High spatial resolution myocardial perfusion MR imaging in patients with coronary artery disease using k-t SENSE

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Introduction:

First-pass contrast-enhanced myocardial perfusion MR imaging requires high temporal resolution, high in-plane spatial resolution and multi-slice myocardial coverage. Conventional MR pulse sequences can only partially meet these requirements. Echo-planar imaging (1) or parallel data acquisition methods (2) have therefore been applied to myocardial perfusion MR imaging, but provide only relatively modest acceleration without excessive SNR penalty or occurrence of artifacts. The recently proposed method *k-t* SENSE (3) exploits coil encoding and spatiotemporal correlations and allows up to 10-fold accelerated data acquisition. Applied to myocardial perfusion MR imaging these acceleration factors can be invested in acquiring data with very high spatial resolution. The clinical usefulness of such high-resolution imaging remains to be investigated. Also, the feasibility of *k-t* SENSE accelerated myocardial perfusion imaging for clinical application is untested. It was the purpose of the current study to investigate the clinical applicability of high-resolution *k-t* SENSE accelerated myocardial perfusion MR imaging in patients with coronary artery disease at 1.5T and 3T.

Methods:

20 patients (16 male, 4 female, mean age 56 years) awaiting invasive x-ray angiography were recruited for this study. All underwent 2 MR imaging studies in random order and within 14 days of the x-ray angiogram, one on a 1.5T Philips MR system and one on a 3T Philips MR system. A saturation recovery segmented gradient echo pulse sequence was used for perfusion assessment with the following parameters:

- TR: 2.7-3.1 ms, TE: 0.9-1.1 ms, flip angle: 15 deg, saturation prepulse delay: 150 ms, 62.5% partial Fourier
- *k-t* factor of 5 with 11 *k-t* interleaved training profiles (net acceleration 3.8)
- 4 slices acquired sequentially over 2 RR intervals and timed to midsystole (apical and high midventricular slices) and middiastole (low midventricular and basal slice) in order to minimize motion artifacts
- Shot duration 120ms, FOV 380mm, slice thickness 10mm, RFOV 80
- Dynamic data set acquired at inspiration over 25-30 seconds following intravenous administration of 0.1mmol/kg Gadovist (Schering)

At 1.5T we used a 5 element cardiac phased array receiver coil, while at 3T a 6 element coil was used. Because of different gradient performance, at 1.5T the pulse sequence allowed use of a 256 matrix yielding an in-plane spatial resolution of 1.5x1.5 mm^2, while at 3T a 340 matrix could be used yielding an in-plane resolution of 1.2x1,2 mm^2.

After scout imaging to define the left ventricular short axis, Adenosine stress was applied (140 mg/kg/min) and stress perfusion images were acquired. After a delay of 10 minutes, a rest perfusion study was carried out with identical parameters followed by cine imaging of LV function and late-contrast-enhanced images for scar delineation.

SI curve characteristics were compared between the two field strengths. Image quality was graded on a scale of 1 (poor) to 4 (excellent). Occurrence of all artifacts was recorded and graded from 1 (none) to 4 (images non-diagnostic). Dark-banding artifacts were recorded separately (1 none to 4 severe). Perfusion data were reviewed visually and perfusion defects reported using the AHA classification. Diagnostic accuracy of MR perfusion analysis to detect coronary artery stenosis of > 70% on QCA of the x-ray angiogram was determined for patients as a whole and for individual coronary vessels.

Results:

All studies were completed successfully. The hemodynamic stress response showed no significant differences between the two stress perfusion acquisitions.

The mean image quality scores were 3.3 for 1.5T and 3.7 at 3T (difference not significant, Table 1). Only one study at 1.5T was graded as non-diagnostic. Overall artifact scores were similar between the two field strengths. The most commonly observed artifacts were due to respiratory motion (occurring in 7 patients at 1.5T and 6 patients at 7T). Dark banding artifacts were seen in half of the image data sets at both field strengths but were limited to the endocardial border in the diastolic images and measured no more than one pixel. In no case did dark banding artifacts interfere with diagnosis.

Sensitivity to detect significant CAD on a patient basis was high at both field strengths (92% vs 100%). With 4 false-positive studies in both groups, specificity was 57% on a patient level. Sensitivity and specificity of CMR perfusion imaging to localize disease to specific coronary vessels ranged from 71% to 100%. An example of an infero-lateral perfusion defect is given in Figure 1.

Two of the 4 patients with "false positive" MR perfusion studies showed circumferential subendocardial perfusion not corresponding to an individual coronary supply territory (Figure 2). Both patients had significant left ventricular hypertrophy, one due to long-standing hypertension, and one due to aortic stenosis.

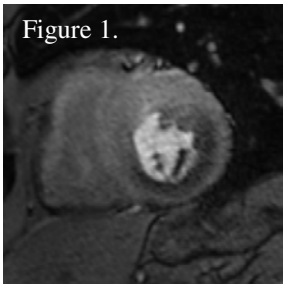
Figure 1.

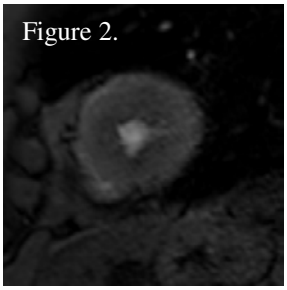
Figure 2.

Table 1.	Image quality score	Artefact score	Dark banding	Sensitivity/ Specificity CAD	Sensitivity/ Specificity LAD	Sensitivity/ Specificity CX	Sensitivity/ Specificity RCA
1.5Tesla	3.3	1.6	1.5	92%/57%	100%/78%	75%/83%	80%/80%
3Tesla	3.7	1.5	1.5	100%/57%	100%/71%	86%/92%	80%/80%

Discussion:

k-t SENSE accelerated imaging is feasible in patients with suspected coronary artery disease. Good breathholding is essential for adequate image quality and respiratory motion is the most common cause of artifacts. Using a *k-t* acceleration factor of 5, a spatial resolution of 1.2 to 1.5 mm can be achieved in a shot duration of 120ms. At this resolution, subendocardial ischemia can be confidently identified and dark banding artifacts pose no diagnostic limitation. In our study *k-t* SENSE accelerated MR perfusion imaging yielded a high sensitivity. Potentially, hypertensive microvascular disease can be identified as circumferential subendocardial ischemia and may have been the cause for the relatively low specificity. Imaging at 3T improves image quality but not diagnostic performance compared with 1.5T.

[1] Epstein FH, et al. MRM 2002; **47**: 482-491. [2] Pruessmann KP, et al. MRM 1999;**42**:952-62. [3] Reeder SB, et al., MRM 2005; **54**:748-54.