average all-lobe Dice similarity coefficients were 95.0±2.8 (mean±pooled SD [%]), 96.4±2.5, 93.0±2.0, and the average median Hausdorff distances were 6.1±0.9 (mean±SD [mm]), 5.3±1.1, 7.1±1.3, for Network-1, Network-2, and Network-3, respectively.

Conclusions

RNN lung lobe segmentation of 2D ufSSFP imaging is feasible, in good agreement with manual segmentations. The proposed workflow might provide access to automated lobe segmentations for various lung MRI examinations and quantitative analyses.



Teaser figure. *Whole-lung ufSSFP examination of a CF patient included in the testing cohort. The lobe masks are exemplarily displayed for manual segmentation and Network-2 overlaid on ufSSFP images. Mucus consolidations are visible, e.g., in the right upper lobe on slice 6. Network-2 segmented the lobes consistently among the slices, as observable in comparison to the manual segmentations. The lobe masks of the right lower lobe in slices 1 to 3 appear more consistent for the network prediction than for the manual drawn lobe masks. This corroborates that manual segmentation of ufSSFP data is very complex. Slice 5 was acquired just posterior to the pulmonary hila and thus no right middle lobe is present. In this patient, the average all-lobes DSC was 95.2±3.3 % (mean±SD) and the HD was 8.9±2.6 [mm] (mean±SD). The DSCs between manual lobe segmentations and Network-2 predictions were 97.6, 97.9, 94.7, 89.8, 96.0 [%] and the mean HDs were 8.7, 6.2, 6.7, 12.4, 10.7 [mm], for the left upper, left lower, right upper, right middle and right lower lobes, respectively. The corresponding lobe volume percentages were 22.3, 26.6, 15.6, 7.8, 27.8 [%] for the manual segmentations and 22.1, 26.8, 15.6, 7.9, 27.7 [%] for the segmentations derived with Network-2.*