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Rapid Cardiovascular Magnetic Resonance for Ischemic Heart Disease Investigation (RAPID-IHD)

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Introduction: Cardiovascular Magnetic Resonance (CMR) is widely used for diagnostic and prognostic determination in patients with suspected/known ischemic heart disease (IHD)[1]. CMR is advocated in international clinical practice guidelines and recent multi-centre trials like CE-MARC-2 [2] and MR-INFORM [3] have shown that CMR as a first-line test is highly effective as a gatekeeper for diagnostic invasive coronary angiography and also to guide coronary revascularization. However, a perceived limitation of CMR is that it is difficult and time consuming to perform. The aim of this feasibility study was to show that using a standard MR scanner, assessment of left ventricular function, ischemia and myocardial viability could be reliably performed in ~20 minutes, whilst maintaining image quality.

Methods: Consecutive stable patients in sinus rhythm, referred for routine comprehensive assessment of suspected/known IHD, were investigated on a 1.5T Philips Ingenia system equipped with a 24 channel digital receiver coil and patient-adaptive RF shimming. The 'Rapid-IHD' protocol consisted of:

1) Free breathing low resolution survey of the chest and standard cine imaging to define long and short axis (balanced steady-state free precession (bSSFP), single-slice/breath-hold, typical parameters: echo time 1.3ms, repetition time 2.6ms, flip angle 40°, field of view 320-420mm, sensitivity encoding (SENSE, undersampling factor 2), slice thickness 10mm, spatial resolution 1.1x1.1mm, 30 phases/cardiac cycle).
2) Stress perfusion: Adenosine 140µg/kg/min (option to increase to 170 and/or 210µg/kg/min in the absence of symptoms or adequate hemodynamic response). Sequence: 2D, T1-weighted saturation recovery–prepared gradient echo-pulse sequence in 3 short-axis slices, using SENSE (factor 2) after iv bolus of 0.075mmol/kg dimeglumine gadopentetate gadobutrol (Gadovist®, Bayer Inc.) followed by 15ml saline flush (5ml/s).
3) A further intravenous bolus of 0.075mmol/kg Gadovist®, followed immediately by early gadolinium enhancement imaging (2D inversion recovery sequence, FOV 350mm TR/TE 5.5/2.7ms TI 440ms, flip angle 25°).
4) Short-axis LV cine stack: contiguous stack (10-12 slices) of multiphase bSSFP cine images (pulse sequence as Stage 1).
5) Late gadolinium enhancement (LGE): single breath-hold 3D mDIXON with 24 short-axis slices, slice thickness 5mm, repetition time 4.0ms/echo times 1.21ms and 2.5ms,

flip angle 15º, FOV 300x300x120mm, matrix 169/384, acquired in-plane resolution 1.83x2.00mm^2 reconstructed to 1.17x1.17x5mm^2[4].

Scan duration was recorded as time of initiation of table movement for patient positioning in the scanner isocentre to end of table movement after removal from the scanner bore. Written informed consent was provided. Image quality for each component (function, perfusion, LGE) was graded.

Results: Eighteen patients (15 male) were investigated (14 with de-novo chest pain and 4 with known IHD); all completed the full protocol without complication. All components of the multi-parametric scan were of diagnostic quality with high image quality scores (Table 1). Mean time taken to perform the 'Rapid IHD Protocol' was 17.2±0.5minutes.

Conclusion: Rapid comprehensive assessment of IHD by CMR is feasible to perform in under 20 minutes, whilst the excellent image quality that is an inherent strength of CMR was maintained. In general, CMR protocols can be shortened by several methods: a) speeding up the acquisition such as by using compressed sensing (not used here) or using 3D sequences such as the mDIXON LGE sequence (used here), which allowed full coverage of the LV in a single breath-hold as opposed to a 2D LGE stack that requires a breath-hold for each slice [4]; b) eliminating unnecessary components of the protocol, for example rest perfusion imaging, which is increasingly recognised to add little to diagnostic accuracy by visual or quantitative techniques [5]. Ultimately one of the major rate limiting steps to faster scanning is the time taken for gadolinium to reach steady state prior to performing LGE (scar) assessment. Potential methods to reduce this period include using a PSIR dark blood sequence with the inversion time set to null the blood pool, allowing earlier LGE images to be acquired or perhaps using non-contrast based techniques such as T1 mapping for scar detection

In summary, comprehensive CMR assessment of IHD is feasible in approximately 20min, with shorter scan times being potentially more tolerable for patients and allowing improved workflow efficiency.

References

1. Hendel RC, et al. CMR First-Pass Perfusion for Suspected Inducible Myocardial Ischemia.

JACC Cardiovasc Imaging 2016;9:1338-48.

2. Greenwood JP, et al. Effect of care guided by CMR, MPS, or NICE guidelines on subsequent unnecessary angiography rates: a randomized trial (CE-MARC 2). *JAMA* 2016;316(10):1051-1060.

3. Nagel E, et al. Magnetic Resonance Perfusion or Fractional Flow Reserve in Coronary Disease. *NEJM* 2019;380:2418-28.

4. Foley JRJ, et al. Feasibility study of a single breath-hold, 3D mDIXON pulse sequence for late gadolinium enhancement imaging of ischemic scar. *JMRI* 2019;49(5):1437–45.

5. Biglands JD, et al. Comparison of the Diagnostic Performance of Four Quantitative Myocardial Perfusion Estimation Methods Used in Cardiac MR Imaging: CE-MARC Substudy. *Radiology* 2015;275(2):393–402.

Table 1. Patient demographics and image quality scores (IQS) (mean±SD).

Age/yrs	Height/cm	Weight/cm	LVEDVi ml/m^2	LVEF/%	IQS function	IQS perfusion	IQS LGE
61.6±10.9	171.2±7.3	84.4±16.9	87.6±28.4	49.9±10.9	1.3±0.6	1.4±0.5	1.6±0.6

Image grading score

4=non-diagnostic, 3=acceptable diagnostic quality, 2=good quality, 1=excellent quality