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CASE REPORT
Cardiac Imaging

Cardiac magnetic resonance imaging unmasks presumed embolic myocardial infarction due to patent foramen ovale case report

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Background Occurrence of paradoxical coronary embolism is reported in up to 10–15% of all myocardial infarctions but embolic infarctions presumed to be as a result of a patent foramen ovale (PFO) are rare. Although rare, it is important to identify these patients as they need appropriate investigations to confirm their diagnosis and guide further treatment.

Case summary We present the case of a gentleman with troponin positive chest pain with non-obstructed coronaries on invasive coronary angiogram. Subsequent cardiac magnetic resonance imaging (MRI) demonstrated multi-focal myocardial infarctions in several coronary artery territories. Further investigations including echocardiogram were performed in order to identify a cause and source of the embolic infarctions and led to the diagnosis of patent foramen ovale. The patient was treated as myocardial infarction with non-obstructed coronary arteries most likely due to embolic phenomena in the presence of a PFO.

Conclusion Multiple focal infarctions in multiple coronary artery territories should raise the suspicion of an intra-cardiac shunt. Multi-modality imaging with cardiac MRI and echocardiogram is important in correctly identifying any source of emboli and the diagnosis of any intra-cardiac shunt. Whilst PFO closure is a possible treatment for patients, considerations regarding risk stratification and local provisions needs to be taken into account. Patients should be referred to the appropriate subspecialist to ensure suitable long-term follow-up.

Keywords Cardiac MRI • Multi-modality imaging • MINOCA • Embolic myocardial infarction • Patent foramen ovale • Case report

ESC Curriculum 2.1 Imaging modalities • 2.2 Echocardiography • 2.3 Cardiac magnetic resonance • 3.2 Acute coronary syndrome • 9.7 Adult congenital heart disease

Learning points

- Cardiac magnetic resonance imaging is a useful, non-invasive diagnostic tool in myocardial infarction with non-obstructed coronary arteries which helps differentiating myocarditis from myocardial infarction (MI).
- The use of multi-modality imaging is important in identifying the diagnosis of patent foramen ovale (PFO).
- Embolic MI as a result of paradoxical embolus is rare. Definitive management of PFO closure in these cases remains case by case and subject to local/national provisions.

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Introduction

Myocardial infarction with non-obstructed coronary arteries (MINOCA) occurs in 5–15% of cases of acute coronary syndromes.[1] These cases may have an underlying atherosclerotic cause, such as plaque disruption, or non-atherosclerotic causes such as coronary dissection or coronary embolus.[2] Myocardial infarction (MI) due to a secondary embolic phenomenon is rare with frequency reported as low as 3%.[3] Diagnosis at the time of cardiac catheterization can be challenging and further investigations are required to confirm the diagnosis and identify a source of embolism. Multi-modality cardiac imaging has an important role in the management of such patients with. His case highlighting its role in the clinical diagnosis and treatment of a case of presumed embolic MI due to patent foramen ovale (PFO).

Timeline

Day 1	Patient experiences chest pain with elevated troponin on admission bloods
Day 2	Coronary angiogram performed but demonstrates non-obstructed coronaries
Day 4	Cardiac magnetic resonance (CMR) imaging performed as diagnostic work up for possible myocardial infarction with non-obstructed coronary arteries.
Week 2 to 4	Treated as probable embolic myocardial infarction, patient underwent investigations for source
Week 5	Repeat CMR: resolving oedema; transthoracic echocardiogram:mild regional wall motion abnormalities with no obvious intra-cardiac shunt
Week 7	Contrast bubble echo: confirmation of inter-atrial communication
Week 20	Transoesophageal echocardiogram: confirmation of patent foramen ovale with right-to-left shunt
Week 27	Repeat CMR—resolution of oedema with residual scar

Case presentation

A 44-year-old Caucasian male was admitted to the hospital following an unheralded episode of chest pain 12 h prior to admission. The patient described transient chest tightness occurring at rest, associated with diaphoresis, dyspnoea, and anxiety. This was followed by an intermittent ache radiating to the left arm. This was not associated with eating or a heavy meal. There was no history of illicit drug use; the only recent medication of relevance was of sildenafil 3 days prior for erectile dysfunction.

