

Emerging electromagnetic interferences between implantable cardioverter-defibrillators and left ventricular assist devices

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Received 26 September 2019; editorial decision 18 December 2019; accepted 13 January 2020; online publish-ahead-of-print 31 January 2020

Aims

To investigate the prevalence of electromagnetic interference (EMI) between left ventricular assist devices (LVADs) and implantable cardioverter-defibrillators (ICDs)/pacemakers (PMs).

Methods and results

A retrospective single-centre study was conducted, including all patients undergoing HeartMate II (HMII) and HeartMate 3 (HM3) LVAD implantation ($n = 106$). Electromagnetic interference was determined by the inability to interrogate the ICD/PM. Overall, 85 (mean age 59 ± 8 , 79% male) patients had an ICD/PM at the time of LVAD implantation; 46 patients with HMII and 40 patients with HM3. Among the 85 LVAD patients with an ICD's/PM's, 11 patients (13%) experienced EMI; 6 patients (15%) with an HMII and 5 patients (11%) with an HM3 ($P = 0.59$). Electromagnetic interference from the HMII LVADs was only present in patients with a St Jude/Abbott device; 6 of the 23 St Jude/Abbott devices. However, in the HM3 patients, EMI was mainly present in patients with Biotronik devices: 4 of the 18 with only one (1/25) patient with a Medtronic device. While initial interrogation of these devices was not successful, none of the 11 cases experienced pacing inhibition or inappropriate shocks.

Conclusion

In summary, the prevalence of EMI between ICDs in the older and newer type of LVAD's remains rather high. While HMII patients experienced EMI with a St Jude/Abbott device (which was already known), HM3 LVAD patients experience EMI mainly with Biotronik devices. Prospective follow-up, preferably in large registries, is warranted to investigate the overall prevalence and impact of EMI in LVAD patients.

Keywords

Left ventricular assist device • Implantable cardioverter-defibrillator • Pacemaker • End-stage heart failure • Electromagnetic interference

Introduction

Left ventricular assist device (LVAD) therapy is increasingly utilized to treat end-stage heart failure patients who are in dire need of circulatory support.¹ Most patients who are eligible for continuous-flow LVAD therapy, already have an implantable cardioverter-defibrillator

(ICD) and/or pacemaker (PM) implanted.¹ However, following LVAD implantation, electromagnetic interference (EMI) can occur between the LVAD and the ICD/PM. Recently, multiple cases of EMI between LVADs and ICD's/PM's have been reported.^{2–4} The EMI hinders the interrogation of the ICD/PM's and leaves clinicians in the dark. Therefore, the aim of the present study was to investigate the

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What's new?

- Left ventricular assist device (LVAD) therapy is increasingly utilized to treat end-stage heart failure patients. However, following LVAD implantation, electromagnetic interference (EMI) can occur, in this study mainly between HeartMate 3 and Biotronik ICD devices.
- Following a stepwise approach could enable interrogation of the ICD/PM; however, in some cases surgical repositioning is necessary.

prevalence of EMI between different types of ICD/PM in patients implanted with HeartMate II (HMII) and the recently introduced HeartMate 3 (HM3).

Methods

Study design

We reviewed all patients who received an LVAD between December 2006 and February 2019 in our tertiary referral centre with a prior ICD/PM implantation or device replacement due to end-of-life. The study was approved by the institutional review board of the Erasmus MC Medical Centre Rotterdam.

Endpoints

The primary outcome was the occurrence of EMI, defined as ICD/PM telemetry interference (i.e. the inability to interrogate ICD/PM).

Data collection

All data were obtained from the electronic patient records. Baseline characteristics were collected pre-operatively for all patients. Devices included were the HMII, HM3 (Abbott, IL, USA).

Statistical analysis

Continuous parameters are expressed as median and inter-quartile range or mean and standard deviation, depending on the distribution. Categorical parameters were expressed as number and percentage and compared by χ^2 test. Analyses were performed using the SPSS statistical software package, version 24.0 for Mac (SPSS Inc., IBM Company, Chicago, IL, USA).

