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**CASE REPORT**
*Arrhythmias/electrophysiology*

# Temporary device malfunction of an MR conditional cardiac resynchronization defibrillator when undergoing MRI without appropriate re-programming: a case report

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**Background** Magnetic resonance (MR) imaging (MRI) for patients with implantable cardiac devices is becoming more routine, with the development of MR conditional devices allowing more patients access to the imaging they need. However, for this to be performed safely, strict protocols must be followed necessitating close collaboration between cardiology and radiology departments. We present a case where mandatory device re-programming of a cardiac resynchronization therapy defibrillator device into MRI mode was not performed pre-scan leading to temporary device dysfunction with no clinical consequences.

**Case summary** A 72-year-old man presented to a device clinic for a routine device interrogation. An atrial tachycardia response episode was recorded at the same time as the patient reported having undergone an MRI scan at a local centre. The electrogram demonstrated temporary right ventricular loss of capture with standard output programming, and a short episode of oversensing on the atrial and ventricular channel which was not sustained for long enough to meet tachycardia detection.

**Discussion** We demonstrate two potential electrophysiological effects of MRI on pacemakers, where the device had not been appropriately re-programmed pre-procedure. This illustrates that whilst MRI in patients with implantable cardiac devices is safe, strict protocols must be followed requiring robust multidisciplinary communication.

**Keywords** MRI • Pacemakers • Implantable cardioverter-defibrillator • Cardiac resynchronization defibrillator • Loss of capture • Programming • MRI safety • Case report



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## Learning points

- Prior to magnetic resonance imaging (MRI) strict protocols should be enforced to ensure patients with implantable cardiac devices are identified and re-programmed to ensure safety.
- Even for patients with magnetic resonance conditional devices failure to re-programme to MRI mode pre-scan can lead to device malfunction and potential clinical complications.
- Optimizing patient safety requires close collaboration between cardiology and radiology departments to ensure device conditions are met.

# Introduction

Increasing demand for magnetic resonance (MR) imaging (MRI) in patients with implantable cardiac devices resulted in development of MR conditional cardiac implantable electronic devices (CIEDs).[1,2] Although MR conditional, all CIEDs require reprogramming into 'MRI mode' prior to scanning to prevent adverse effects from the magnetic fields including electromechanical interference (EMI). EMI can lead to oversensing of noise due to the radiofrequency (RF) gradients, which in turn can lead to inappropriate inhibition of demand pacing or activation of anti-tachycardia (ATP and shocks) therapies in patients with defibrillators. Patients with stable underlying rhythms can have devices programmed with pacing off (ODO/OVO) for the duration of the scan, whereas those patients who require pacing must have sensing programmed off and will pace asynchronously (VOO/DOO) with lead voltage outputs increased to ensure capture.[1] Tachycardia therapies and defibrillation must be disabled in patients with implantable cardioverter-defibrillators.[1]

We present the case of a patient with an MR conditional CIED who underwent MRI without reprogramming. This resulted in transient RF-induced noise on all leads, which was inappropriately sensed as tachyarrhythmias, and in addition there was intracardiac electrogram (EGM) evidence of intermittent loss of right ventricular (RV) pacing capture, but with no adverse clinical events.

# Case presentation

A 72-year-old man with underlying dilated cardiomyopathy had an MR conditional cardiac resynchronization therapy defibrillator (CRT-D), Boston Scientific D179 device with lead models 7736 (right atrial), 0692 (RV), 4677 (left ventricular, LV). The system was implanted in 2015 for primary prevention following unexplained syncope with LV ejection fraction of 24% (normal range > 55%), left bundle branch block and New York Heart Association class II.

The patient attended for a routine device interrogation in March 2019, which demonstrated satisfactory battery, lead and device settings, consistent with previous follow-up (*Table 1*). On review of the events, there was a single stored atrial tachycardia response (ATR) episode which correlated temporally with him undergoing brain MRI at another centre for investigation of trigeminal neuralgia. Though the device logged this as an atrial arrhythmia episode it shows features on the EGM of the potential effects of MRI on CIED's.