The patient was a former smoker of 10–15 cigarettes/day for 12 years, having stopped smoking 14 years ago. He reported drinking only 1–2 glasses of wine per week. He had a history of varicose veins but no other significant past medical history, family history, or other cardiac risk factors. Clinical examination was unremarkable. Clinical observations were within normal parameters.

Electrocardiogram (ECG) demonstrated normal sinus rhythm without any specific ECG changes (*Figure 1*). Relevant abnormal bloods included a Troponin T of 777 ng/L rising to 1050 ng/L (normal <14 ng/L), a C-reactive protein of 30 mg/L (normal <6 mg/L), and N-terminal prohormone of brain natriuretic peptide of 183 pg/mL (normal <100 pg/mL). All other blood tests and chest X-ray were unremarkable. Invasive coronary angiography demonstrated non-obstructed coronary arteries (*Figure 2*). The patient was treated as myocardial infarction with unobstructed coronary arteries (MINOCA). No intracoronary imaging was performed at the time.

Cardiac MRI (CMR) was performed to further delineate the diagnosis. This demonstrated hypokinesia in the mid to distal left circumflex artery (LCx) and mid to distal right coronary artery (RCA) territories with associated myocardial oedema on T2-STIR imaging. There were multiple focal areas of transmural late gadolinium enhancement (LGE) in the lateral and inferior walls (*Figure 3*). This pattern was in keeping with an ischaemic cause rather than myocarditis (which would be mid-myocardial and/or epicardial). Based on the CMR findings, the diagnosis of multiple focal embolic infarctions in the LCx and RCA territories was established.

To investigate the cause of embolism, bilateral leg ultrasound Doppler was performed but was negative for deep venous thrombosis. Thrombophilia screen was performed shortly after admission but during the period of presumed acute thrombosis and therefore inconclusive in supporting any significant predisposition for thromboembolism. Transthoracic echocardiogram demonstrated normal left ventricular (LV) systolic and diastolic function with hypokinesia matching the CMR regional wall abnormalities, but no obvious intracardiac shunt, or other structural abnormality.

Further investigations to find an embolic source included a contrast bubble echocardiogram. A right-to-left shunt was demonstrated at rest and on the sniff, with an excess of 150 bubbles seen in the LV on the release of Valsalva (*Video 1*). These findings were consistent with a communication within the inter-atrial septum. A slit-like tunnelled patient foramen ovale (PFO) was further confirmed on transoesophageal echocardiogram (TOE) with no evidence of intra-cardiac thrombus (*Figure 4*).

Following confirmation of the right-to-left shunt on TOE, the patient was converted to oral anticoagulation with input from an adult congenital heart specialist regarding possible defect closure. Despite suitability for defect closure, this was not pursued due to the lack of local funding of this procedure for the indication for presumed embolic MI. Repeat cardiac MRI at 6 weeks and 6 months show resolution of oedema with residual late enhancement representing fibrosis in the areas of infarction (*Figure 5*). The patient remains well without any further admission with embolic phenomena.

