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Noncardiac Pathology on Clinical Cardiac Magnetic Resonance Imaging

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OBJECTIVES We sought to determine the prevalence of noncardiac pathology in a large consecutive series of patients referred for clinical cardiac magnetic resonance (CMR) studies.

BACKGROUND The imaging field for many CMR sequences extends outside of the heart border. As a result, noncardiac pathology may be identified. These noncardiac findings have clinical significance because they often lead to subsequent imaging/testing and intervention. The prevalence of noncardiac findings on clinical CMR studies has not been well described.

METHODS The reports of all 1,534 (62% male, age 50 ± 15 years) clinical CMR studies performed at an academic medical center during calendar years 2002 to 2006 were reviewed. All studies had been interpreted by both a staff cardiologist (level III trained in CMR) and a board-certified radiologist (with fellowship training in CMR). For each study, sex, age, indication for CMR study, and reported noncardiac pathology were extracted. Follow-up for each major noncardiac pathology was evaluated by reviewing the patient's medical center electronic medical record. These noncardiac pathologies were then categorized as significant if an intervention or change in the patient's management ensued.

RESULTS A total of 116 (7.6%) studies had at least one noncardiac finding. These findings included 55 major findings (e.g., lymphadenopathy, lung abnormalities, mediastinal masses) in 48 distinct reports (prevalence of 3.1%) and 74 minor findings (e.g., small pleural effusions, liver cysts, renal cysts) in 70 distinct reports (prevalence of 4.6%). The majority (62%) of major findings were previously known, with only 8 findings in 6 (0.4%) of 1,534 reports ultimately deemed to be new and clinically important/significant. The age of those with noncardiac pathology was greater (54 ± 16 years vs. 49 ± 16 years, $p < 0.001$).

CONCLUSIONS In this large series of consecutive clinical CMR studies interpreted by both staff cardiologists and radiologists, noncardiac pathology is uncommonly reported. When reported, the majority of major findings are previously known. New major findings were detected in <0.5% of reports. (J Am Coll Cardiol Img 2009;2:980–6) © 2009 by the American College of Cardiology Foundation

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Cardiac magnetic resonance (CMR) has been used increasingly to evaluate a variety of cardiac conditions, including biventricular volumes/ejection fraction, viability, coronary artery disease, valvular function, congenital heart disease, cardiomyopathy, and pericardial pathology (1–8). The extent to which other thoracic and upper abdominal organs are captured by this imaging technique leads to the possibility of identifying noncardiac pathology. Such findings could lead to either identifying previously undiagnosed pathology or recommending further testing that may be associated with additional cost, morbidity or patient anxiety. Although the frequency of reported noncardiac pathology has been well described for patients undergoing electron beam CT and multidetector computed tomography (MDCT) for assessment of epicardial coronary calcium (9–14), the prevalence of noncardiac pathology in clinical CMR has not been as well described. We sought to evaluate the rate at which major and minor noncardiac pathology are reported in a large consecutive series of clinical CMR studies.

METHODS

Patients. The reports of 1,534 consecutive clinical CMR studies performed at a single academic medical center during calendar years 2002 to 2006 were reviewed. Studies are interpreted in a joint (or serial) reading session attended by staff cardiologists (Level III-trained in CMR) and board-certified radiologists who had completed a fellowship in magnetic resonance (MR). Standardized reports included descriptive details of each scan as well as a summary of all findings. This retrospective study was approved by the hospital Committee on Clinical Investigation, which waived informed consent.

CMR. Clinical CMR studies were conducted by the use of a standardized protocol based on indication (Table 1). All studies included serial thoracic scout images (fast gradient echo axial, coronal, sagittal), assessment of left ventricular and right ventricular systolic function by the use of breath-hold cine steady-state free precession sequences, and an axial stack of T1-weighted electrocardiogram-triggered fast-spin echo images of the thorax. Additional sequences (e.g., T2-weighted fast-spin echo, late gadolinium enhancement, myocardial tagging, pulmonary vein angiography, coronary imaging) were performed as dictated by the clinical indication for CMR. Sixty-three percent of patients received 0.1 to 0.2 mmol/kg of intravenous gadopentetate dimeglume (Magnevist, Bayer Pharmaceuticals, Wayne, New Jersey), primarily those referred for assessment of pulmonary vein anatomy, cardiomyopathy, myocardial viability, pericardial disease, and cardiac mass assessment.

