Incidental extra-cardiac findings on clinical CMR

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Received 25 February 2012; accepted after revision 7 June 2012; online publish-ahead-of-print 6 July 2012

Aims
Cardiac magnetic resonance (CMR) imaging benefits from a large field of view, but consequently captures incidental extra-cardiac findings (IEFs). There is a relative paucity of data for CMR in this regard. Our objectives were to assess the frequency and significance of IEFs reported from clinically indicated CMR scans, and additionally to ascertain if reporting rates differed between radiologist and cardiologist in a ‘real-world’ setting.

Methods and results
A total of 714 patients were included for the study. All patients were referred to a single tertiary cardiac unit for clinically indicated scans. The clinical reports were retrospectively reviewed for reported IEF, and classified as ‘minor’, or ‘major’ depending on the need of further investigation or clinical correlation. A total of 180 IEFs were reported in 154 (21.6%) patients. Ninety IEFs were considered minor, and 90 major. Of the latter, eight (1.1%) were considered highly significant. Two hundred scans were reported by a consultant radiologist, and 514 by cardiologists. There was no significant difference in the rates of IEF reporting between the two specialties (P = 0.38).

Conclusion
IEFs are common, requiring further investigation in a substantial minority. The incidence of highly significant findings in this study was low (~1%), and similar to the reported incidence in the computed tomography literature. No significant difference was found between the reporting rates of IEFs between different specialties.

Keywords
Cardiac magnetic resonance • Incidental extra-cardiac findings

Introduction
Cardiac magnetic resonance (CMR) is now an established imaging modality with well-described clinical indications1 and appropriateness criteria.2

In addition to the heart, a typical CMR examination will also image adjacent thoracic and abdominal structures. Most centres utilize gradient echo ‘scout’ imaging of several slices in coronal, sagittal, and axial planes; these are typically followed by multiple slice axial imaging of the thorax and the upper abdomen, conventionally using half-Fourier single-shot fast spin echo sequences (e.g. HASTE). Consequently, findings incidental to the cardiac examination may be encountered, some of which may be clinically relevant.

Although well described in the computed tomography (CT) literature,3–7 there is a relative paucity of data regarding the frequency and clinical impact of incidental extra-cardiac findings (IEFs) discovered during routine CMR. The few studies5,8–12 and preliminary reports13,14 available to date demonstrate considerable variability, with IEF detection rates ranging from 7.6 to 81%. This indicates that the prevalence of IEF is dependent on multiple factors. Such variables may include the population studied, the image sequences applied, and the definitions utilized to classify and categorize IEF. CMR studies are generally reported by specialists from both radiology and cardiology backgrounds. It is reasonable to assume that radiologists will have greater experience in recognizing extra-cardiac abnormalities. It is unknown whether radiologist’s formal training in the assessment of thoracic and abdominal non-cardiovascular disease affects IEF reporting rates in real-world practice.

In the current study, we sought to assess the frequency of IEFs reported in consecutive patients referred for clinically indicated
CMR, in a single centre NHS tertiary care setting. Additionally, we aimed to detect any difference in the reporting rates for IEFs between radiology and cardiology specialists.

**Methods**

The setting for this study was a dedicated CMR unit, run collaboratively as a managed care service by Alliance Medical and the University Hospital of South Manchester (UHSM), a tertiary cardiac centre in the north of England. Data were collected from all patients attending for CMR studies in the period from August 2008 to September 2009. The study was prospectively planned, with retrospective review of clinical reports.

**Patients**

All study subjects were referred for clinically indicated CMR. All 714 studies were acquired by four CMR-trained radiographers. Reporting was performed by one of three physicians [two cardiologists (M.S., N.A) and one radiologist (M.G.)], employed by UHSM Foundation Trust. All reports were subsequently and retrospectively reviewed and audited by either a CMR-Level II-trained cardiology (R.B.I.) or CMR-Level II-trained radiology fellow (T.N.). The presence of IEFs and any recommendations on the need for further investigation and/or clinical correlation were noted. Both fellows collaborated to assure application of identical criteria for categorization of IEFs, in line with a pre-defined classification. The study adhered to the Caldicott principles and was approved by the divisional audit committee. All patients gave written informed consent at the time of their scan, stating that data and images may be subsequently used for research purposes.

