Regional Pulmonary Blood Flow: Comparison of Phase Contrast MR and Dynamic Contrast-Enhanced MR Perfusion

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Introduction

Dynamic contrast-enhanced (DCE) MR has received considerable attention for its ability to assess pulmonary perfusion over the entire lung (1). However, its ability to monitor rapid changes in flow during therapy or intervention is limited because contrast agents must be allowed to disperse between scans. Injection of contrast may also result in pulmonary hypertensive crisis in pediatric pulmonary hypertension, limiting the use of DCE-MR in this population. Here we explore the use of phase-contrast (PC) MR to measure regional pulmonary flow in comparison with DCE-MR.

Methods

Alveolar collapse was induced in Yorkshire piglets (N = 2, age 7 days, 2.7 and 2.8 kg) by inflation of a balloon catheter in the right lower lobe. The animals were studied under anesthesia and mechanical ventilation while varying the physiologic state as follows: breathing room air; breathing 100% oxygen; alveolar collapse; vasodilator therapies (e.g. Sildenafil); recovery.

A 1.5 T MR system (Signa Excite, GE Healthcare) and 8-channel phased-array knee coil were used to scan the animals. Regional pulmonary blood perfusion measurements were made with DCE-MR in the left and right lower lobes. Perfusion parameters were estimated using a two compartment method (2) with an arterial input function measured in the main pulmonary artery. Flows to the left and right lower lobes were measured from PCMR velocity data in the feeding arteries labeled in Fig. 1. Scan parameters were as follows: DCE-MR (3DFT gradient echo, TRICKS, Gadolinium, breath-held, TR/TE 2.2-2.6/0.9-1.0 ms, 75% partial k-space, α 45º, FOV 20×20×12 and 20×20×19 cm, matrix 96×96×20 and 160×160×32, 57 frames, temporal resolution 0.2-0.3 s); PCMR (retrospective vector ECG gated, free-breathing, TR/TE 8.5/4.1 ms, 3 averages, α 15º, FOV 12×12 cm, matrix 256×256, 20 frames, 1 view-per-segment, 100 cm/s through-plane velocity encoding).

All measured PCMR and DCE-MR flows were normalized as percent change from 100% oxygen to allow for comparison across regions and piglets. Similarity of the measurements was assessed by regression analysis and Bland-Altman plot.

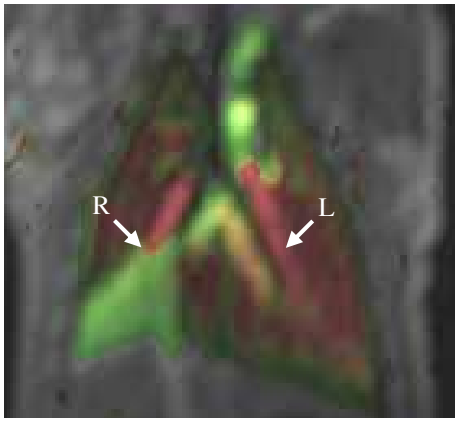

Fig. 1 Blood flow perfusion map showing voxel-by-voxel blood flow (light green=low, dark red=high) under alveolar collapse. Arrows show arteries feeding collapsed right (R) and normal left (L) lower lobes. Note the low perfusion in the collapsed region.

Results and Discussion

As shown in Fig. 2a, a strong correlation ($R^2 = 0.73$, $p = 1.3e\text{-}5$) was observed between the PCMR and DCE-MR measurements of regional pulmonary blood flow. A bias towards lower flows was seen in the DCE-MR values (slope = 0.89), further illustrated in the Bland-Altman plot in Fig. 2b.

Discrepancies between the PCMR and DCE-MR values may arise from several sources: a) the physiology of the animal may have varied between measurements, b) perfusion over the DCE-MR region of interest may not change in proportion to flow through the feeding vessel (e.g. due to increased blood volume in regions of collapse) and c) DCE-MR was performed under short breath-hold while PCMR was performed under free breathing. However, a strong correlation was obtained despite these limitations and the fundamental differences between the two methods.

In conclusion, PCMR and DCE-MR provide similar information about regional pulmonary blood flow. Whereas DCE-MR can provide a snapshot of global pulmonary perfusion, PCMR can detect rapid changes in flow to a targeted segment. This may be useful for monitoring therapy, especially where MR contrast injection is contraindicated.

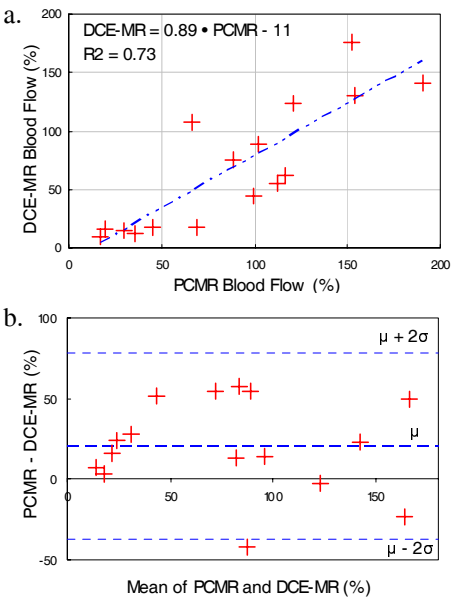

Fig. 2 (a) Correlation of PCMR and DCE-MR blood flow and (b) Bland-Altman plot.

References

(1) Hatabu *et al*. MRM 42(6):1033-1038 (1999) (2) Tofts *et al*. JMRI 10(3):223-232 (1999)