COMPARISON OF THE QUANTITATIVE FIRST-PASS MYOCARDIAL PERFUSION MRI WITH AND WITHOUT PROSPECTIVE SLICE TRACKING: COMPARISON BETWEEN BREATH-HOLD AND FREE-BREATHING CONDITION

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INTRODUCTION

Robust quantification of myocardial blood flow (MBF) using dynamic contrast enhanced (DCE) MRI depends strongly on the absence of respiratory heart motion. The common clinical approach uses breath-holding to minimize this problem, but in cases with a poor breath-hold the remaining motion renders reliable measurements of the signal time-courses (STC) almost impossible. STCs may appear well characterized, but an unclear prior history of RF excitations, undefined volume of signal generation and increased partial volume effects may render the results unusable, although there is no evidence of this in the data. As a result it may be hard to detect cardiac tissue with abnormal perfusion. Another approach for freezing the heart's motion is navigator-based MRI with prospective slice tracking (PST). In this method the slice position is adapted during the MRI measurement to the diaphragm position, which is assumed to be strongly correlated to the motion of the heart. In a recent study [1] it was shown that this approach reduced the error of calculated perfusion significantly by decreasing the motion through plane.

The aim of this study was to compare PST under free-breathing condition to breath-hold measurements for quantitative MBF measurements.

METHODS

Rest myocardial DCE-MRI was performed in 3 healthy pigs with approval of the local animal care committee. The pigs were ventilated with supplemental oxygen, anesthetized and examined on a whole-body 1.5T MR system (Magnetom Sonata; Siemens Medical Solution). For data acquisition a six-element phased-array cardiac coil was used in combination with two elements of the spine array. For PST high-resolution navigator echoes were used to monitor cardiac motion online by detecting the heart-lung interface at the basis of the heart. To deal with residual cardiac motion during the time interval dT between the acquisition of the navigator and the k-space centerline of the corresponding perfusion slice, additional pre-scans consisting of two navigators separated in time by dT were performed. Therefore, this shift in position was accounted for during PST. Contrast agent (CA) was administered in a dose of 0.02 mmol/kg (Gd-DTPA). The following protocol was used: (1) DCE-MRI measurement without pre-scan under free-breathing conditions; (2) DCE-MRI in a breath-hold; (3) DCE-MRI measurement with pre-scans under free-breathing conditions (with a delay of at least 30 minutes to allow for wash-out of CA between each CA administration). A total of 4 independent measurements were performed. For image acquisition a home made saturation recovery TurboFlash (SRTF) sequence (α=18°; TR/TE/TI=3.5/1.7/110ms; FOV= 380x285mm2, slice thickness = 8 mm, GRAPPA factor 2) was used [2], which acquired one short-axis slice with PST and one without within every heartbeat in order to acquire both corrected and uncorrected STCs under the same physiological conditions (Fig. 1).

STCs of the myocardium divided in 6 segments were extracted for both image series of a perfusion measurement by spatially averaging signal intensity (SI) for each segment. The associated AIF was derived from a ROI in the center of the left ventricle cavity in the same image. Bias by image noise was removed [3] and quantitative MBF was calculated from baseline-standardized concentration time curves (CTC) to avoid dependency on remaining CA from previous injections derived from the corrected STCs using:

$$c_{CA}(t) = \frac{1}{-TR \cdot r_1} \ln\left[\frac{(S(t)-S_0)}{E_1 \cdot (S(t)\cdot\cos\alpha - S_0)}\right]$$

where S(t) is the steady state SI during the perfusion measurement, S0 is the spin density and α=18°, r1=4.26 and E1=exp(-TR/T1) (T1,AIF=(1267+/-72)ms[4], T1,Myocard=(834+/-47)ms[5]). For quantification of MBF the fitting algorithm SENSOP of XSIM [6,7] was used.

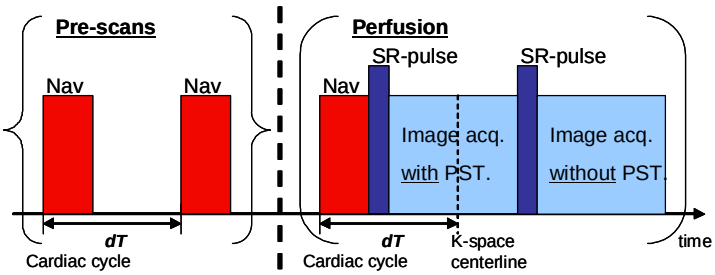

Figure 1: Timing diagram of the SR-TurboFlash sequence with PST

RESULTS AND DISCUSSION

PST significantly reduces variation of the results due to cardiac motion (cf., Fig. 2/(I)-(III)). Even during breath-hold conditions quantification benefits from PST because residual motion (e.g., by oxygen consumption in the lung) is eliminated (cf., Fig. 2/(IV),(V)). The median MBF values measured with PST combined with pre-scans (1.05 (range = 0.47) mL/g/min) and without pre-scans (1.04 (range = 0.58) mL/g/min) under free-breathing conditions are within the same range as expected from PET measurements in healthy myocardium (0.98 (range=0.46) mL/g/min) [8].

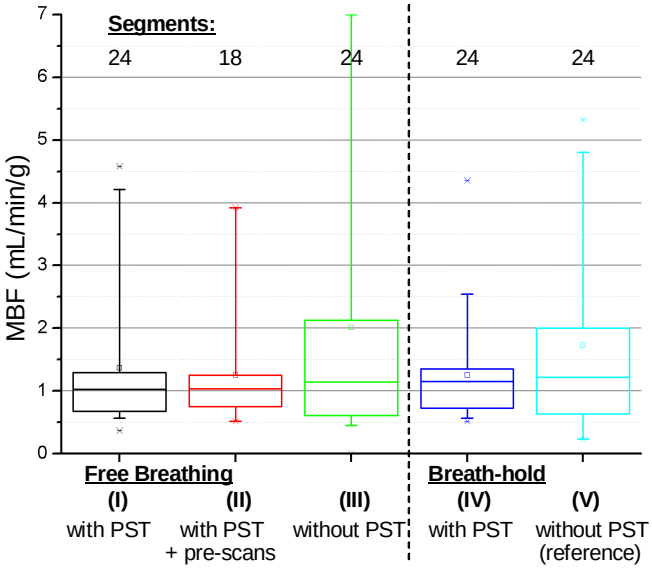

Figure 2: Box and whisker plot of quantitative MBF of the animal study separated in each method and condition. Percentile ranges of MBF values measured with PST are comparable under both conditions and significantly smaller than for values measured without. Medians of (I),(II) are as predicted for healthy hearts, whereas medians of the other approaches are notably higher.

CONCLUSION

PST reduces variation of results induced by residual cardiac motion in breath-hold and free-breathing conditions.

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