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Technical assessment of whole body angiography and cardiac function within a single MRI examination

S.J. Gandy [a,b,*], M. Lambert [c], J.J.F. Belch [c], I.D. Cavin [b], E. Crowe [a], R. Littleford [c], J.A. Macfarlane [b], S.Z. Matthew [c], P. Martin [a], R.S. Nicholas [a,b], A.D. Struthers [c], F. Sullivan [d,e], S.A. Waugh [b], R.D. White [a,f], J.R. Weir-McCall [c], J.G. Houston [a,c]

[a] NHS Tayside Clinical Radiology, Ninewells Hospital, Dundee DD1 9SY, UK
[b] NHS Tayside Medical Physics, Ninewells Hospital, Dundee DD1 9SY, UK
[c] Medical Research Institute, College of Medicine, University of Dundee, Dundee DD1 9SY, UK
[d] Department of Family and Community Medicine, University of Toronto, Toronto, Canada
[e] Department of Research and Innovation, North York General Hospital, Toronto, Canada
[f] Department of Clinical Radiology, University Hospital of Wales, Cardiff CF14 4XW, UK

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AIM: To evaluate a combined protocol for simultaneous cardiac MRI (CMR) and contrast-enhanced (CE) whole-body MR angiography (WB-MRA) techniques within a single examination.

MATERIALS AND METHODS: Asymptomatic volunteers ($n = 48$) with low-moderate risk of cardiovascular disease (CVD) were recruited. The protocol was divided into four sections: (1) CMR of left ventricle (LV) structure and function; (2) CE-MRA of the head, neck, and thorax followed by the distal lower limbs; (3) CMR LV "late gadolinium enhancement" assessment; and (4) CE-MRA of the abdomen and pelvis followed by the proximal lower limbs. Multiple observers undertook the image analysis.

RESULTS: For CMR, the mean ejection fraction (EF) was 67.3 ± 4.8% and mean left ventricular mass (LVM) was 100.3 ± 22.8 g. The intra-observer repeatability for EF ranged from 2.1–4.7% and from 9–12 g for LVM. Interobserver repeatability was 8.1% for EF and 19.1 g for LVM. No LV delayed myocardial enhancement was observed. For WB-MRA, some degree of luminal narrowing or stenosis was seen at 3.6% of the vessel segments (involving $n = 29$ of 48 volunteers) and interobserver radiological opinion was consistent in 96.7% of 1488 vessel segments assessed.

CONCLUSION: Combined assessment of WB-MRA and CMR can be undertaken within a single examination on a clinical MRI system. The associated analysis techniques are repeatable and may be suitable for larger-scale cardiovascular MRI studies.

* Guarantor and correspondent: S. J. Gandy, Department of Medical Physics, Ninewells Hospital, Dundee DD1 9SY, UK. Tel.: +44 (0)1382 496210; fax: +44 (0) 1382 425610.
E-mail address: Stephen.Gandy@nhs.net (S.J. Gandy).

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Introduction

Cardiovascular disease (CVD) accounts for a significant burden of mortality and morbidity in developed societies. Although the majority of CVD deaths are from coronary heart disease (CHD) or stroke, the disease is often spread across all vascular territories and may present elsewhere first, e.g., in the arteries of the legs. Disease in more than one vascular bed (especially when involving the peripheral arteries) is known to have a cumulative effect on worsening prognosis, so early detection and stratification of the whole-body burden of CVD (e.g., identifying those at highest risk of sudden death through CHD or stroke) is desirable. Primary prevention of CVD events is effective, but targeting suitable treatment, such as protective drug therapy and/or procedural interventions, to those most likely to benefit remains a challenge. Current decisions are based on estimated CVD risk, but risk scores do not have good external validity, and a significant number of events occur in those deemed to be at low or intermediate risk. Therefore, a method to screen for "pre-clinical" cardiovascular disease may help to improve how primary prevention is targeted.

Cardiac MRI (CMR) has developed into the imaging standard for evaluating cardiac left ventricular (LV) structure and function.[1,2] Numerous studies have defined normal ranges for LV parameters[3,4] and these have been stratified by demographics such as age,[5] gender,[6] and ethnicity.[7] However, cardiac structure and function is only deemed to represent part of the solution towards a more comprehensive cardiovascular MRI assessment, where further desired information would be provided by arterial luminal imaging of the vascular tree.