1. Oversensing EMI—atrial fibrillation and ventricular fibrillation (*Figure 1*)
   *Figure 1* shows intermittent oversensing of EMI on the atrial and RV channels from the RF gradients during the MRI scan. There are periods of inhibited pacing and intervals in the ventricular arrhythmia detection zones. No tachycardia therapy is delivered as there are not enough intervals to meet the detection criteria. The device inappropriately detects an ATR episode, mode switches and stores an EGM of the event. There was no evidence of oversensing at any time point remote from the MRI scan (before or after).

3) Loss of RV capture (*Figures 2* and *3*)

4) *Figure* EGM demonstrates temporary loss of capture on the endocardial RV lead, however, there is capture on the epicardial (coronary sinus LV lead. This is proved in *Figure 3*, where the loss of evoked response on the RV channel is shown compared to the capture seen in clinic (*). The implications for our patient were minimal due to his continuing pacing from his LV lead and underlying AV conduction.

Provocation manoeuvres were performed in the clinic with no changes in impedance values and no oversensing seen proving satisfactory lead integrity and performance.

In discussion with the local hospital, it was determined that device re-programming was not performed prior to the patient being scanned, although the patient was asymptomatic throughout and the scan was completed without clinical complication.

# Timeline

| | |
|---|---|
| Implant 2015 | Primary prevention magnetic resonance conditional cardiac resynchronization tderapy defibrillator (CRT-D) implanted for underlying dilated cardiomyopatdy at tertiary centre for syncope, New York Heart Association class 2, left bundle branch block (QRS 160 ms), left ventricular ejection fraction 24% |
| Early March 2019 | Magnetic resonance imaging (MRI) of brain at local centre for trigeminal neuralgia—inadvertently undertaken without device re-programming with no complications |
| Late March 2019 | Routine CRT-D check at tertiary centre demonstrated evidence of a stored episode logged as an atrial tachycardia response contemporaneous with prior MRI scan. The CRT-D interrogation showed no other abnormalities |
| September 2019 | Routine CRT-D check via remote monitoring system showing satisfactory device function and for subsequent routine follow-up |

**Table 1 Device and lead measurements before and after the patient attended for his MRI**

| | Pre-MRI test results via remote home monitor (October 2018) | Post-MRI test results (Routine check on March 2019) | September 2019 (routine remote home monitor) | Permanent programmed settings (no programming changes during checks) |
|---|---|---|---|---|
| Atrial threshold | 0.5 V at 0.4 ms | 0.7 V at 0.4 ms | 0.5 V at 0.4 ms | 2 V at 0.4 ms |
| RV threshold | 0.5 V at 0.4 ms | 0.5 V at 0.4 ms | 0.6 V at 0.4 ms | 2 V at 0.4 ms |
| LV threshold | Not available | 0.9 V at 1 ms | Not available | 2.6 V at 0.4 ms |
| Atrial impedance | 693 ohms | 608 ohms | 602 ohms | |
| RV impedance | 459 ohms | 425 ohms | 424 ohms | |
| LV impedance | 1070 ohms | 952 ohms | 768 ohms | |
| High voltage lead impedance | 67 ohms | 68 ohms | 57 ohms | |
| Atrial sensing | 5 mV | 9.4 mV | 8.9 mV | AGC 0.25 mV |
| RV sensing | Not available | 14.7 mV | Not available | AGC 0.6 mV |
| LV sensing | 4.5 mV | 2.8 mV | Not available | |
| Battery longevity (years) and charge time (s) | 8 years and 9.6 s charge time | 7 years and 9.7 s charge time | 6.5 years and 9.8 s charge time | |
| Biventricular paced | 99% | 98% | 97% | Programmed mode: DDDR at 60–130 b.p.m. |
| Atrial paced | Not available | 72% | 75% | Biventricular pacing with -40 ms LV offset |
| Tachycardia detection | | | | VF zone: 230 b.p.m. at 5 s (ATP during charging and shocks)<br>VT zone: 200 b.p.m. at 6 s (ATP and shocks)<br>VT monitor zone: 160 b.p.m. at 10 s (no programmed therapy) |

The data immediately pre- and post-MRI scan is unavailable. Table includes programmed device settings and there were no programming changes made throughout this time. Automatic gain control (AGC), left ventricular (LV), anti-tachycardia pacing (ATP), ventricular fibrillation (VF), and ventricular tachycardia (VT).