Table 1. Indications for Which Evaluation Was Requested by Cardiac Magnetic Resonance in the 1,534 Study Reports

Ventricular function	517 (34)
Pulmonary vein anatomy	386 (25)
Cardiomyopathy	362 (24)
Valvular disease	252 (16)
Coronary artery assessment	151 (10)
Myocardial viability	116 (8)
Congenital heart disease	105 (7)
Pericardial disease	59 (4)
Other	120 (8)

Studies could have more than 1 indication. Data are presented as n (%) of reports.

Data analysis. For each CMR report, the subject's age, sex, indication(s) for CMR, and any noncardiac pathology were extracted. Noncardiac pathology was classified as "major" if it was more likely to require further follow-up (e.g., lymphadenopathy, lung abnormalities, mediastinal masses, breast lesions, ascites, and soft-tissue masses). Minor noncardiac pathology was considered to more likely be benign and not require specific follow-up (e.g., small pleural effusion, benign liver lesion [cyst or hamartomas], renal cyst, hiatal hernia, diaphragmatic abnormality, splenic abnormality, paraspinal lipoma, and anomalous vasculature).

Follow-up. To assess the clinical impact of the major noncardiac pathology, the medical center's electronic medical record through February 2009 of each patient with major pathology was reviewed. Follow-up was deemed to have occurred if a subsequent imaging study was performed to further evaluate the new finding. A finding was considered previously known if it was referenced in a previous imaging study or office note. A finding was considered clinically significant if it led to a new diagnosis and/or an intervention or change in patient management.

Statistics. All data are presented as mean ± SD. Prevalence was described by absolute number as well as percentage. Comparisons were performed by standard *t* test and the Fisher exact test with a statistical significance level of $p \leq 0.05$.

ABBREVIATIONS AND ACRONYMS

CCT = cardiac computed tomography

CMR = cardiac magnetic resonance

CT = computed tomography

MDCT = multidetector computed tomography

MR = magnetic resonance

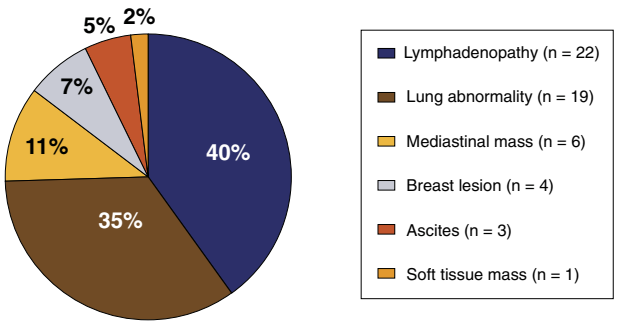

Figure 1. Distribution of Major Noncardiac Pathology

Pie chart distribution of the individual major noncardiac pathologies identified on cardiac magnetic resonance scanning. These findings were noted in 48 distinct reports for an overall prevalence of 3.1%. Lymphadenopathy and lung abnormalities were the most common. Data are presented with the number of major noncardiac findings, with the pie chart demonstrating the percent of total major noncardiac findings.

RESULTS

Of the 1,534 studies, 62% were performed in male patients. Age ranged from 10 to 89 years, mean 50 ± 15 years. Indications for CMR (multiple potential indications for each study) are summarized in Table 1. The most common included assessment of ventricular function (34%), pulmonary vein assessment (25%), and evaluation of cardiomyopathy (24%). The age of those with noncardiac pathology was greater than those without (54 ± 16 years vs. 49 ± 16 years, $p < 0.001$). There was no significant difference in sex.

A total of 129 noncardiac findings were reported in 116 (prevalence of 7.6%) studies, including 55 major findings in 48 studies (prevalence of 3.1%) and 74 minor findings in 70 studies (prevalence of 4.6%). Figure 1 shows the distribution of major findings. The most common major findings included lymphadenopathy (n = 22, 40%), lung abnormalities (e.g., nodules, masses, and infiltrates; n = 19, 35%), and mediastinal masses (n = 6, 11%). Examples of noncardiac major pathology are shown in Figures 2 to 5. There was no correlation of CMR indication with the finding of noncardiac pathology.

The distribution of minor findings across all 74 instances is displayed in Figure 6. The most common noncardiac minor pathologies were small pleural effusions (n = 30, 40%), benign liver cysts or hamartomas (n = 15, 20%), and renal cysts (n = 14, 19%). An example of noncardiac minor pathology is the simple liver cyst shown in Figure 7.

