ESC European Society of Cardiology
European Heart Journal - Case Reports (2020) **4**, 1–4
doi:10.1093/ehjcr/ytaa083

CASE REPORT
Cardiac imaging

The mysterious needle in the heart: a case report

Ciara Mahon [1]*, Peter Gatehouse [1], John Baksi[1,2], and Raad H. Mohiaddin[1]

[1]Department of Cardiovascular Magnetic Resonance, Royal Brompton Hospital, Sydney Street, London SW3 6NP, UK; and [2]National Heart and Lung Institute, Imperial College London, South Kensington, London SW7 2AZ, UK

Received 9 September 2019; first decision 31 October 2019; accepted 17 March 2020; online publish-ahead-of-print 3 May 2020

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Background A 53-year-old female with dyspnoea and atypical chest pain. Her electrocardiogram demonstrated a left bundle branch block, transthoracic echocardiogram demonstrated a mildly impaired left ventricle ejection fraction, and coronary angiogram revealed unobstructed coronary arteries. She was referred for cardiovascular magnetic resonance (CMR) for structural and functional assessment. Her imaging revealed an unexpected finding of an off-resonance artefact within the ventricle wall. This material was secondary to a ferromagnetic material.

Case summary Chest X ray and computer tomography confirmed a needle-shaped structure in the ventricle wall. Understanding the basis of this off-resonance artefact aided in a new diagnosis, raised questions on the origin of the material, patient safety, and implementation of corrective strategies to optimize image acquisition.

Discussion The continued development of CMR is revolutionizing our ability to establish diagnosis and guide patient treatment. The CMR sequences can be prone to artefact. This case highlights the importance of understanding the basis of CMR artefacts.

Keywords Case report • Cardiovascular magnetic resonance imaging • Off-resonance artefact • Patient safety • Image optimization

Learning points

- Ferromagnetic materials produce off-resonance artefact in cardiac magnetic resonance imaging.
- Identification of an unexpected off-resonance artefact should prompt consideration of patient safety.
- Understanding fundamental principles to adjust sequence protocols and acquisition techniques can reduce off-resonance artefact and optimize images.

Introduction

The development of cardiac magnetic resonance (CMR) pulse sequences and interpretation methods are revolutionizing our ability to establish diagnosis and guide patient treatment. Despite these advances, artefacts can still be encountered. We report the case of an off-resonance artefact that lead to recognition of a needle within the cardiac apex. Clinical history did not determine the source. Recognition of this artefact is important for patient safety and implementation of corrective strategies to optimize the CMR acquisition of images.

* Corresponding author. Tel: 07500697686, Email: c.mahon@rbht.nhs.uk
Handling Editor: Richard Alexander Brown and Monika Arzanauskaite

Peer-reviewers: Alberto Bouzas-Moscquera, Hafiz Naderi, and Piotr Nikodem

Compliance Editor: Carlos Minguito Carazo

Supplementary Material Editor: Ross Thomson

Timeline

May	Presented with dyspnoea and atypical chest pain.
June	Coronary angiogram demonstrated unobstructed coronary arteries.
	Transthoracic echocardiogram demonstrated mildly reduced left ventricular function.
	Cardiac magnetic resonance (CMR) imaging demonstrated that ventricular apical segments were partially contaminated by off-resonance artefact. Patient was treated for a non-ischaemic cardiomyopathy and follow-up CMR imaging deemed safe. Adjustments were made to the CMR protocol to optimize future images.

Case presentation

A 53-year-old female presented with dyspnoea and atypical chest pain on a background of hypertension, impaired glucose tolerance and asthma. The patient was normotensive, normal saturation on room air, with a normal heart rate and rhythm. There were no significant clinical findings on examination. Electrocardiogram was significant for a left bundle branch block. Transthoracic echocardiogram showed normal left ventricular (LV) size with mildly reduced ejection fraction. Coronary angiography demonstrated unobstructed coronary arteries. She was referred for CMR to further assess her LV dimensions and function..