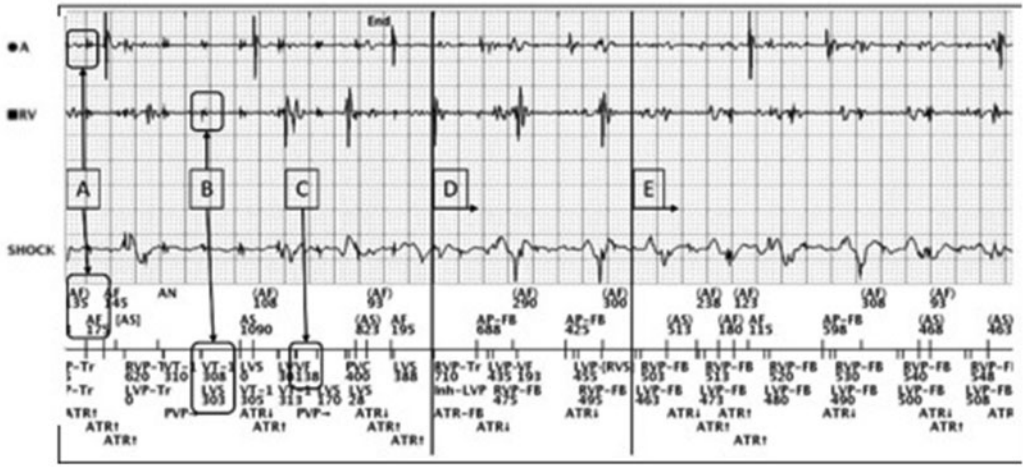


**Figure 1** This is a continuation of the stored atrial tachycardia response trace, channels are the sameIntracardiac electrogram showing oversensing interpreted as ventricular fibrillation due to electromechanical interference from magnetic resonance imaging radiofrequency gradients (*Figure 1*). Point A: inappropriate mode switch due to oversensing of magnetic resonance imaging rotational artefacts on the atrial channel. Point B: right ventricular and left ventricular oversensing of magnetic resonance imaging rotational artefacts. Point C: Interval falling into the ventricular fibrillation tachycardia detection zone, however, not enough to meet tachycardia detection. Point D: trigger pacing from the oversensed artefact. Point E: magnetic resonance imaging artefacts no longer senses on the right ventricular channel.