Follow-up clinical data were available on 52 (95%) of the 55 major noncardiac findings in 45 (94%) of 48 patients. The majority (62%; 29 of 50) of major findings were previously known, whereas 13 were deemed clinically unimportant or not confirmed (e.g., lung abnormality not confirmed by chest computed tomography [CT]) on follow-up

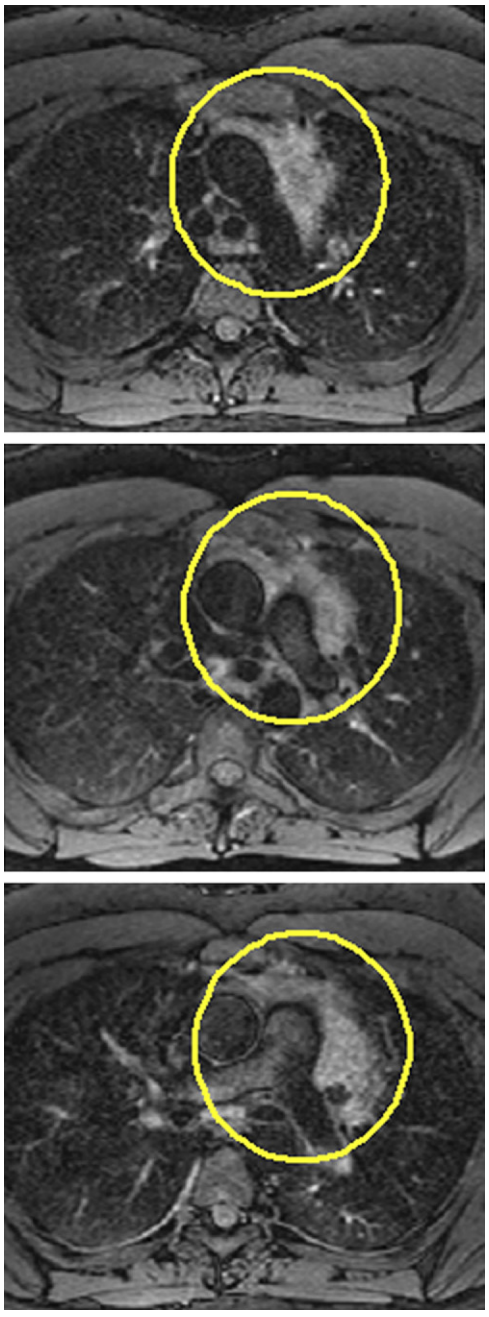

Figure 2. Example of Major Noncardiac Pathology

An example of major noncardiac pathology. Axial T2-weighted fast-spin echo fat-suppressed cardiac magnetic resonance images in a patient with previously unrecognized Hodgkin's lymphoma. Note the marked and diffuse increase in mediastinal lymphadenopathy **(white areas within yellow circles)**, which represent prominent lymph nodes. Subsequent biopsy confirmed Hodgkin's lymphoma.

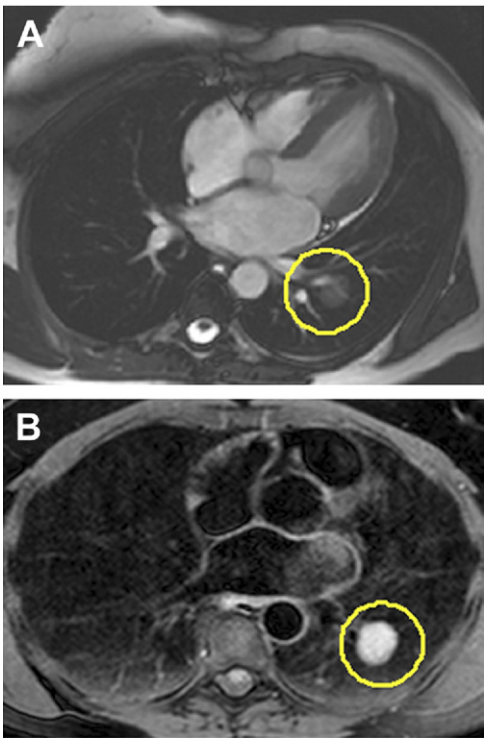

Figure 3. Example of Major Noncardiac Pathology

(A) Balanced cine steady-state free precession cardiac magnetic resonance (CMR) in the double oblique 4-chamber orientation and **(B)** axial T2-weighted fast spin echo axial image with fat saturation (no exogenous contrast). A lung mass **(bright white mass within the yellow circle)** on the T2-weighted fast spin echo axial image is readily apparent. Although present, the abnormality is more subtle on the balanced steady-state free precession image. This highlights the potential of noncardiac pathology to be masked using some of the common CMR sequences. Subsequent evaluation determined this to be a pulmonary carcinoid tumor.