Recent advances in MRI hardware such as radiofrequency (RF) coil connectivity have resulted in the emergence of the whole-body MR angiography (WB-MRA) technique,[8,9] which can potentially add to a more comprehensive whole-body cardiovascular assessment. The WB-MRA examination can be performed using a "stepping table" approach[10] or by the use of continuously moving table methods.[11] WB-MRA can be performed on 1.5[12] or 3 T[13] machines, but the use of a 3 T MRI system is deemed to present an advantage[14] by virtue of the additional signal available that can be traded-off for improved in-plane resolution or faster scan times. Refinement work to the WB-MRA technique at 3 T has previously been reported and this has included the optimization of single injection strategies,[15] double injection strategies,[16] and contrast medium dose optimization.[17] The use of CMR has also been validated at 3 T, where electrocardiogram (ECG)-gated two-dimensional (2D) segmented cine steady-state free precession (SSFP) techniques can be implemented and compare favourably with data acquired at 1.5 T.[18]

For data analysis, quantitative methods for 3 T CMR are widely described[19,20] and LV segmentation can be performed using a host of commercially available software packages. However, WB-MRA is more suited to qualitative approaches where scoring systems can report regional[21] or total[22] indices of CVD, which can then be correlated with symptoms in patients.[23]

The present study was undertaken to incorporate CMR and WB-MRA into a single 3 T "hybrid" clinical protocol capable of acquiring images of the vascular tree together with assessment of heart structure, function, and late gadolinium enhancement (LGE) within a single examination. The protocol consists of four sections, each made up of sequences (that are all widely available on commercial MRI systems) as follows: (1): CMR of LV structure and function; (2) contrast-enhanced (CE)-MRA of the head/neck/thorax and the distal lower limbs (contrast medium injection 1); (3) CMR of LGE; and (4) CE-MRA of the abdomen/pelvis (contrast medium injection 2).

To date, no work has been reported looking at the role of this combined protocol in a low or intermediate risk cohort, nor to assess the technical reproducibility of the study in such a population. The primary objectives of the study were therefore: (1) to implement this MRI protocol on a cohort of asymptomatic volunteers with known risk of CVD but with no previous clinical diagnosis; and (2) to evaluate data analysis strategies for CMR and WB-MRA with input from multiple observers in order to establish the intra- and interobserver repeatability. WB-MRA combined with CMR and LGE represents an attractive proposal for cardiovascular work given its systemic assessment of the heart and vascular tree. The WB-MRA technique on its own is known to correlate better with future cardiovascular risk than current scoring mechanisms in a high-risk population.[12]

Materials and methods

Following local ethical committee approval, $n = 48$ volunteers (17 men, 31 women, mean age 54 years, range 41–71 years) were recruited after providing informed consent. Inclusion criteria were as follows: (1) >40 years; (2) free from CVD or other indication for statin therapy as recommended by the Scottish Intercollegiate Guidelines Network (SIGN) report 97 (www.sign.ac.uk) published in February 2007, and (3) had a serum B-type natriuretic peptide (BNP) level greater than their gender-specific median indicating non-specific stress on the cardiovascular system. Exclusion criteria included: (1) pregnancy; (2) known primary muscle disease; (3) known atherosclerotic disease, including unstable angina, previous myocardial infarction, peripheral arterial disease, amputation, revascularization, hypertension, heart failure, or cerebrovascular event; (4) known diabetes; (5) active liver disease; (6) other known illness or contraindication to MRI; (7) participation in a clinical trial; (8) inability to give informed consent; (9) known alcohol abuse; and (10) blood pressure of greater than 145/95 mmHg.

Imaging was performed (head-first, supine orientation) using a 3 T (102 × 32) Magnetom Trio Scanner (Siemens, Erlangen, Germany) with a coil combination using head (12 elements), neck (four elements), body (two coils of six elements each), spine (up to 24 elements), and peripheral angiography (16 elements) RF coils. Preliminary three-plane "localizer" images were acquired for WB-MRA via the use of 500 mm field-of-view (FOV) gradient echo fast low-angle