The patient underwent standard comprehensive screening for contraindications to CMR. This was negative. The CMR demonstrated a small LV cavity with mildly impaired ejection fraction, dyssynchronous contraction and mild concentric LV hypertrophy. Right ventricular volumes and function were normal. There was no myocardial infarction or infiltration. Unexpectedly the apical segments were partially contaminated by signal loss and distorted by off-resonance artefact consistent with a potentially ferromagnetic body (FB). This artefact was particularly prominent on balanced steady-state free precession (bSSFP) sequences (*Figure 1*). The patient had no history of previous surgery, other intervention, penetrating injury, and no recollection of an event that would have resulted in a FB within the thorax. She was not on iron supplementation. The patient was well and had no ill effect at clinical follow-up.

Further investigation with chest X-ray revealed a thin needle-shaped structure near the cardiac apex (*Figure 2*). A three-dimensional volume-rendered image on multi-detector computer tomography (Somatom flash, Siemens Medical Solutions, Erlangen, Germany) showed a thin needle-shaped metallic density in the right ventricular side of the apical septal wall (*Figure 3*).

Previous transthoracic echocardiogram images were reviewed. The FB was not visible. This patient's coronary angiogram report was requested from the referring institution and reviewed. The coronary angiogram had made incidental note of a slim line of radio-opacity that moved in time with the heart, but the exact location was unclear.

Controversy was raised regarding patient safety in undergoing further CMR examination vs. inappropriate refusal to arrange follow-up imaging for a patient with cardiomyopathy. Following a review, the patient was treated for a non-ischaemic cardiomyopathy and follow-up CMR imaging deemed safe. Finally, protocol adjustments were required to optimize images and minimize the artefact. Informed consent was obtained for this publication.

Discussion

Ferromagnetic material within the body causes local field distortions of the static magnetic field leading to off-resonance artefact. This off-resonance artefact is most commonly encountered in patients who have an implant containing a ferromagnetic material.[1] Off-resonance artefact varies depending on the type of pulse sequence and imaging parameters used.[2] It causes signal loss as well as alternating dark and bright bands on bSSFP sequences.[3] The bSSFP images are widely used in imaging of the heart, especially for functional assessment.[4,5] The bSSFP sequences used in our patient identified an off-resonance artefact due to a needle of unknown origin (*Figure 1*).

Needles embedded in the pericardium and myocardium have been previously described using other imaging modalities.[6–8] Needle embolization has been reported in intravenous drug users[9] and acupuncture patients.[10] The presence of a needle-shaped FB in the heart may result from either a direct injury, or embolization from distal penetration.[11] The CMR has identified ferromagnetic material within the stomach following ingestion of an iron supplement,[2] and it is utilized to quantify iron deposition in certain disease pathologies.[12]

Although it was not possible to determine the origin of the FB in our patient, the safety concerns needed consideration and implementation of corrective strategies to optimize the images.

Several studies have been conducted to determine which ferromagnetic materials can be examined safely with MR.[13] Safety concerns and artefacts associated with FB in CMR arise from three distinct mechanisms: (i) static magnetic field; (ii) radiofrequency (RF) energy; and (iii) gradient magnetic fields.

Our institution uses a 1.5 T static field CMR (Magnetom Avanto, Siemens Medical Solutions, Erlangen, Germany). At the entry to the bore of the magnet, the sharply increasing static magnet field exerts an attractive force on a FB. This force can potentially cause displacement, resulting in cardiac damage and patient injury. Within the nominally more uniform region of static magnetic field nearer isocentre, where the heart should be positioned during imaging, there is no such net force on a FB. However, there is a strong alignment torque acting on the FB if it does not happen to be already aligned with the direction of the static magnetic field through the bore.

In this case, the needle-shaped FB is firmly implanted within the ventricular septum. The stability is likely reinforced by fibrous tissue that would have formed following embedding. This is inferred from its durability in an environment of constant intra-cardiac haemodynamic forces. In general, the greater the static magnetic field, the higher the resultant forces and torques on a FB. Furthermore, the severity of off-resonance artefact is directly proportional to field