study. The remaining 8 major findings in 6 distinct reports (0.4% of all 1,534 reports) led to a new diagnosis and/or change in patient management). These findings included a nonsmall cell lung cancer with lymphadenopathy, expanding pulmonary nodules with lymphadenopathy leading to bronchoscopy and a new diagnosis of pulmonary malignancy, a pulmonary infarction, a cryptogenic organizing pneumonia, and a pulmonary carcinoid.

DISCUSSION

In this large consecutive series of 1,534 consecutive clinical CMR studies, the reported prevalence of any noncardiac pathology was <10%, with only 3% representing major findings. The majority of major noncardiac pathologies were previously known with

Figure 4. Example of Major Noncardiac Pathology

(A) Axial T2-weighted fast spin-echo image, **(B)** balanced cine steady-state free precession cardiac magnetic resonance (CMR) in the double-oblique short axis orientation, and **(C)** large gadolinium enhancement (fibrosis imaging 15 min after administration of 0.2 mmol/kg of gadolinium) CMR in the same short axis orientation as **(B)**. Note the lesion in the breast which is "dark" on fast spin echo and steady-state free precession and then "bright" after gadolinium contrast. Subsequent biopsy demonstrated a breast fibroadenoma.

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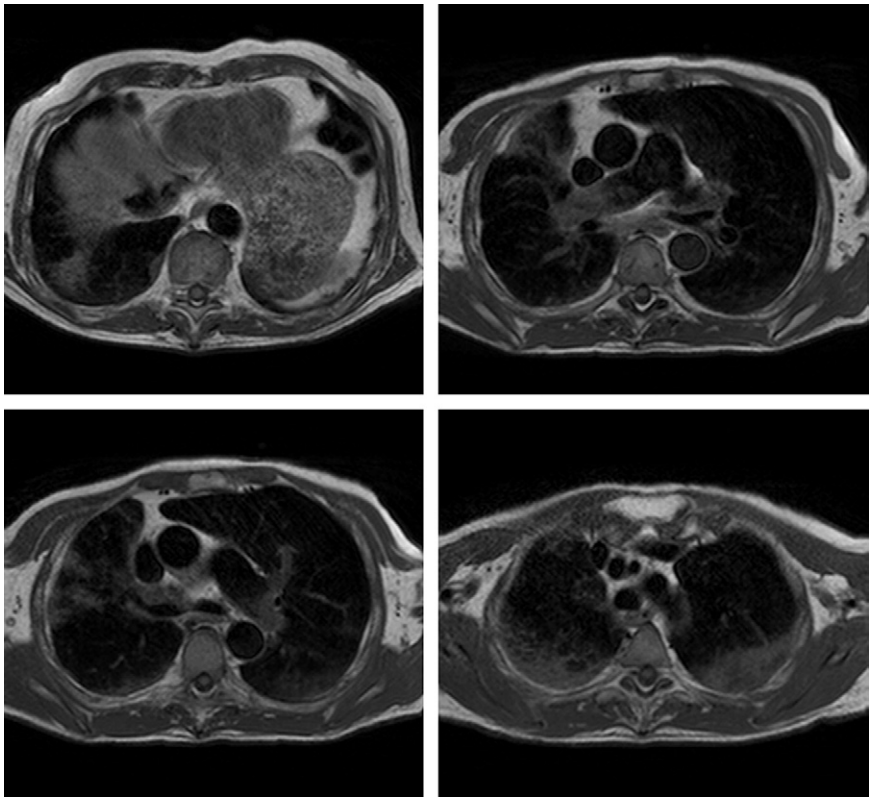

Figure 5. Example of Major Noncardiac Pathology

Series of 4 axial T2-weighted fast spin-echo images of the thorax. Note the patchy and diffuse intermediate signal intensity within the right lung field. More opacities are seen on the right, and not all opacities are dependent (as would be expected with atelectasis). The appearance is suggestive of multifocal pneumonia. Subsequent biopsy demonstrated cryptogenic organizing pneumonia.