Discussion

Patent foramen ovale (PFO) is present in ~25% of the general population.[4,5] In most cases, they may never result in any significant pathology. However, in those that do develop complications related to PFO, the most commonly recognized sequelae are cryptogenic strokes due to paradoxical embolus. Patent foramen ovale has been found to be present in 40–50% of these patients.[6]

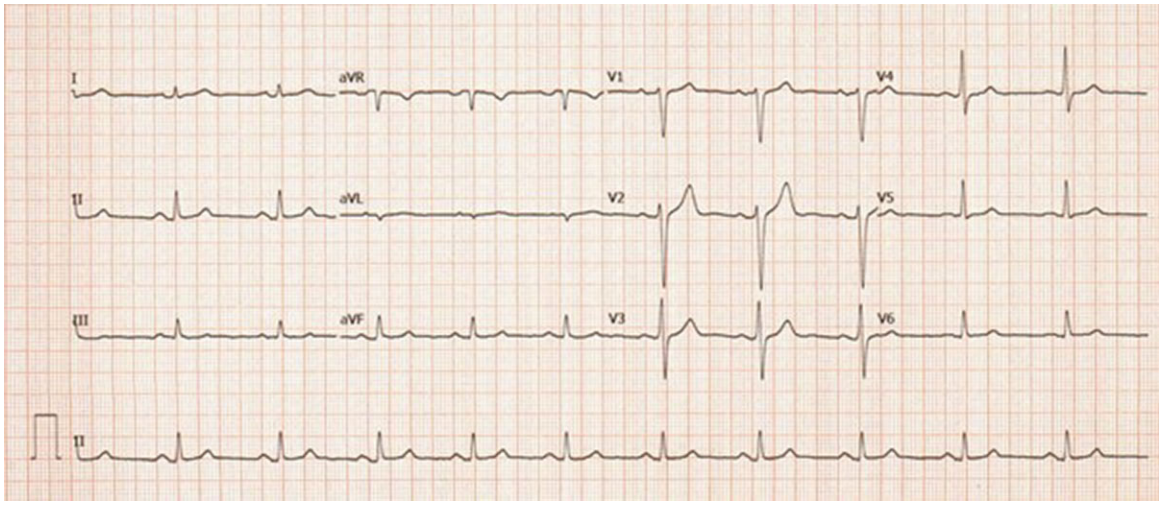

Figure 1 Admission electrocardiogram. Normal sinus rhythm with no specific ST-T changes.

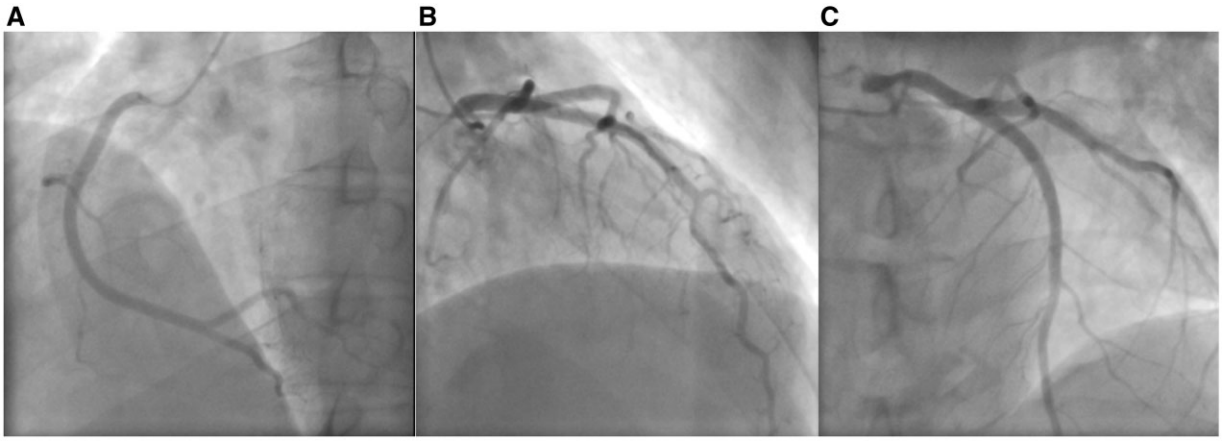

Figure 2 Cardiac catheterization demonstrating unobstructed coronary arteries. (*A*) Right coronary artery, (*B*) left anterior descending artery, (*C*) left circumflex artery.

