3D quantitative contrast-enhanced perfusion measurements of the human lung using the prebolus approach and signal corrections

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Introduction:

Contrast-enhanced MRI enables the quantitative determination of pulmonary blood flow (PBF) [1] by acquiring the passage of the contrast agent bolus through the lung. A main problem for accurate quantification is the determination of the arterial input function (AIF). Applying high doses leads to signal saturation and thus to underestimation of the AIF. But higher doses improve the SNR of the lung parenchyma. One attempt to overcome this problem is the prebolus approach [2]. Successful application to quantitative heart perfusion [3] and pulmonary perfusion [4] was reported. Another problem is the variation of the coil-sensitivity over the lung volume [4]. This results in faulty values, if signal curves from different slices are deconvolved with the AIF, which is taken from a medial slice. In the present work, whole lung quantitative first-pass contrast-enhanced pulmonary perfusion measurements were performed for different contrast agent doses. PBF was calculated using the prebolus approach and compared to single dose results. Additionally, signal corrections for the variation of the sensitivity profile of the array-coil over the thorax volume were performed.

Methods:

All measurements were performed on a 1.5 Tesla scanner (Magnetom Avanto, Siemens Medical Solutions, Erlangen, Germany) using a 32-channel phased-array coil (Rapid Biomedical, Rimpar, Germany). For PBF quantification, the contrast agent Gd-BOPTA (MultiHance, Bracco ALTANA Pharma, Konstanz, Germany) was injected into an antecubital vein using a power injector (Medrad, Volkach, Germany) at a flow of 4ml/s, followed by a flush of 20ml saline. Nine healthy volunteers were examined by injection of a 0.8 ml, 1.5 ml, 3.0 ml and 6.0 ml bolus. Dynamic image series were acquired using a 3D FLASH sequence (TE/ TR/ α = 0.7 ms/ 1.7 ms/ 20°, slab thickness = 140 mm, 28 partitions, matrix: 100 x 192, partial fourier 6/8, FOV = 440 x 480 mm^2, BW = 1300 Hz/pixel, GRAPPA factor 3). With the injection of the contrast agent, 18 consecutive measurements were started (TA ~ 26s). All measurements were performed in expiratory breath-hold. A ROI was drawn inside the left pulmonary artery to evaluate the AIF. Using the prebolus approach, AIFs for higher doses were constructed from a low dose AIF by time-shifting and summation [3]. Signal-time curves of the lung parenchyma were taken from ROIs over the right and left lung. Baseline-corrections were preformed on all signal-time courses. Perfusion values were calculated by deconvolution of the lung signal-time courses with the AIF and an exponential function as residuum. Perfusion maps were generated by fitting the whole lung pixel by pixel. On six volunteers, additional measurements were performed with the array-coil and the body-coil using a 3D FLASH sequence (TE/ TR/ α = 0.8 ms/ 2.2 ms/ 9°, slab thickness = 140 mm, 28 partitions, matrix: 100 x 192, partial fourier 6/8, FOV = 440x 480 mm^2, BW = 650Hz/pixel). From these images, correction factors were calculated by dividing the body-coil images by the array-coil images. The signal-time curves were corrected by multiplication of the signal curves with the corresponding correction factors.

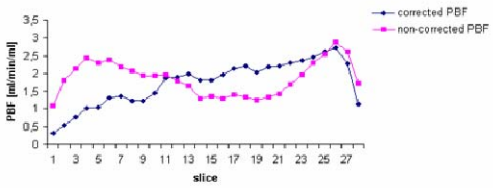

Fig. 1: PBF of a volunteer over the whole lung (ventral-dorsal). Displayed are coorected and uncorrected PBF values

Results:

Figure 1 shows PBF values of all slices of a volunteer, with and without signal correction. The corrected PBF values increase from ventral to dorsal. Without signal correction, higher PBF can be seen for outer slices, compared to middle slices. The maximum increase in signal intensity for different contrast agent doses is ploted in fig. 2. Additionally, a linear signal increase is depicted. A distinctly deviation from this linear increase can be seen for the 6.0 ml doses. Mean PBF values for single doses and 0.8 ml prebolus measurements of medial slices are displayed in tab. 2. PBF maps of the whole lung are depicted in fig. 3.

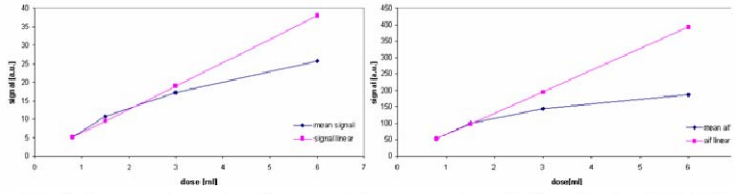

Fig. 2: Mean maximum signal increase in lung parenchyma (left) and for the AIF (right) for different doses. Additionallly, a linear signal increase is ploted

AIF single	0.8	1.5	3.0	6.0
PBF	248 ± 81	312 ± 129	339 ± 126	343 ± 113

AIF prebolus	0.8 - 1.5	0.8 - 3.0	0.8 - 6.0
PBF	328 ± 159	267 ± 121	201 ± 89

Tab. 2: Mean PBF values calculated with single bolus (top) and a 0.8 ml prebolus

Discussion:

Using the signal correction resulted in increased PBF from ventral to dorsal, due to gravitation. Without correction, higher PBF values were found in ventral slices, reflecting the influence of the coil-sensitivity. The single bolus PBF for 1.5ml, 3.0ml and 6.0 ml achieved corresponding values, although distinctly signal saturation can be seen for the 6 ml bolus (fig. 2). This saturation occured in the lung parenchyma as well as in the AIF resulting in apparent accurate values. The 0.8 ml single bolus yielded only poor SNR and thus unreliable values. Using the prebolus approach, decreased PBF was determined for 3.0 ml and 6.0 ml. This can be explained by signal saturation in the lung parenchyma. The calculated perfusion values for the single bolus and the 0.8-1.5ml prebolus are in good agreement to literature values measured in expiration [6]. In conclusion, signal corrections for the coil-sensitivity improves the accuracy of whole lung perfusion quantification. Furthermore, higher SNR in lung parenchyma can be achieved using the prebolus approach, but the dose has to be choosen carefully.

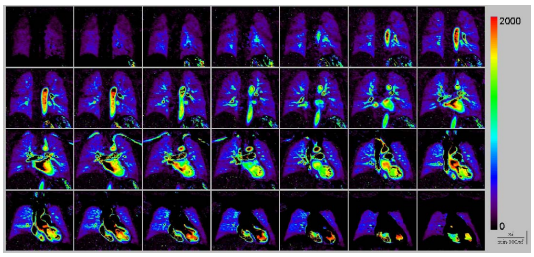

Fig. 3: PBF maps of a volunteer for all 28 slices, calculated with a 0.8-1.5 ml prebolus

References

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