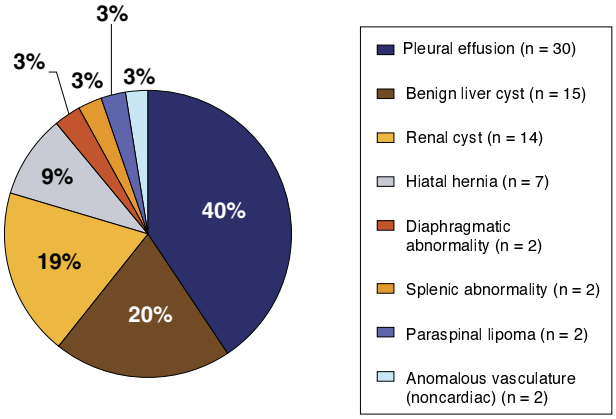

Figure 6. Distribution of Minor Noncardiac Pathology

A pie chart distribution of the individual minor noncardiac pathologies identified on cardiac magnetic resonance scanning. These findings were noted in 70 distinct reports for an overall prevalence of 4.6%. Pleural effusions and benign liver and renal cysts were the most common. Data are presented with the number of minor noncardiac findings with the pie chart demonstrating the percent of total minor noncardiac findings.

<0.5% of all reports representing new major noncardiac findings of clinical significance.

Our results contrast to studies examining the prevalence of noncardiac findings in cardiac computed tomography (CCT). Hunold et al. (12) found extra-coronary abnormalities in 53% of 1,812 patients who underwent electron beam CT for the assessment of coronary artery calcification (12), whereas Onuma et al. (13) reported that 58% of 503 patients who underwent MDCT of the heart had new, noncardiac pathology. In 2 smaller studies, Dewey et al. (9) found 16 (15%) of 108 patients had noncardiac pathology on coronary artery CT imaging, whereas Haller et al. (10) found noncardiac pathology in 25% of 166 patients who underwent contrast-enhanced MDCT. Finally, a retrospective study by Schragin et al. (14) found 20.5% of 1,356 subjects who had undergone electron beam CT for coronary artery calcification had 1 or more noncardiac pathology.

In our study, only 3% of studies were found to have major noncardiac findings. This frequency is

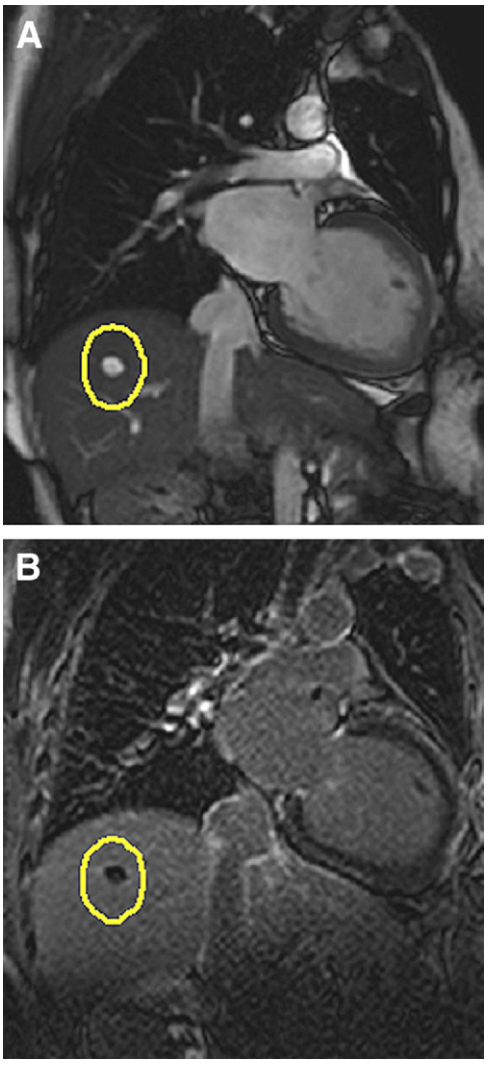

Figure 7. Example of Minor Noncardiac Pathology

Double oblique cardiac magnetic resonance (CMR) imaging using **(A)** cine steady-state free precession and **(B)** late gadolinium enhancement CMR imaging in the same orientation. The abnormality **(yellow circle)** is "bright" in the cine steady state free precession sequence **(A)**, suggesting a cystic (or vascular) structure. The dark appearance on late gadolinium enhancement CMR is consistent with a cyst **(B)**.