**Definitions**

We prospectively categorized IEFs into ‘minor’ or ‘major’ findings. Minor findings were defined as those considered benign or of no clinical importance, not requiring clinical correlation or follow-up. Major findings were those IEFs potentially or definitely considered to be of clinical significance, and/or requiring further clinical correlation or investigation.

Only truly incidental findings were classified as IEFs. For example, pleural effusions and/or ascites co-existing with significant ventricular impairment were not classified as IEFs. Equally a dilated main pulmonary artery in the context of an atrial septal defect or a dilated aorta with a bicuspid aortic valve, would not be reported as IEFs.

Although there was variability in caseload among the reporting physicians, their relative reporting contributions did not change throughout the course of the study.

**CMR**

All clinical CMR studies were vetted and coded by a single consultant (M.S.) and for auditing purpose grouped in to one of eight clinical indication groups (UK national magnetic resonance imaging (MRI) codes (see Appendix 1). All patients were scanned on a 1.5 Tesla scanner (Avanto; Siemens Medical Imaging, Erlangen, Germany; maximum gradient amplitude 45 mT/m, slew rate 200 T/m/s) with a 32-element phased-array coil. Eighty-nine per cent of patients received a single-shot steady-state sequences in three orthogonal planes, followed by axial multi-slice HASTE. These sequences were acquired from the top of the aortic arch to the diaphragm. The field of view chosen was dependent on both the patient size and shape, and typically ranged from 340 × 233 mm to 390 × 344 mm. Base resolution and phase resolution were 256 and 59%, respectively. Slice thickness and slice gap were 8 and 2 mm, respectively. This resulted in a spatial resolution typically ranging from 2.3 × 1.3 mm × 8 mm to 2.5 × 1.5 mm × 8 mm.

All studies included the assessment of left and right ventricular function by means of breath hold cine steady-state free precession (SSFP) sequences. Additional sequences were performed as clinically indicated. Late enhancement imaging was performed in all studies utilizing contrast. In this real-world study, IEFs were reported from any of the sequences employed in the clinically driven scan protocol.

**Statistics**

A Chi-square analysis was performed to compare reporting rates between specialties.

**Results**

A total of 714 studies were included in the analysis. The mean age of the subjects was 54.5 years (range 16–85 years). The male to female ratio was 1.8:1, and the mean body surface area 1.92 ± 0.015 m².

An analysis of the clinical indications for the study cohort is displayed in Figure 1. This represents the typical workload of our centre, with the two most prevalent clinical indications of stress perfusion and ‘myocardial viability’ assessment accounting for over 75% of studies. The latter indication included imaging for possible arrhythmogenic right ventricular cardiomyopathy (ARVC).

From the 714 patients scanned, a total of 180 IEFs were reported in 154 patients. Twenty-three patients had more than one IEF reported. This resulted in an overall prevalence of

![Figure 1 Indication for the CMR study by group. Studies with more than one clinical indication were allocated to a single primary indication for coding and auditing purposes. Data are presented as percentages. *Dobutamine stress with wall motion analysis; †investigation of arrhythmogenic right ventricular cardiomyopathy (ARVC); and ‡no contrast administered.](image-url)
reported IEFs in the study of 25.2%, affecting 21.6% of patients. As outlined above, these findings were further characterized into those perceived as clinically significant or ‘major’, and those considered insignificant or ‘minor’. Ninety IEFs of both minor and ninety of major significance were reported (see Tables 1 and 2). Nine patients (1.3%) were diagnosed with more than one major IEF.

Among the major IEFs, eight (1.1%) findings were considered highly significant including the following: one bronchio-alveolar carcinoma stage 1B, two cases of advanced pulmonary fibrosis, one ascending thoracic aortic aneurysm (6.6 cm) requiring surgery and a case of iatrogenic liver haemorrhage following placement of a pericardial drain.

Two hundreds from 714 scans were reported by a specialist from a radiology background (M.G.), with the remaining 514 scans reported by cardiologists (M.S., N.A.).