The majority of cases of myocardial infarction (MI) are due to a coronary plaque rupture event.[7] Myocardial infarction with non-obstructed coronary arteries can occur in 5–15% of all acute coronary syndromes.[1] It is important to identify the underlying aetiology of their presentation to appropriately manage them. Differential diagnoses such as myocarditis and Takotsubo's syndrome may mimic a presentation of MINOCA, and further investigations such as CMR should be used to differentiate these diagnoses from infarctions. In particular, where multi-territory infarctions are seen on CMR, myocardial infarction due to secondary embolism should be considered and the next step in clinical management is to identify potential sources of emboli.

The occurrence of MI due to a suspected paradoxical coronary embolism is reported in up to 10–15%[8] but embolic infarctions presumed to be as a result of a PFO are rare.[9] Although rare, it is important to identify these patients as they need appropriate investigations to confirm their diagnosis and guide further treatment.

The cardiac MRI in this case demonstrated multiple focal infarctions in the multiple coronary artery territories. No obvious shunt was seen on CMR although most PFOs are anatomically too small to be detected by CMR and TOE remains the favoured diagnostic test to reliably identify PFO.[10] The combination of multi-territory infarctions and unobstructed coronaries on coronary angiography should raise the suspicion of an intra-cardiac shunt and prompt further diagnostic investigations to confirm or refute the presence of any shunt and presence of thrombus.

Investigation of embolic MI should encompass a thorough assessment searching for precipitant of thromboemboli such as atrial fibrillation and related structural heart disease, and cardiomyopathies.[11] The pattern of LGE on CMR usually identifies the most likely underlying differential, but rare mimics of patterns, such as transmural LGE in Parvovirus B19 myocarditis, should also be considered if there is clinical correlation to suspect this.[12] Presence of thrombus should be identified and appropriately

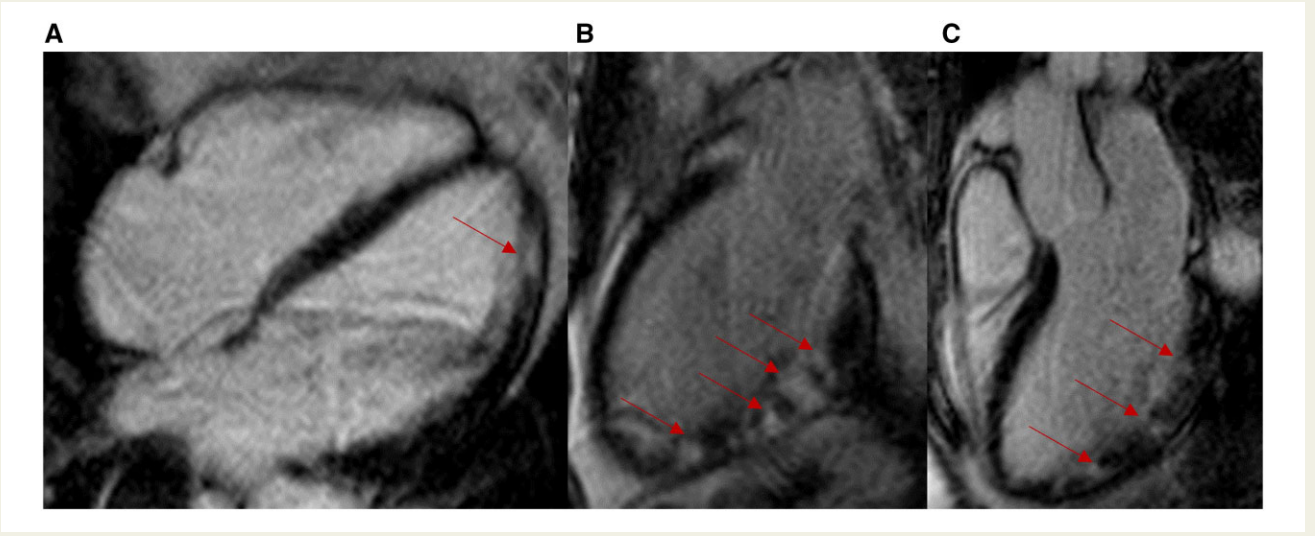

Figure 3 Late enhancement imaging of the four chamber (*A*), two chamber (*B*), and three chamber (*C*) demonstrating multi-focal transmural enhancement in the circumflex and right coronary artery territories (highlighted by the red arrows).

