First-pass myocardial perfusion: comparison between full-dose hybrid-EPI and half-dose balanced-SSFP

P. D. Gatehouse[1], C. Bucciarelli-Ducci[2], J. C. Lyne[2], D. N. Firmin[2], and D. J. Pennell[2]
[1]Royal Brompton Hospital, London, United Kingdom, [2]Royal Brompton Hospital

Aim:
To compare first pass myocardial perfusion imaging using a centre-out hybrid-EPI sequence at full contrast dose versus a linear-ordered bSSFP at half contrast dose.

Background: Non-invasive evaluation of myocardial perfusion with cardiovascular magnetic resonance (CMR) is clinically valuable but dark rim artifacts mimicking mild perfusion defects remain a diagnostic challenge. The perfusion protocol (pulse sequence and dose of contrast) giving highest diagnostic confidence is not standardised. Hybrid EPI (hEPI) is a fast sequence reducing motion artifact by its short imaging time, but with low SNR. On the other hand, balanced SSFP (bSSFP) has greater SNR but previously has been reported as more prone to dark subendocardial rim artifacts: field distortion by the high-dose bolus is one suspected reason, and this distortion could potentially be reduced by using a half contrast dose, making use of bSSFP's abundant SNR.

Methods: Eight patients were scanned at 1.5T (Siemens Avanto) with both protocols, of which 6 had invasive coronary angiography (ICA). Five patients were normal (4 had normal ICA, and 1 had a low pre-test likelihood of CAD and normal perfusion); the other two patients had CAD by ICA. The high prevalence of normals was intentional for clearer comparison of dark-rim artefacts. The dose of gadolinium-chelate contrast (Magnevist) was 0.1mmol/kg for the hEPI sequence and 0.05mmol/kg for bSSFP, with 15ml saline flush right antecubitally at 7ml/s.

Centre-out hEPI (TR 5.8ms, 30º, ETL 4, 1860Hz/pixel) acquired 2.8x2.8x8mm voxels over typically 360x270mm FOV (adapted per patient) at TI=110-160ms for each of 3 fat-suppressed slices per cycle, using TSENSE (R2), typical image time 75ms (i.e. excluding prepulses). Linear-ordered bSSFP (TR 2.6ms, 70º, 930Hz/pixel) acquired the same voxel size at the same TI for central of k-space for each of 3 fat-suppressed slices per cycle, using TSENSE (R2), typical image time 125ms. The slice acquisition order was the same in hEPI and bSSFP, resulting in approximately similar image timings through the cardiac cycle in both. Slice positions in the heart were reproduced by viewing the first study while piloting the second.

The randomised scans were scored by 2 blinded experienced observers based on the 16-segment model. Perfusion scan myocardial SNR and diagnostic confidence were assessed subjectively (results not reported here). Perfusion defects were graded as 0=none, 1=mild, 2=moderate, 3=severe, A=dark rim artefact. Dark-rim artefact was identified based on its transience, particularly a temporal correlation with blood brightness, or if the artefact was also clearly present at rest in segments that showed no late-Gd enhancement. Other artefacts such as parallel imaging effects were not scored. For statistical analysis, comparison of agreement between observers and scan methods was assessed by kappa coefficients. Scan results were compared to coronary angiography as the gold standard for CAD, and chi-squared was applied to compare the proportion of dark-rim artefacts in the two sequences. A total of 128 (8 patients x 16) segments were analyzed, but Observer 1 rejected one scan as non-diagnostic (due to late bolus arrival) leaving 112 segments in some of the statistical tests.

Results and Discussion: According to Observer 1, hEPI and bSSFP agreed on normal perfusion in 64 segments, the presence of dark-rim artifacts in 8 segments and stress perfusion defects in 2 segments. Observer 1's overall agreement between hEPI and bSSFP was 66% (k=0.29, 95% CI: 0.18-0.4, $p<0.001$, n=112). According to Observer 2, hEPI and bSSFP agreed on normal perfusion in 51 segments, dark-rim artifacts in 9 segments and stress perfusion defects in 0 segments. Observer 2's overall agreement between hEPI and bSSFP was 56% (k=0.28, 95% CI: 0.18-0.37, $p<0.001$,n=128).

For hEPI scans, Observer 1 and 2 agreed on normal perfusion in 80 segments, dark-rim artifacts in 5 segments and stress perfusion defects in 2 segments. For bSSFP scans, Observer 1 and 2 agreed on normal perfusion in 42 segments, dark-rim artifacts in 26 segments and stress perfusion defects in 2 segments. Twenty-six of the 31 observed segments with dark-rim artefacts were normal in coronary angiography. Analysing only these 26 confirmed artefacts, they occurred more frequently in bSSFP (n=23) than in hEPI (n=3) ($p<0.001$).

Most reasons for dark-rim artefact tend to strengthen the artefact when the blood signal is bright compared to the myocardium, and the ratio between (the peak-enhancement of) blood/myocardium was approximately 4 in bSSFP compared to 2.5 in hEPI. The longer image time of bSSFP compared to hEPI is another potential factor. However, using these matched TI values, the half-dose bSSFP showed SNR similar to the full-dose hEPI. Half-dose bSSFP is more likely to avoid compression of myocardial response curves, while also reducing B0-distortion as a source of dark-rim artefact.

Conclusions: Dark-rim artifacts occurred more frequently in the bSSFP than hEPI, even when the half-contrast dose was used. However, the observers were usually able to correctly identify dark-rim artefacts. We observed a fair agreement between full-dose hEPI and half-dose bSSFP in normal segments. The small sample size for genuine stress defects is inconclusive, with no agreement so far. The continuing study with more angiographic data will support firmer conclusions.