Table 3  Cross-tabulation representing reporting rates for all IEFs (absolute numbers)

<table>
<thead>
<tr>
<th></th>
<th>No abnormality</th>
<th>Any IEFs</th>
<th>Total</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpreter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiology</td>
<td>389</td>
<td>125</td>
<td>514</td>
<td>0.38</td>
</tr>
<tr>
<td>Radiology</td>
<td>145</td>
<td>55</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>534</td>
<td>180</td>
<td>714</td>
<td></td>
</tr>
</tbody>
</table>

Patients presenting with VT and normal echocardiography, one case of pulmonary aspergillosis, two cases of advanced pulmonary fibrosis, one ascending thoracic aortic aneurysm (6.6 cm) requiring surgery and a case of iatrogenic liver haemorrhage following placement of a pericardial drain.

Two hundreds from 714 scans were reported by a specialist from a radiology background (M.G.), with the remaining 514 scans reported by cardiologists (M.S., N.A.). Table 3 shows the reporting data for any reported IEFs; cardiology reported IEFs in 24.3% of studies, vs. 27.5% by radiology (P = 0.38). Tables 4 and 5 reveal the breakdown by IEF subtype. The proportion of scans reported with minor IEFs from radiology and cardiology background was 14.5 vs. 11.9%, respectively (P = 0.34). The corresponding reporting rates for major IEFs were 12.5 and 13.0%, respectively (P = 0.84).

**Discussion**

The literature describing the prevalence of IEFs during cross-sectional cardiac imaging is predominated by publications based
on cardiac CT. In contrast, there is a paucity of data characterizing the prevalence and clinical significance of IEFs on CMR, especially in a pure clinical setting.

What the current study adds in the context of previous publications on IEFs

The present study is to our knowledge, the second largest consecutive series reporting the prevalence of (previously unknown) IEF in clinically indicated CMR studies. In keeping with the cardiac CT literature (~21% prevalence), our study found that the overall detection rate of IEFs on clinically indicated CMR is relatively high (22.7%). Interestingly, our reporting rate was almost identical to a preliminary report of identical size also performed within the UK-NHS setting. Burchel et al. reported IEFs in 218 (24%) out of 714 patients, albeit from a slightly older population (61.3 ± 15 years, range 16–86). In contrast, the largest published US-based study to date by Chan et al. concluded that non-cardiac pathology is uncommonly reported. In their cohort (1534 patients, 62% male, age 50 ± 15 years) 116 studies (7.6%) identified at least one non-cardiac finding, of which 48 (3.1%) reports were deemed to demonstrate major, and 70 (4.6%) minor findings. Only eight findings in six reports (0.4%) were ultimately deemed to be clinically significant. As might be expected, the age of those with clinically significant non-cardiac pathology was greater (54 ± 16). Two studies based on post hoc image analysis have recently been published. Both groups reported IEFs in 43% of scans. The larger of these studies (495 patients) reported a rate of ‘worrisome’ findings (the most significant class) of 2.8%.

Our study is unique in analysing the IEF reporting rates between the two specialties of radiology and cardiology. We found no significant differences in the reporting rates either overall or for IEF subtype. The number of scans reported from a radiology background composed of just under one-third of the entire cohort. We cannot therefore exclude the possibility that with a higher proportion of radiologist reporting, or with a greater study population, a significant difference may have been observed.

Why the (apparent) discrepancies in IEF prevalence?

The few studies and preliminary reports available demonstrate considerable variability in IEF diagnosis with rates ranging from 7.6 (0.4% for major findings) to 81% (17%). These data indicate that the prevalence of IEFs is dependent on multiple factors including cohort studied, ‘clinical setting’, sequences applied and reading session format. Perhaps most importantly, the definitions used to categorize IEFs will result in variability.

**Figure 2** A 56-year-old male patient, referred for stress perfusion imaging to evaluate cardiac-sounding chest pain, is found to have two IEFs on CMR. (A) A well-demarcated lung lesion in the left lower zone (yellow arrow) with low central and higher peripheral signal on coronal scout image. Additionally, (red arrow) a well-rounded liver lesion with lower signal than the surrounding liver was seen. The liver lesion was further investigated with Ultrasound and judged to reflect a haemangioma. No change in size has occurred over 24 months. The presence of the lung lesion was confirmed by lateral (B) and posterior–anterior (C) chest radiographs and further evaluated with contrast-enhanced CT (D). The nodule demonstrated a benign pattern of dense calcification and as such was followed with plain chest radiographs. It has remained unchanged in size for 2 years.
With respect to ‘minor’ IEFs, it is not unreasonable to assume that a significant degree of variation in the literature reflects different attitudes and weighting of the most common abnormalities (such as simple renal or hepatic cysts and vascular abnormalities) by the reporting clinicians. This theory is plausible given that the majority of the published literature is based on retrospective review of reports rather than images. Such an assumption is also supported by the significantly smaller variation in ‘major’ IEFs in the same cohorts. Some studies use different terminology altogether and may include IEFs that are previously known.\textsuperscript{10,11} What constitutes a major IEFs is unfortunately not standardized in the literature, with definitions ranging from ‘one that requires follow-up or clinical correlation’, to ‘one that needs immediate evaluation or treatment’.\textsuperscript{16}

