Free-breathing vs. breath-hold pulmonary perfusion MRI: Quantification and reproducibility

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Target audience:

Radiologists and physicists

Purpose

Recently, the feasibility of the assessment of pulmonary perfusion by DCE MRI with a measurement during free breathing (FB) was demonstrated [1], thereby eliminating the need for breath holding (BH) during the acquisition and substantially increasing patient compliance. It is a well-known fact [2] that pulmonary perfusion, assessed during breath hold, varies strongly between inspiration and expiration; perfusion parameters are higher during breath hold in expiration. It is the purpose of this study to investigate whether the assessment of pulmonary perfusion during FB by DCE MRI has the additional advantage to yield quantitative values with a better reproducibility than those from BH measurements.

Methods

Acquisition Ten healthy, male volunteers without any symptoms or previous medical history of chest disease were enrolled; informed consent was obtained from all volunteers. Each volunteer was examined twice at a clinical 1.5-T MRI system (Magnetom Aera, Siemens Healthcare, Erlangen, Germany), separated by one week +/- one day. Each of these two examinations included a BH and a FB DCE-MRI acquisition, separated by at least 20min to minimize potential effects of residual contrast agent, so that a total of 40 DCE MRI datasets was acquired. For the dynamic acquisitions, an accelerated 3D SPGR sequence with a temporal resolution of 1.3s per volume was used (matrix size 128x104x36, TE/TR 0.9/2.0ms). For both FB and BH measurements, a standard dose of contrast agent (Gadobutrol) was injected with a flow of 3 ml/s; the acquisition was started simultaneously with the injection. For the BH measurements, volunteers were instructed to hold their breath in mild inspiration during the total acquisition time of 53s; for the FB measurement, volunteers were instructed to breathe shallowly throughout the acquisition time of 110s.

Post processing Lung tissue was segmented automatically based on the dynamic properties of each pixel curve [3]; parameter maps of pulmonary plasma flow (PPF) and pulmonary plasma volume (PPV) were calculated with a one-compartment model. Median values of anterior and posterior halves of the lung were determined separately and used for further evaluation.

Statistical analysis Both for FP and BH measurements, the intra-class correlation coefficient (ICC) and the coefficients of variation (CV) between first and second measurement were calculated to assess test-retest reproducibility. Differences of CV between FB and BH measurements were assessed with a non-parametric, paired two-sided Wilcoxon signed rank test. Reproducibility R of PPF and PPV was calculated as root-mean-square average of CV over all 10 volunteers [4], a lower value of R indicates better reproducibility.

Results

Figure 1 shows parameter maps from the same volunteer, obtained during breath hold and in free breathing. Mean values over all volunteers were for BH: PPF=182ml/100ml/min, PPV=9.8ml/100ml and for FB: PPF=232ml/100ml/min, PPV=12.6ml/100ml. CV values of PPF and PPV for BH and FB measurements are displayed in Figure 2; CV is significantly lower for the FB measurements both for PPF (p=0.008) and PPV (p=0.03). ICC values of PPF and PPV are higher for FB than for BH measurements and test-retest reproducibility is significantly better (p<0.05) for FB than for BH measurements (Table).

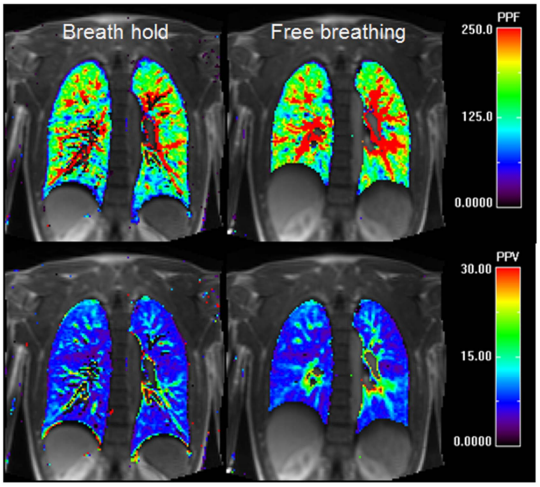

Figure 1: Parameter maps from BH (left) and FB (right) measurements. Top row: PPF (in ml/100ml/min), bottom row: PPV (in ml/100ml)

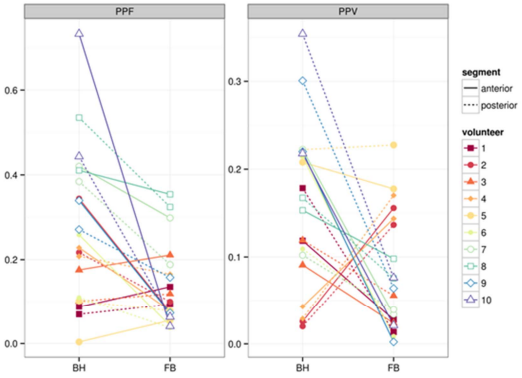

Figure 2: Comparison of coefficients of variation between BH and FB for PPF and PPV – CV values are lower for FB than for BH

Discussion

This study demonstrates that FB measurements, which inherently have better patient compliance, also have the advantage of better reproducibility, indicated by lower values of R and higher values of ICC, both of PPF and PPV, even if breathing motion is ignored in the analysis. The reason for this better reproducibility may be found in the fact that a FB measurement averages over the entire breathing cycle, instead of acquiring during one phase only, such as in- or expiration.

It is worth mentioning that the reproducibility of free breathing pulmonary perfusion MRI might be improved even further by more elaborated means of dealing with diaphragm motion such as retrospective triggering or elastic registration.

Table: Values of ICC and reproducibility for the BH and FB measurements. FB measurements have both better ICC and better reproducibility than BH measurements

	BH	FB	
PPF	0.37	0.69	ICC
PPV	0.69	0.84	
PPF	0.32	0.16	R
PPV	0.18	0.10	

Conclusion

A free-breathing measurement of pulmonary perfusion has better patient compliance, is suitable for the quantification of pulmonary perfusion and leads to parameter estimates with a **better reproducibility** than the conventionally used measurements during breath hold.

References

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