similar to analogous CCT studies by Schragin et al. (14), Haller et al. (10), and Dewey et al. (9), who reported a prevalence of significant noncardiac pathology on CCT of 4.2%, 4.8%, and 5%, respectively. Slightly greater rates were found in the reports of Horton et al. (11), Hunold et al. (12), and Onuma et al. (13) at 7.8%, 11%, and 22.7%, respectively.

There are few data regarding noncardiac findings in CMR studies. To our knowledge, our study is the first to examine the prevalence of noncardiac findings in a large consecutive series of patients referred for clinical CMR for a broad range of indications. In a smaller study of 108 patients undergoing coronary MR, Dewey et al. (9) reported 2 (2%) significant noncardiac findings and 7 (6%) insignificant noncardiac findings, values that are similar to our data in a population referred for a broader spectrum of indications. McKenna et al. (17) reported on noncardiac pathology among a group of 107 predominantly male subjects who underwent a screening CMR for research using similar CMR sequences. Images were specifically reviewed for noncardiac pathology. The authors found 81% of their subjects had noncardiac pathology, including 17% with potentially significant pathology (17). The difference in noncardiac pathology prevalence is likely related to their unusual population and different methodology, including a dedicated image review for noncardiac pathology. Our population is likely to be more reflective of those referred for clinical CMR. In addition, no data were reported by McKenna et al. (17) as to whether the pathology was "previously known," nor was follow-up provided to know the true impact of whether the pathologies had an impact on patient care.

The lower prevalence of noncardiac findings in our study as compared with those in CCT might be explained by several issues. Criteria for reporting of minor findings in our study were not specified prospectively. The reporting of benign noncardiac findings may have been influenced by a given readers decision to include (or not include) findings that would not impact the patient's care. CT has greater spatial resolution and is generally considered to be superior to CMR in detecting pulmonary pathology. Unlike CT, the CMR examination does not capture the entire chest, and CMR sequences are not optimized for noncardiac pathology. Our data suggest that physicians referring their patients for CMR should be aware that noncardiac pathology is unlikely to be reported (as compared with CCT for which noncardiac pathology is very common). Although the number of clinically important findings is likely to be very low, this does not obviate the need for interpreting physicians to be aware of noncardiac pathology.

The identification of noncardiac pathology is likely influenced by the training of interpreting physicians and the reading session style. Our clinical studies are interpreted at a joint reading session (or serial independent reading sessions) attended by board-certified radiologists who have completed MR fellowship and Level III-trained CMR cardi-

ologists. Many centers have CMR study interpretations performed by a radiologist or a cardiologist. Preliminary data do suggest that more noncardiac findings are reported in a joint imaging session as compared with serial interpretation (separate cardiologist and radiologist interpretations) (18). Current CMR training guidelines (15,16) do not include specific training in noncardiac pathologies. Although there was a small percentage of noncardiac findings that led to a new diagnosis, some of these were of critical importance, including the initial detection of cancer that may have otherwise not been discovered. A better understanding of how various sequences impact the ability to detect noncardiac pathology would help the development of guidelines in CMR training. The clinical impact of these noncardiac findings appears to be small. Our follow-up data show only 0.4% of all reports led to a new diagnosis, although these diagnoses included initial detection of cancer that may have otherwise not been detected.

Study limitations. Our study has several limitations. It is a retrospective review of clinical reports and the clinical impact of the major noncardiac pathology was limited to review of the patient's electronic medical record at our institution. This electronic medical record has been in use for >20 years and includes both inpatient and outpatient visits and reports; however, further evaluation performed or not referenced by physicians at our institution would not be captured. In addition, the categorization of major and minor findings was subjective. Other studies have used the definition of a significant finding as one that results in further imaging or change in treatment.

CONCLUSIONS

In this large review of consecutive clinical CMR reports interpreted by both staff cardiologists and radiologists, noncardiac findings were uncommonly reported, with the majority being previously known. Further study is needed to elucidate the optimization of detection of noncardiac findings as well as the impact of these incidental findings on clinical practice and patient outcomes.

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