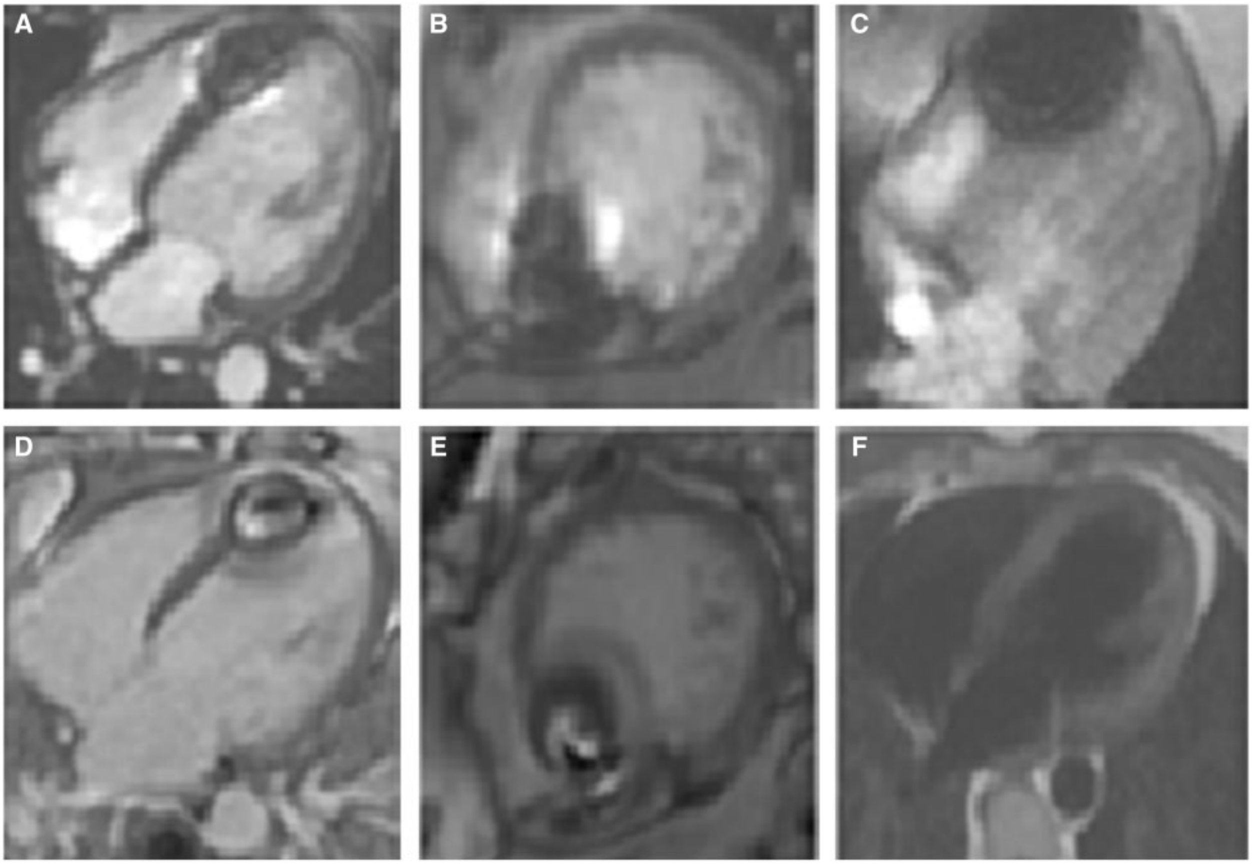

Figure 1 Cardiac magnetic resonance images of metallic artefact; (*A*) four-chamber balanced steady-state free precession; (*B*) short-axis balanced steady-state free precession in the ventricular apical septum; (*C*) four-chamber gradient echo sequence; (*D*) four-chamber late gadolinium by balanced steady-state free precession; (*E*) short-axis late gadolinium by balanced steady-state free precession; and (*F*) four-chamber of echo-planar fast spin-echo sequence.

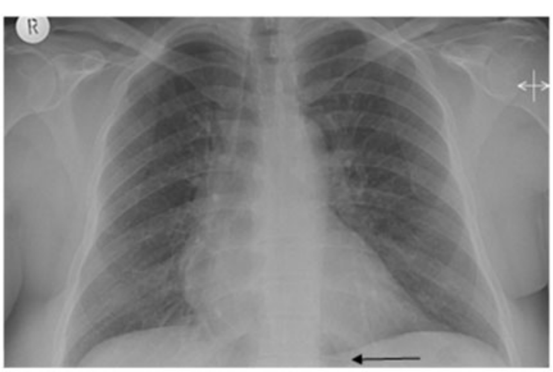

Figure 2 Chest X-ray image of a small linear focus of relative high density projected over the cardiac silhouette.

strength. Overall safety can be guaranteed in a 1.5 T scanner. However, it cannot be guaranteed, and image quality will likely be negatively impacted at field strengths above 1.5 T.

