Qualitative and quantitative lung perfusion imaging of children with congenital diaphragmatic hernia at 3T: initial results

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Introduction

Congenital diaphragmatic hernia (CDH) occurs in approximately one in 2000 to one in 4000 live births. Thereby, left-sided hernias are much more frequent (> 85%) than right-sided or bilateral hernias [1, 2]. In CDH, lung hypoplasia and secondary pulmonary hypertension are the major causes of death. After early surgical repair of CDH, long-term follow-up of paediatric patients is necessary. Recent studies involving MRI in the pre- and postnatal evaluation of CDH-patients comprised fetal MRI with lung volume determination and postnatal cerebral MRI , extra- and intracranial MR angiography [3], in particular after extracorporeal membranoxygenation (ECMO-therapy) with carotid artery repair, and morphological lung analysis. To the best of our knowledge, quantitative perfusion imaging of the lung in CDH has not been utilized so far. Therefore, the aim this study was to investigate whether dynamic contrast enhanced MR imaging (DCE-MRI) of the lung in survivors after CDH-repair at 3.0T is feasible.

Materials and Methods

Ten children (mean age 2 ± 0.2 years, 5 male, 5 female, 9-12 kg body weight) after CDH-repair were examined using a 3.0T scanner (Magnetom Trio, Siemens Healthcare Sector). Each patient underwent surgery to correct for CDH within the first 10 days after birth and was enrolled in our long-term follow-up program. Eight children had a left-sided hernia and two a right-sided hernia. Imaging was performed using a time-resolved angiography with stochastic trajectories (TWIST) sequence [4] with parameters TR/TE/FA=2.55ms/0.95ms/20°, FOV=320x260mm², parallel imaging (GRAPPA) factor 3 and 96 slices. Matrix size was 256x256 resulting in an isotropic voxel resolution of 1.3x1.3x1.3mm³. TWIST view sharing was set to 15% central region and 20% sampling density in the outer region. Temporal resolution was 3sec per volume. In total 25 volumes were acquired. 0.05 mmol/kg body weight of contrast agent (Dotarem, Guerbet, France) was administered manually after the fifth volume acquired. Patient related information was removed from the data set before offline processing. Image quality was accessed by calculating the signal-to-noise ratio (SNR) in pre-contrast images as well as peak SNR (PSNR) during the first pass [5]. Regions of interest (ROI) were placed in the apical lung parenchyma avoiding the inclusion of larger pulmonary arteries and veins. Quantification of lung perfusion was performed using a pixel-by-pixel deconvolution approach implemented in PMI 0.4 [6]. For calculations, the arterial input function was determined by placing a ROI in the pulmonary artery main stem. To access differences between left and right lung, ROIs were placed in one slice on the calculated pulmonary blood flow (PBF) maps and average regional PBF (rPBF) was extracted.
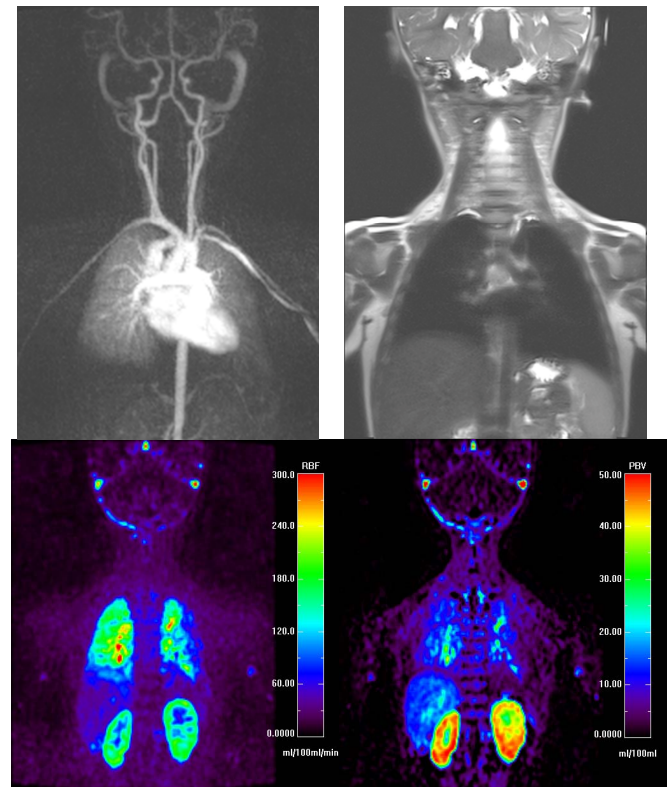

Fig. 1: MR images and parameter maps obtained from one patient. Upper row: MIP reconstructed from the TWIST image data. T2 weighted image of lung. Lower row: Pulmonary blood flow (left) and blood volume (right) maps.

Results

For all ten patients lung perfusion measurements could be obtained. Average SNR of the pre contrast images was 6.4±0.7. PSNR was 31.6±8.9. Figure 1 shows MIP image of time-resoved TWIST MRA, T2-weighted HASTE image and maps of PBF and pulmonary blood volume (PBV) of one of our patients. Table 1 demonstrates average PBF values and their standard deviation of ROIs placed in the left and right lung of the patients. In nine out of ten hypoplasic lungs a significant difference in the PBF compared to the contralateral side could be observed. Mean rPBF for the hypoplasic lungs was 34.3 ± 18 ml/100ml/min and 89.7 ± 27 ml/100ml/min for the contralateral side. In one case no differences could be detected (cf. Tab. 1, patient 4), however the patient is status post left-sided CDH repair.

Discussion

DCE-MRI of the lung in two-year old patients is feasible at 3.0T. Ipsilateral lung

Patient	1	2	3	4	5	6	7	8	9	10
right lung ROI	103±36	126±14	73±23	118±28	84±17	13±7	19±14	122±15	92±25	43±13
left lung ROI	35±14	36±18	45±24	114±31	17±8	63±28	101±34	71±25	47±29	26±17

Tab. 1: Average regional pulmonary blood flow in ml/100ml/min of a ROI placed in the apical left and right lung of each patient.

hypoplasia with reduced perfusion is reflected by significant lower rPBF values compared to the contralateral lung. MRI of lung is challenging as of low signal reception from the lung parenchyma. PSNR is only five times higher than baseline SNR. This might explain why the standard deviations within the ROI measurements of calculated PBF values are high. Certainly, also respiratory movement might contribute to the variations within the data, since no motion correction was applied so far. In our approach a higher spatial resolution was realized than having a high temporal resolution. In adult DCE-MRI of lungs, temporal resolutions between 1 and 1.5 sec are reported, however at lower in plane resolution and thicker slices. In a recent study, a temporal resolution of up to 3 sec was found not to influence the deconvolution analysis [5]. In conclusion, DCE-MRI of the lung in CDH can help characterizing lung hypoplasia initially and in long-term follow-up of children after CDH-repair.

References

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