Results

In total, 109 patients received an LVAD (mean age at implantation 52 ± 12 , 83% male). Overall, 86 (mean age 59 ± 8 , 79% male) patients had an ICD ($n = 85$) or PM ($n = 1$) at the time of LVAD implantation; 46 patients with HMII and 40 with HM3. One patient with an ICD was excluded from further analysis because of missing follow-up data. None of the ICDs/PMs showed any abnormalities prior to the LVAD implantation. The implanted ICD/PM devices were from Medtronic (Dublin, Ireland) ($n = 25$), St Jude/Abbott (Chicago, IL, USA) ($n = 23$), Biotronik (Berlin, Germany) ($n = 18$), Boston Scientific (Marlborough, MA, USA) ($n = 18$), and Microport (Shanghai, China) ($n = 1$) (see Figure 1). Among the 85 LVAD patients with an ICD's/PM's, 11

patients (13%) experienced EMI; 6 ICD patients (15%) with an HMII and 5 ICD patients (11%) with an HM3 ($P = 0.59$).

Electromagnetic interference from the HMII LVADs was only present in patients with a St Jude/Abbott device; 6 of the 23 St Jude/Abbott devices (1 Atlas, 1 Unify, 1 Fortify, 1 Eclipse, and 2 Promote). However, in the HM3 patients, EMI was mainly present in patients with Biotronik devices: 4 of the 18 (device types: Lumax, Ilivia, llesto, and Iperia) with only one (1/25) patient with a Medtronic (Claria) device (see Table 1 for complete overview). None of the PM patients showed any signs of EMI.

Clinical outcomes

In 4 out of 11 patients, interrogation could not be performed in any form. For the other seven patients, with some minor adjustments, interrogation was made possible. While initial interrogation of these devices was not successful, none of the 11 cases experienced pacing inhibition or inappropriate shocks.

Discussion

The current study was aimed to gain insight on the prevalence of EMI between the HMII and HM3 LVAD's and several ICD/PM device types. The principal findings are as follows: (i) EMI is present in 13% of LVAD patients with ICD's *in situ*. (ii) In patients with an HMII, EMI is present only when they had an ICD from St Jude/Abbott implanted. However, in HM3 LVAD patients, EMI was mainly present in patients with ICD's from Biotronik. (iii) While 11 patients presented with difficulties regarding interrogation of their ICD, none of the patients experienced pacing inhibition or inappropriate shocks.

Currently, the LVAD literature mainly describes EMI in patients with a St Jude/Abbott device. Yet in the more recent HM3 type LVADs, it almost exclusively occurred in patients who had received a Biotronik device. Recently, several reported cases noticed the occurrence EMI between a Biotronik ICD and an HM3 LVAD.²⁻⁴ This emerging phenomenon warrants increased vigilance as an increasing number of patients receive HM3 LVAD therapy. Of note, since in our single cohort, no pacing inhibition or inappropriate shock has been administered, the clinical implication of the phenomenon appears limited. However, in larger cohorts with longer follow-up and/or emergency settings, the recognition of this phenomenon, the possible following complications and subsequent appropriate approach of EMI between ICD and LVAD could be of paramount importance.

The occurrence of EMI most likely occurs due to the magnetic components of the HMII and HM3 LVAD's, which hinder the interrogation of the ICD. The use of radiofrequency (RF), which is not affected by EMI, could be used to bypass this issue. Therefore, activating the RF use prior to LVAD implantation (if possible) should be considered. In patient with an LVAD *in situ* this is no longer is an option. Nonetheless, RF use can be beneficial. However, to activate the RF use, initial contact with the ICD is required. To achieve this, it seems that the distance between the ICD and the LVAD must be increased. Raising the ipsilateral arm and/or raising the ICD in its pocket can create enough distance to enable RF use. Alternatively, a Faraday cage (using copper or iron plates) can be put over the area with the LVAD to minimize EMI and enable RF use. Unfortunately, in some

Table 1 Electromagnetic interferences between implantable cardioverter-defibrillators and left ventricular assist devices observed in study population