When images are reviewed specifically for IEFs, and compared with the original cardiac-focused report, the prevalence of IEF increases significantly, particularly for minor findings.\textsuperscript{12} This raises the question of whether all such scans should undergo a ‘second read’ (most likely a chest radiologist) focused on detecting IEFs. Perhaps a more important question is if such an increased awareness of IEF results in benefit or harm for patients? Beyond these current unknowns, it seems apparent that specific searching will increase IEF yield, and may also account for some of the discrepancies in IEF prevalence. It is interesting to note that in our study there was no difference between reporting physicians from different training backgrounds, with respect to referral bias, it is apparent that the population in the study by Chan et al. clearly differs significantly from that in both UK-based studies, both in population age and scan indication. While the assessment of ischaemic heart disease (i.e. perfusion and viability) was the predominant clinical indication in both UK studies, the two largest referral cohorts in the US-based study were the assessment of ventricular function (34%) and the assessment of pulmonary vein anatomy (25%). The latter is often a prelude to pulmonary vein isolation, a procedure still predominantly performed in a relatively young cardiac population.\textsuperscript{17} It is plausible that the difference in IEF incidence may be more representative of local practice variation, and the academic nature of the US institution, rather than being representative of differing technology application between healthcare systems.

Although partly coming to different conclusions with respect to the frequency of IEF, the overriding commonality between the current study and those detailed above is that highly significant findings (i.e. a finding that in line with the 2010 Expert Consensus requires immediate evaluation or treatment) occur with a prevalence varying between 0.4 and 2.8%.

Arguably, the current body of literature remains insufficient to answer the important question of whether IEFs found during cross-sectional cardiac imaging has a significant impact on patient health and long-term outcomes. Little is known about the cost-effectiveness of IEF reporting, nor the potential negative impact of increased patient anxiety or other harms that may result.

**Figure 3** A 43-year-old female non-smoker referred for evaluation of atypical chest pains. Coronal localizer (A) and axial HASTE imaging (B) depict an ill-defined region of increased signal in the apical segment of the left lower lobe. Axial CT ‘lung windows’ (C) confirms the presence of a 2.7-cm ill-defined soft tissue nodule. (D) The tumour (red arrow) and CT-guided needle biopsy (yellow arrow). The patient underwent curative resection of a broncho-alveolar carcinoma T2 M0 N0 stage 1B. A follow-up CT 18-month post-surgery demonstrates freedom from local recurrence.
Nevertheless, in the increasingly litigious healthcare environment of Western societies it appears unwise not to have policies in place that report and deal with potentially significant IEFs (Figures 2–6).

What is the impact of the sequences used? A recent meta-analysis investigating the prevalence of incidental findings on MRI of the brain found unsurprisingly that sequences applied and sequence resolution were important determinants of the frequency with which IEFs were identified.18 Also Chan et al. pointed out that: ‘a better understanding of how various sequences impact on the ability to detect non-cardiac pathology would help the development of guidelines in CMR training’.8

The study by Khosa et al.10 demonstrated that 99% of all IEFs are detectable on either SSFP scout or black-blood fast spin echo sequences (e.g. HASTE). In this study, 63 and 60% of IEFs were detected by each sequence, respectively. This suggests that if no IEF is evident after thorough review of these images, the chance of an IEF on later sequences such as SSFP cine or late enhancement imaging, is actually very small.