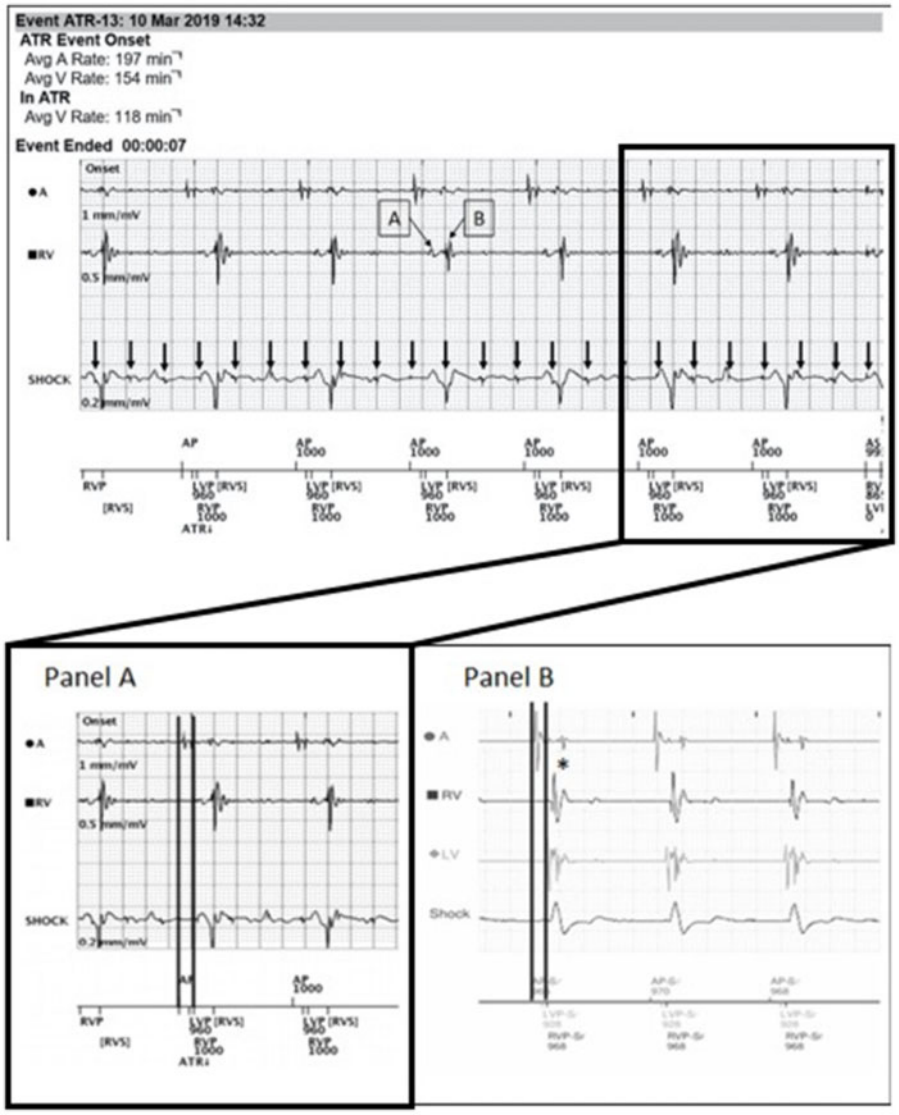


**Figure 2** Stored atrial tachycardia response episode during the magnetic resonance imaging scan. Electrograms: Top—right atrial (A); second—right ventricular; third—shock/farfield; bottom—marker channel. Point A on the trace shows loss of capture on the right ventricular lead. Point B indicating right ventricular activation from left ventricular pacing. The arrows on the shock channel indicate electromagnetic interference artefact (which also correspond visibly on the A and right ventricular channels). The signals are regular, high frequency and low amplitude at the rate of magnetic resonance imaging rotation.

After a satisfactory device interrogation, the patient was followed-up via remote monitoring, with no subsequent events, battery or lead abnormalities.

## Discussion

Undergoing MRI for patients with MR conditional devices is safe provided that published conditions are followed.[1,3] This case illustrates that re-programming to MRI mode is essential in all patients with pacemakers, CRT devices, and defibrillators—even if MR conditional. We describe a patient with an MRI conditional CRT-D that was scanned without re-programming into MRI mode. As a result, although without clinical adverse sequelae, this patient had both temporary loss of RV lead capture and oversensing of EMI artefacts.

Inhibition of pacing and activation of antitachycardia therapies have both previously been described with CIEDs undergoing MRI without device re-programming, due to oversensing of noise due to RF gradients.[1,4–6] The stored EGMs demonstrates this complication. In this patient, the RF gradients did not induce sufficiently sustained EMI to meet tachycardia detection criteria, so therapies were not delivered. Of note, the only major complication described in the Magnsafe registry of patients with non-MR conditional CIEDs undergoing clinical MRI was from tachycardia therapies not being disabled prior to scanning.[1]