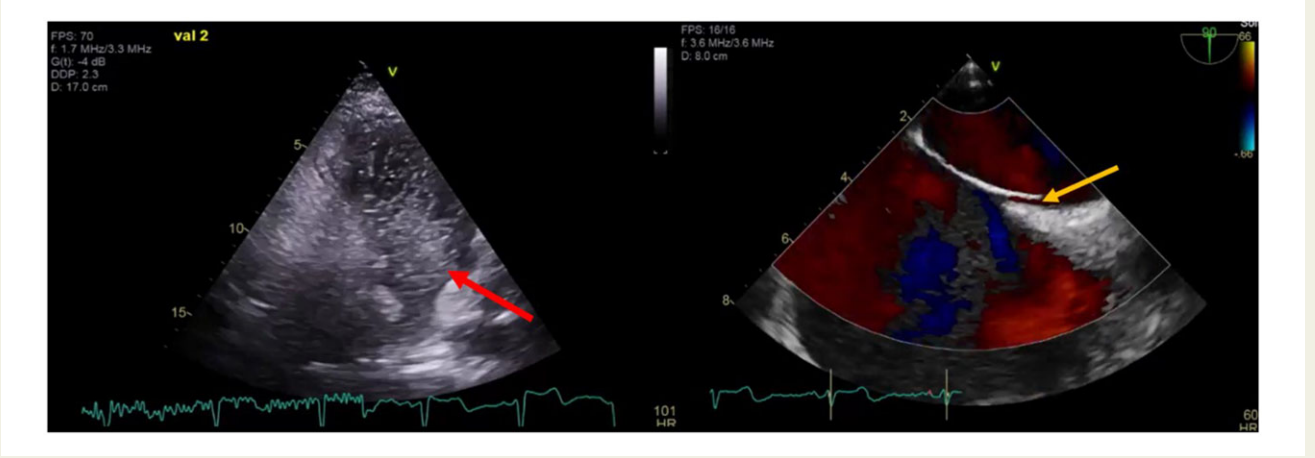

Figure 4 Contrast bubble echocardiogram (left image)—multiple bubbles seen within left ventricular cavity (red arrow) on release of Valsalva manoeuvre demonstrating a large inter-atrial shunt. The transoesophageal echocardiogram (right image) shows the presence of the slit-like patent foramen ovale highlighted by yellow arrow.

treated with anticoagulation,[13] which can be assessed on contrast echocardiography, TOE, and long TI CMR imaging.

A recent position paper by Pristipino *et al.*[14] summarizes the relevant diagnostic investigations and discusses the appropriate management of patients with left circulation thromboemboli, including the use of closure devices and anticoagulation. The paper highlights the value of interdisciplinary input and shared decision-making, taking into account risk factors to determine the best treatment option for patients with PFO and subsequent embolic events.

In this particular case, whilst he would have been a candidate for a PFO closure device, the local governance surrounding the funding of this procedure was unfortunately prohibitive. The continuing rarity of these particular cases will unlikely change this is the near future. However, with the increasing collaborative multi-modality imaging that most centres are taking, it is more likely that these cases will be correctly identified and perhaps result in the justification for more cases amenable to closure devices. In this case, the patient was given oral anticoagulation as secondary prevention for further embolic events as an alternative to closure of the PFO.

