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Quantitative myocardial perfusion with simultaneous-multi-slice stress CMR for detection of significant coronary artery disease.

Shor Title: SMS stress perfusion in coronary artery disease

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First-pass stress myocardial perfusion with cardiovascular magnetic resonance (CMR) is used to assess for ischemia in patients with coronary artery disease (CAD) and has excellent diagnostic accuracy. (1) Standard CMR myocardial perfusion techniques typically image three discrete slices and thus lack complete spatial coverage which may potentially underestimate ischemia. Other strategies achieve increased spatial coverage but at the expense of in plane resolution which may impact on diagnostic accuracy. We have devised methods to achieve greater spatial coverage with high in-plane spatial resolution using simultaneous multi slice (SMS) imaging with iterative reconstruction. (2) The objective of this study was to determine the diagnostic accuracy of quantitative SMS stress myocardial perfusion CMR in patients with suspected CAD against the reference standard of invasive coronary angiography (ICA) and fractional flow reserve (FFR).

In this single center, prospective clinical study at St Thomas' Hospital, London, patients with suspected CAD scheduled for ICA underwent CMR on a 1.5T MRI scanner (MAGNETOM Aera, Siemens Healthcare, Erlangen, Germany) with dedicated 32-channel spine coil and 18-channel body coil. The CMR scan was performed before ICA, or after ICA if no revascularization was performed in the interim. The study was approved by the National Research Ethics Service (15/NW/0778) with prospective written informed consent obtained from all patients. Stress perfusion images were acquired following intravenous adenosine administration at 140 mcg/kg/min for a least three minutes. At peak stress, an intravenous bolus of 0.075 mmol/kg body weight of gadobutrol (Gadovist, Bayer, Berlin, Germany) was injected followed by 25 ml normal saline flush by a power injector. First-pass stress perfusion images were acquired using an SMS accelerated bSSFP prototype sequence with gradient controlled local Larmor adjustment to acquire six short axis slices across the heart as previously described.(2-4)

Two expert CMR readers blinded to the ICA findings and undertook a consensus rating of the diagnostic confidence, and perfusion defects. A summed stress score was calculated as a product of the presence of a perfusion defect and confidence in reporting at each segment. Myocardial blood flow (MBF) was quantified using Fermi-constrained deconvolution of the arterial input function and the myocardial signal intensity on a pixel-wise basis. (5) MBF was derived on a per patient level according to the 16 American Heart Association (AHA) model. Significant disease was defined as vessel with FFR value of ≤0.80, and/or coronary luminal stenosis >70% on QCA, and diagnostic accuracy was determined based on receiver operator characteristic curves.

Thirty-eight patients (14 female, mean age 61±11 years) completed the protocol. There was significantly lower MBF in those with flow limiting disease than without (2.03 [1.82 – 2.37] vs 2.68 [2.31 – 2.93] ml/g/min, p<0.001). There was a high diagnostic accuracy for detection of ischemia for quantitative stress MBF with AUC 0.84 (95% confidence interval [CI] 0.68-0.94, p<0.001), and for visual analysis with AUC 0.89 (95% CI: 0.75 – 0.97), p<0.0001). These were not significantly different (DeLong's test, p=0.52). ROC analysis using the Youden index identified the optimal threshold for MBF detection of CAD was ≤2.50 ml/g/min, with sensitivity of 100% (95% CI: 77%-100%) and specificity of 71% (95% CI: 49%-87%).

In conclusion, SMS quantitative stress perfusion CMR provides a high diagnostic accuracy, comparable to expert visual analysis for the detection of significant CAD. The strength of this technique is that six slices are acquired per R-R interval without compromising the temporal resolution necessitated for quantification of MBF. Importantly, compared to earlier attempts to gain greater spatial coverage, this technique does not trade off in-plane spatial resolution. This technique could be considered for automated deployment to a wide range of centers that

do not require expert readers in visual analysis of first-pass dynamic perfusion series, and through rapid stress perfusion-only protocols, may facilitate translation to the clinic

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Figure legend. Sample patient with quantitative SMS perfusion and coronary angiography findings.
Perfusion maps in a patient with significant coronary disease. Global myocardial blood flow was 1.85ml/g/min. Panel A: Left to right and top to bottom: basal to apical slice perfusion maps. Panel B: AHA segmentation (left) and coronary angiogram depicting severe stenosis in the proximal left anterior descending artery (red arrow).