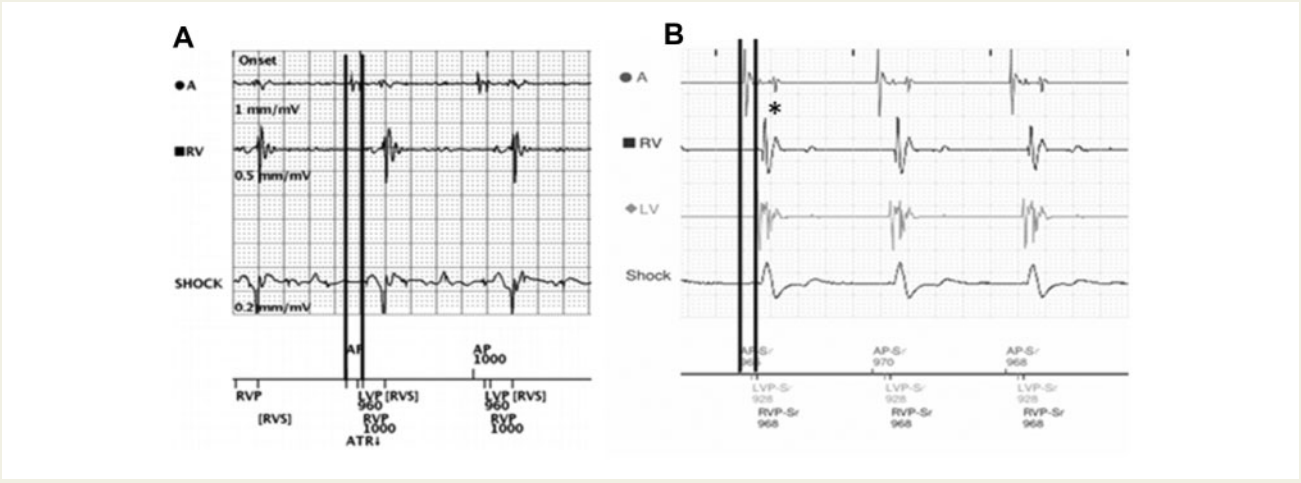


**Figure 3** (*A*) Stored atrial tachycardia response trace. (*B*) True biventricular pacing with capture. *Evoked response from local right ventricular capture.

In that case, noise was sensed as a ventricular tachyarrhythmia leading to repeated capacitor charging of the defibrillator, failure to discharge in the MR environment and subsequent premature battery depletion.

We present the first case displaying loss of capture on an intracardiac EGM *in vivo* due to MRI. The likely mechanism for loss of capture in the MR environment is from tissue heating at the lead tip resulting in myocardial oedema and increased capture threshold.[1,5–8] Heating effects at the myocardium-pacemaker lead tip interface have previously been found in animal models with chronically implanted pacemaker systems during MRI at 1.5 Tesla,[6,7] with temperature increases of up to 20°C in both active and passive leads. This may induce tissue inflammation around the pacing lead tip that could increase the stimulation threshold, although this has never been specifically demonstrated. It is however important to note that there are no clinical reports to date of adverse clinical sequelae from tissue heating, and tissue heating effects have not been demonstrated to differ between MR conditional and legacy non-MR-conditional leads.

In our case, we have no assessment of the transient nature of the capture threshold as a post-MRI device interrogation was not performed. The programmed output for this patient's device was three times the safety margin during the scan, meaning that albeit transiently, capture threshold must have increased by 1.5 V during the MRI scan (*Table 1*). It appears the LV lead-maintained capture during the scan, there has been no published investigation into epicardial pacing thresholds during MRI scans. Due to the differing lead myocardial tissue interface, this is likely to have differing heating effects compared to endocardial pacing leads.[2,3,6–8]

In conclusion, the availability of MR conditional CIEDs has ensured that all patients are able to access optimal diagnostic imaging; however, all patients with CIEDs including those with MR conditional devices should be re-programmed to MRI mode prior to scanning in order to avoid adverse consequences from the MR environment. Failure to perform this may lead to loss of capture, inhibition of demand pacing or activation of tachyarrhythmia therapies. As MRI scanning of cardiac devices is becoming commonplace with the widespread uptake of MRI conditional devices, it is essential that all remain vigilant to following appropriate procedures and ensuring that all MRI conditions are followed, requiring close collaboration between cardiology and radiology departments.

## Lead author biography

I have been a cardiac physiologist for 6 years and currently work at Bart's Heart Centre in London. I have a particular interest in cardiac rhythm management and heart failure. Outside of work, I enjoy talking my dog out for long walks in the countryside.

## 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 images and associated text has been obtained from the patient in line with COPE guidelines.

**Conflict of interest:** C.M. has received speaker fees from Abbott Ltd, Biotronik, Boston Scientific & Medtronic.

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