QUANTIFYING PULMONARY PERFUSION IN HEALTH AND PULMONARY DISEASE WITH DCE-MRI: EFFECT OF BOLUS DELAY

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Purpose: The difference in contrast arrival time between the arterial input region (AIF) and the region of interest (ROI) is known as delay. In brain perfusion, this delay leads to underestimation of the blood flow and overestimation of the mean transit time [1]. In pulmonary perfusion, the role of this delay is yet unknown, and correction for this is rarely taken into account in quantitative analysis. The aim of this study is to explore the effect of this delay on the observed pulmonary blood flow.

Methods: Dynamic Contrast Enhanced (DCE) - MRI images were obtained from 5 healthy volunteers, 7 patients with idiopathic pulmonary hypertension (IPAH), 5 patients with unilateral pulmonary artery atresia (PA) and 7 chronic thromboembolic pulmonary hypertension (CTEPH) patients. On a 1.5 Tesla MR-scanner, a 3-D gradient-echo sequence with parallel imaging was used. The scanner was a Siemens Sonata (n= 9 subjects), or a Siemens Avanto (n=15). Eight consecutive slices (each 15 mm thick) were obtained in the coronal plane during a 30-seconds end-inspiratory breath hold. Temporal resolution was 1.1 s. As soon as the image acquisition was started, a Gd-DTPA contrast agent (Magnevist; Schering; Berlin, Germany) was administered by a power injector via an antecubital vein at a rate of 5 ml/s, followed by a 20 ml saline flush at the same rate. Dose was of 0.2 mL/kg body weight. For every subject, a central slice was selected that covered sections of both the main pulmonary artery and the left atrium. A lung segmentation procedure was performed for selecting lung parenchyma, applying a cross correlation analysis with pulmonary artery and left atrium for excluding large pulmonary arteries and venes respectively (fig 2). In this analysis, the signal time-course in a selected vessel of interest serves as a reference function and correlation maps are calculated from this reference function to highlight structures that show similar temporal signal behavior. The AIF was measured in the main pulmonary artery. As ROI was taken the lung parenchyma without vessels (fig 2). Data from both lungs were averaged, except for the PA patients where only the perfused lung was analyzed.

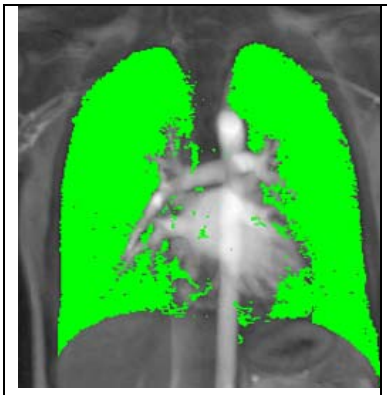

Fig 1. Lung segmentation

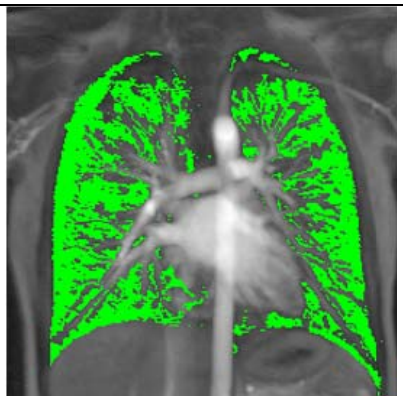

Fig 2. Vessels excluded, resulting in lung parenchyma only.

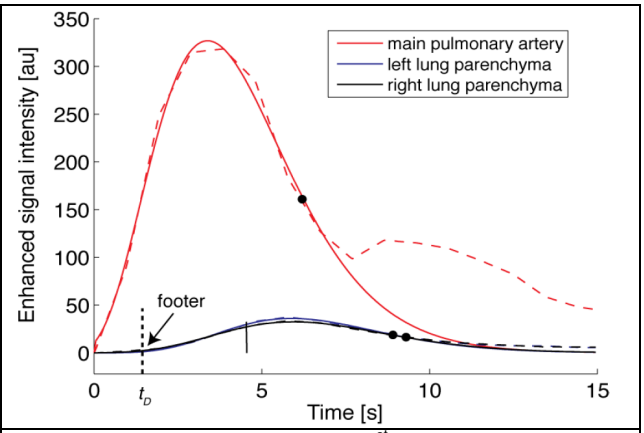

Fig 3. Gamma-variate fitting of the 1st pass, covering time until signal intensity falls below 50% of maximum (black dot).

Bolus delay was assessed by fitting signal intensity curves to the gamma variate function. The delay was defined as the difference between the respective arrival times of the ROI-curve and the AIF-curve. The ROI-curves were then translated over this delay. An impression of the gamma variate fitting and delay correction procedure is given in fig. 3. Then, the deconvolution method with B-splines and Tikhonov regularization[2] was used. This way, the pulmonary blood flow (PBF) was calculated, with and without delay correction.

Results Compared with the healthy controls, the PBF was significantly lower in IPAH patients and in CTEPH patients, but not different for the pulmonary artery atresia patients. Median bolus delay time ranged from 1.5 s for healthy subjects to 3.0 s for IPAH patients. *Not* correcting for delay resulted in an average PBF *under*estimation of 47 percent.

	Controls (n=5)	iPAH (n=7)	Pulm.Atresia n=5	CTEPH (n=7)
PBF (ml/100ml/min) with delay correction	142 (120,152)	37 (21, 57)	205 (71, 341)	28 (18,42)
Delay (s)	1.5 (1, 2)	3 (2, 3)	1.5 (1, 2)	2 (1, 2)
error in PBF (%) without delay correction	- 50 (-56, -39)	-43 (-52,-40)	-49 (-54, -37)	-48 (-55, -26)

All data are median (interquartile range)

Conclusion Correction for bolus delay is essential for accurate estimation of quantitative pulmonary perfusion parameters, both in healthy subjects as well as in pulmonary patients.

References [1] Calamante F, Gadian DG, Connelly A. Delay and dispersion effects in dynamic susceptibility contrast MRI: Simulations using singular value decomposition. Magnetic Resonance in Medicine. 2000 september;44(3):466–473.
[2] Calamante F, Gadian DG, Connelly A. Quantification of bolus-tracking MRI: Improved characterization of the tissue residue function using Tikhonov regularization. Magn Reson Med. 2003 Dec;50(6):1237-47.