The CMR images are generated by applying high-power RF pulses to excite the nuclear magnetization. Most of that power is absorbed by the induction of RF currents in materials placed in the scanner. These materials subsequently heat up directly due to Ohmic heating. The FB located within the ventricular septum is susceptible to RF energy absorption far more than human tissue, and potentially further 'focusing' the RF field in nearby tissue. Both these effects are liable to cause thermal injury. The relatively small size of the FB reduces this potential risk.

Time-varying magnetic fields, called gradients, are used to encode various aspects of the image acquisition. These rapidly changing magnetic fields can induce alternating electrical currents in conductive materials in the region of audio frequencies (and not RF). Although clinical scanners operate at levels that will not directly excite cardiomyocytes, the gradients can induce currents within electrically conductive wires that could induce arrhythmia. The size and site of the FB in our patient is unlikely to pose a risk of arrhythmia.

Finally, to diminish off-resonance artefact, there are other factors to consider including acquiring thinner sections and smaller voxel size. The avoidance of SSFP, gradient-echo, and echo-planar

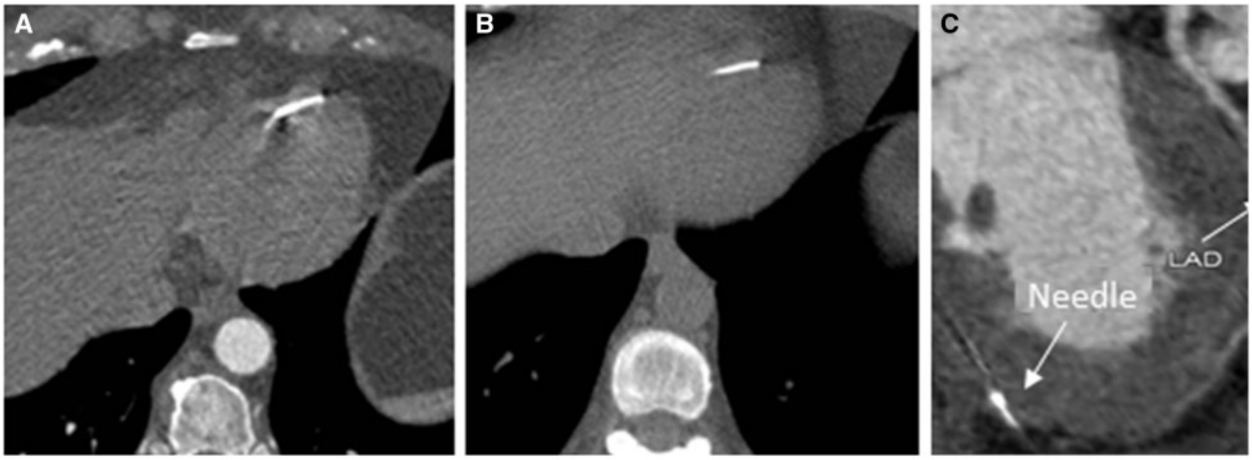

Figure 3 (a-c). Computer tomography images of the needle-shaped ferromagnetic material within the ventricular septum of the heart.

sequences (*Figure 1F*) in favour of spin-echo and fast spin-echo sequences may also reduce the amount of off-resonance artefact.[3] Images can be further improved by increasing the bandwidth which makes the sequence less sensitive to distortions of the static magnetic field.[14] However, this needs to be balanced as increasing the bandwidth decreases the signal to noise.

Conclusion

Ferromagnetic materials generate off-resonance artefact in CMR imaging. Identification of unexpected off-resonance artefact should prompt initial consideration of patients' safety, followed by adjustments to sequence protocol and acquisition techniques to reduce the artefact and optimize images.

Lead author biography

Ciara Mahon is a cardiology fellow in the Royal Brompton and Harefield Trust. Basic cardiology training in Ireland. Studied medicine in Trinity College Dublin, a Masters in molecular medicine in Trinity, and Biochemistry and Genetic in University College Dublin.

Supplementary material

Supplementary material is available at *European Heart Journal - Case Reports* online.

Slide sets: A fully edited slide set detailing this case and suitable for local presentation is available online as Supplementary data.

Consent: The authors confirm that written consent for submission and publication of this case report including image(s) and associated text has been obtained from the patient in line with COPE guidance.

Conflict of interest: none declared.

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