Patient	ICD manufacturer	Type	LVAD type	Indication	Support duration	Type of EMI	Intervention
1	St Jude Medical	Unify (CRT-D)	HMII	Bridge-to-transplantation	25 days	Interference with telemetry function	RF use
2	St Jude Medical	Ellipse (ICD)	HMII	Bridge-to-transplantation	203 days	Interference with telemetry function	No interrogation possible
3	St Jude Medical	Atlas (ICD)	HMII	Bridge-to-transplantation	287 days	Interference with telemetry function	No interrogation possible
4	St Jude Medical	Fortify (ICD)	HMII	Bridge-to-transplantation	970 days	Dysfunction ICD system ^a	Device replacement
5	St Jude Medical	Promote (CRT-D)	HMII	Bridge-to-transplantation	1061 days	Interference with telemetry function	RF use
6	St Jude Medical	Promote (CRT-D)	HMII	Bridge-to-transplantation	1886 days	Interference with telemetry function	RF use
7	Biotronik	Ilesto (CRT-D)	HM3	Bridge-to-decision	199 days	Interference with telemetry function	Patient in lying position
8	Medtronic	Viva (CRT-D)	HM3	Bridge-to-transplantation	275 days	Interference with telemetry function	No interrogation possible
9	Biotronik	Iperia (CRT-D)	HM3	Destination therapy	348 days	Interference with telemetry function	Uplift device
10	Biotronik	Ilivia (CRT-D)	HM3	Bridge-to-transplantation	724 days	Interference with telemetry function	No interrogation possible
11	Biotronik	Lumax (ICD)	HM3	Bridge-to-transplantation	997 days	Interference with telemetry function	Patient in lying position

CRT-D, cardiac resynchronization therapy defibrillator; EMI, electromagnetic interference; HM, HeartMate; ICD, implantable cardioverter-defibrillator; LVAD, left ventricular assist device; RF, radiofrequency.

^aAfter implantation of the LVAD, the ICD device appeared to be in back-up mode (VVI 65 bpm) and shock therapy was disabled. After a multidisciplinary consultation (together with Abbott), it was decided to replace the ICD device. The cause of this problem was attributed to the EMI generated by the implanted HMII. Following the replacement with a device from a different manufacturer, no further issues were observed.