Conclusions

This case presents the complexities of patients with MINOCA and the importance of identifying the correct diagnosis with the use of

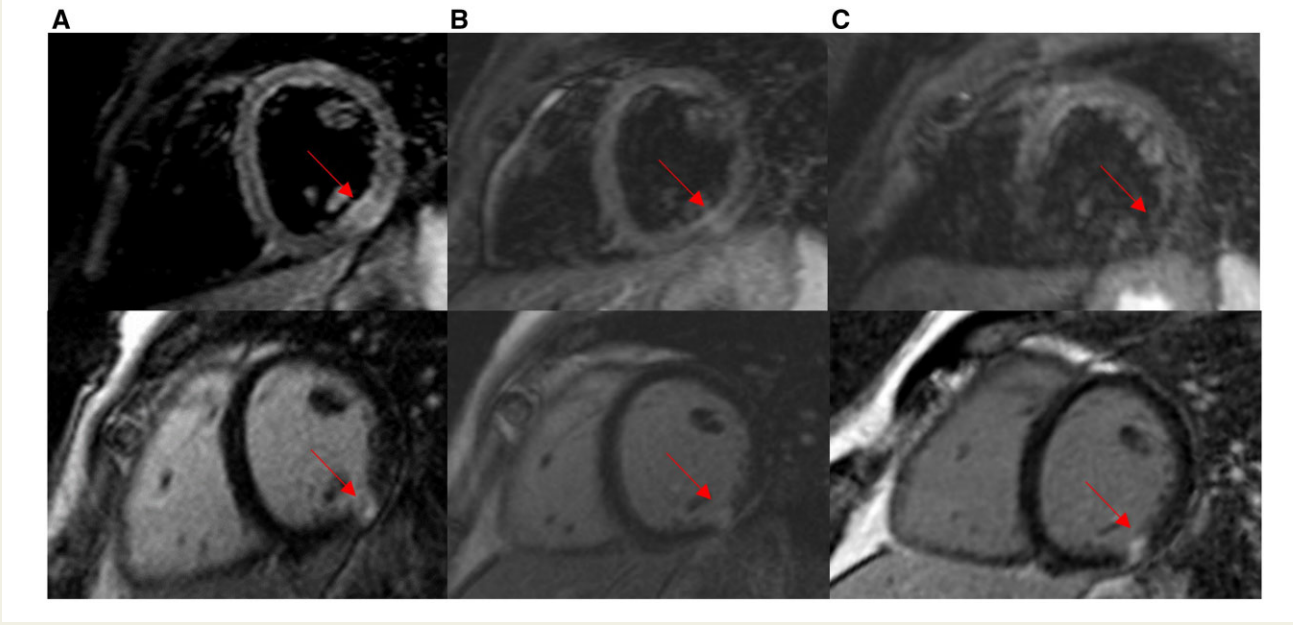

Figure 5 Images at presentation (*A*), 6 weeks (*B*), and 6 months (*C*). The top panel demonstrates high myocardial intensity on T2-STIR imaging which resolves on interval scanning. This is in comparison to the focal transmural scar on late gadolinium enhancement imaging (bottom panel) in the mid-inferolateral segment which persists over repeat imaging.

multi-modality imaging. In the presence of presumed embolic infarctions in non-obstructed coronaries, it is important to identify any potential source of emboli. Although PFO is common, the complication of embolic myocardial infarction is rare. Patent foramen ovale closure is a possible treatment for patients, but considerations regarding risk stratification and local provisions need to be taken into account. Patients should be referred to the appropriate subspecialist to ensure suitable long-term follow-up.

Lead author biography

Dr Kate Liang is a Cardiology Registrar with a subspecialist interest in cardiac imaging. She is currently working as a Cardiac MRI Research Fellow at the Bristol Heart Institute, UK and is undertaking a PhD on the use of Cardiac MRI in myocardial injury at the University of Bristol.

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: C.B.-D. is the CEO of the Society of Cardiovascular Magnetic Resonance (part-time role). The other authors have nothing to disclose.

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