Should one alter protocols during scanning to address IEF? This important question only arises if the IEF is identified during study acquisition. This will be affected by local protocols with respect to physician-supervised or unsupervised acquisition. Even if detected during acquisition, one must consider to what degree additional sequences to further evaluate the IEF would impact on the workflow within a unit. Equally important, one must not ignore the possibility that deviation (in particular if lengthy) from the original protocol, may detrimentally affect the likelihood of answering the original clinical question. Although minor protocol changes with further slices or sequences may be appropriate, more significant changes may not be desirable. Dedicated specialized sequences, contrast and expertise may be required; indeed an alternative imaging modality may be more appropriate and cost-effective.19

Local approach to IEFs
Within our institution the vast majority of scans are fully physician supervised. This allows the clinician to analyse the SSFP scout and HASTE images during the early part of the scan protocol. As.
described above, there is evidence that this approach will allow the detection of the vast majority of IEFs, and allows then the subsequent addition of suitable sequences if desired. We also feel it important to have consistency in our definitions of IEFs and to seek advice from colleagues in alternative disciplines (from cardiologist to musculoskeletal-, breast-, and chest radiologist) whenever there is doubt.

The true significance of IEFs?

Beyond the medico-legal aspects, the discovery of IEF may add diagnostic value, as the so-called ‘incidental’ finding may actually account for patient symptoms. Obvious examples of this would be pleural and lung parenchymal diseases causing dyspnoea. Equally important, IEFs are not infrequently a clue to either a symptom-relevant co-morbidity or again intimately related to the presenting symptoms. Examples in the current study are patients presenting with ventricular tachycardia in the setting of pulmonary sarcoidosis. Furthermore, IEF can provide indirect explanation for cardiac pathology such as abnormal pulmonary venous drainage contributing to shortness of breath.

A range of IEF may be unrelated to presenting symptoms but become highly relevant during future diagnostic workup and subsequent treatment and therefore should be documented. For example, incidental vascular abnormalities such as an interrupted inferior vena cava or a retro-oesophageal course of a right subclavian artery have implications for potential future cardiac catheterization. Finally, it is intuitive to assume that in individual circumstances, action taken based on the detection of an IEFs will improve the outcome, e.g. lung malignancies.

Study limitations

Although the current study is still the second largest published series in this field, the overall study size was still moderate. Clinical reports (and not images) were analysed in order to assess the incidence of IEFs. Additional expert retrospective image analysis of each study would have allowed an estimation of the sensitivity and specificity of our reporting of IEFs. However, our intention was not to study the accuracy of IEF detection, but rather to assess how frequently IEFs are reported and conveyed back to referring clinicians in a ‘real-world’ setting. As mentioned earlier, a higher proportion of scans reported by a radiologist would have
added power to the inter-speciality analysis. The departmental approach to discuss difficult or ambiguous findings may also have diluted any potential differences.

The limited spatial resolution of some CMR sequences must be recognized, and thus the measurements of potentially important IEF are prone to imprecision. Measurements were made as accurately as image quality allowed, with the recognition that smaller structures such as mediastinal lymph nodes and the biliary tree may not be precisely defined.

Review of follow-on investigations and therapy was also retrospective, and limited to medical and electronic records of in-house patients. The latter fact prevented a cost analysis on the impact of IEF, which while an important consideration, was beyond the scope of this work. Perhaps most importantly, while definitions of major and minor criteria were pre-specified and in line with the subsequently published 2010 Expert Consensus on Coronary Computed Tomographic Angiography, they remain subjective and minor variations in weighting cannot be excluded.16

Conclusions
IEFs are commonly reported from routine clinical CMR scanning, and require follow-up or additional investigations in a substantial minority of cases. We did not find any significant difference in the reporting rates of IEFs between the specialities of radiology and cardiology. There remains a need for standardized reporting of such abnormalities. Reassuringly the overall incidence of highly significant findings in the current study was low (~1%), and similar to that reported in the CT literature.

Acknowledgments
We would like to express our gratitude and appreciation to Mrs Julie Morris, Honorary Senior Lecturer and head of medical statistics (UHSM) for her advice and help with this work.

Conflict of interest: none declared.

Appendix 1
MCORP, myocardial perfusion; MCVIA, myocardial viability (Incl. studies for ARVC and myocarditis); MCVVS/MCORV, LV volume study; MCCMS, congenital anomaly study; MCSFS, stress function study; MCRPS, cardiac rest perfusion; MAAOT, MRA Thoracic aorta; MCVFS, valvular study; No studies performed coronary artery imaging in isolation; therefore for audit purposes, MACOA (magnetic resonance angiography coronary arteries) was classified as MCVVS if no gadolinium-based contrast was administered or MCVIA if contrast was given.
References