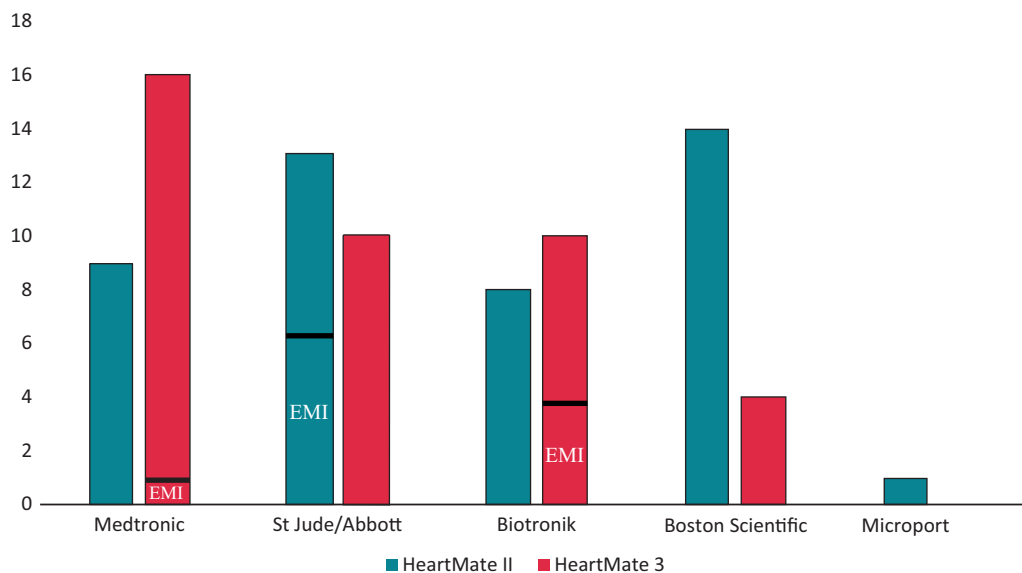
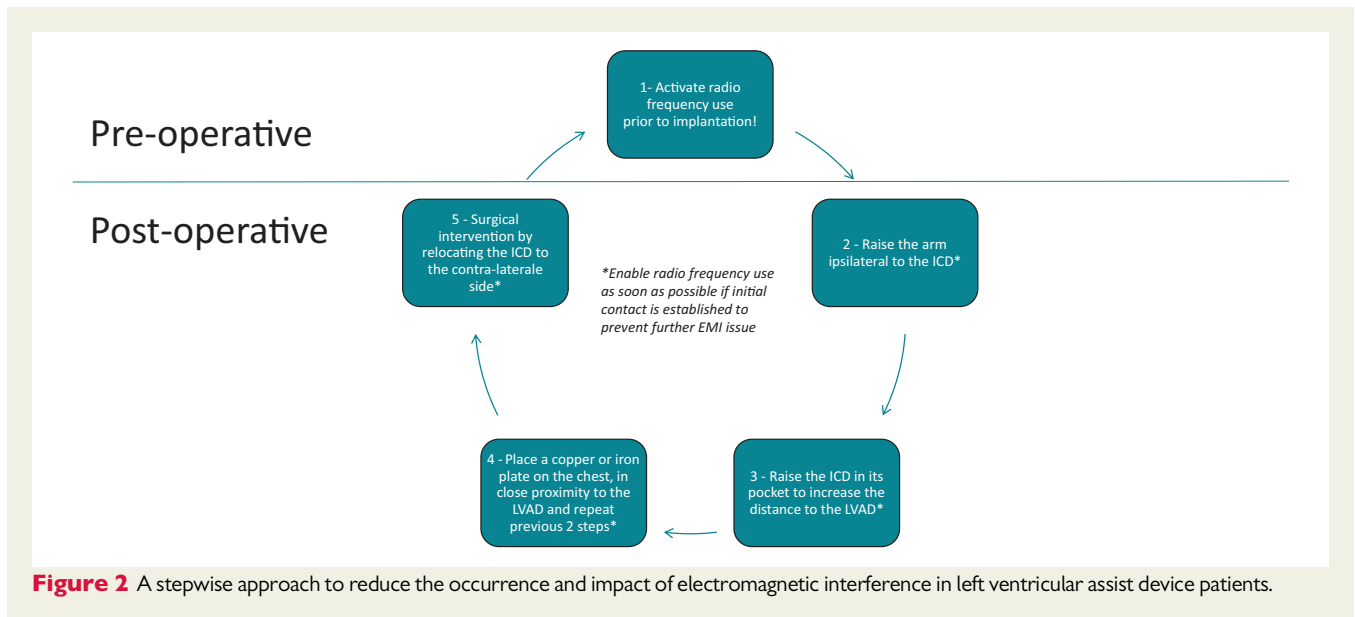


Figure 1 Cardiac implantable electronic device manufacturer distribution among the HeartMate II and HeartMate 3 left ventricular assist device types. HM, HeartMate.



cases, these methods were insufficient, and the ICD could not be interrogated. These situations could benefit from surgical intervention to increase the distance between both devices. This could be done by implanting the ICD in the contra-lateral side (see Figure 2 for complete overview). While no pacing inhibition took place or inappropriate shocks were administered, the EMI between the LVAD and the ICD hampers optimal ICD therapy. As this is a retrospective study, to further elucidate the effect of EMI between the contemporary HM3 LVAD and ICDs, prospective registries like the interagency registry for mechanically assisted circulatory support (INTERMACS) and the European registry for patients with mechanical circulatory support (EUROMACS) should incorporate these findings.

Conclusion

In summary, the prevalence of EMI between ICDs in the older and newer type of LVAD's remains rather high. While HM2 patients experienced EMI with a St Jude/Abbott device (which was already known), in our single-centre cohort, the HM3 LVAD patients experience EMI mainly with Biotronik devices. Ensuring enough distance

between the ICD and the LVAD seems to be beneficial. The provided methods can aid clinicians who experience similar problems with the interrogation of the ICD of their LVAD patients. While the aforementioned options to bypass this issue exist, they are sometimes inadequate. We, therefore, recommend further research, preferably conducted via prospective multicentre registries, to elucidate the full extent of the currently observed issue.

Conflict of interest: none declared.

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