Premature end of service of implantable cardioverter-defibrillator by magnetic interference with left-ventricular assist device

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Introduction
Implantation of left ventricular assist devices (LVAD) has become an important treatment strategy for patients with end-stage heart failure to improve survival and reduce morbidity. As increased susceptibility of ventricular arrhythmias is associated with end-stage heart failure, many patients have implantable cardioverter-defibrillators (ICD) or receive ICD implantation after LVAD implantation. This coexistence of 2 neighboring implanted electrical devices increases the risk of relevant device-device interactions. Several case reports previously described electromagnetic interference of LVAD and ICD systems that result in oversensing leading to inappropriate ICD therapy or an impaired telemetry communication between the ICD and ICD programmer during LVAD support. To avoid generator explantation and replacement, several strategies, including changes in body position and shielding methods to establish a pseudo–Faraday cage, have been proposed. Here, we report a case of a patient implanted with an ICD and an LVAD and premature end of service (EOS) of the ICD by magnetic interference between the 2 devices.

KEY TEACHING POINTS
- Device-device interference between left ventricular assist device (LVAD) and implantable cardioverter-defibrillator (ICD) systems can occur in the context of magnetic interference, resulting in activation of the magnetic sensor of the implanted ICD and premature end of service of the ICD by high energy consumption of repeatedly activated telemetry mode.
- Device-device interference between LVAD and ICD systems can also be present in the context of electromagnetic interference, resulting in telemetry communication failure between ICD and respective programmer.
- Location of ICD and size of generator pocket should be carefully reevaluated in LVAD patients during generator replacement, and maximum distance of these 2 devices should be aimed to avoid interference.

KEYWORDS Device interference; Electromagnetic interference; ICD; LVAD; Magnetic interference; Premature end of service

Case report
A 51-year-old male patient was implanted with a CRT-D system (Maximo II; Medtronic, Minneapolis, MN) and an LVAD (HVAD; Medtronic, Minneapolis, MN) for end-stage heart failure due to dilated cardiomyopathy. During routine follow-up a right ventricular lead dysfunction with reduced sensing and exit block was detected. As battery capacity of the implanted ICD was already significantly reduced, generator replacement (Amplia CRT-D; Medtronic, Minneapolis, MN) and implantation of a new right ventricular lead was performed. Perioperative interrogation revealed regular function of both implanted devices, whereas postoperative chest radiography showed a caudal shift of the ICD generator pocket.
generator. The patient was discharged from hospital. During first follow-up 4 weeks later, the patient reported on a recurrent monotonous acoustic alert signal that also spontaneously occurred during the device interrogation and was recognized as magnet-induced alert signal. Device function and parameters were still found to be within normal limits. As the alert signal was reproducible when the magnetic closure system of the LVAD battery pack bag was held near the ICD, a magnetic interference was first assumed and a nonmagnetic bag system was recommended. At follow-up 1 week later, the recurrent alert signal was still present despite a nonmagnetic bag system. Therefore, a direct interaction of the magnetic sensor of the ICD and the LVAD was assumed. According to the patient, the alert signal occurred several times a day for short periods. As magnet application leads to suspension of tachyarrhythmia detection and therapies in the implanted ICD model, the patient was informed about this condition and a revision of the ICD to correct the location was recommended. The patient rejected another operation. During next follow-up 3 months later, a premature battery depletion of the ICD (EOS) was found. The patient now agreed to an operative revision including generator replacement (Inogen CRT-D; Boston Scientific, Marlborough, MA) and a cranial shift of the generator pocket. Thereafter, no more interactions were detected.

Discussion
This is the first report demonstrating that magnetic interference between LVAD and ICD systems may result in a premature battery depletion of an ICD. In our case, device-device interference resulted in a recurrent acoustic alert signal of the ICD, indicating suspension of tachyarrhythmia detection and therapies as well as initiation of telemetry mode. Whereas the signal occurred only sporadically at first (mainly in a sitting body position), incidence was increasing over time (irrespective of body position) and led to premature EOS of the ICD within a period of only 5 months after implantation (Figure 1). The ICD was almost continuously in highly energy-consuming telemetry mode. Activation of the Hall sensor of the ICD was caused by spatial proximity of both implanted devices. The Hall sensor takes on the role of the Reed switch in magnetic resonance imaging conditional defibrillators. It transduces magnetic into electric information for inhibition of antitachycardia therapies and activation of telemetry mode in magnetic fields >1 mT. Of note, the pump system of the implanted LVAD (HVAD; Medtronic) contains a permanent magnet. Expansion of the generator pocket owing to repetitive surgery led to a closer proximity of both devices (Figure 2). The magnetic field of the LVAD pump system affected the ICD. Each time the magnetic flux at the magnetic sensor of the ICD exceeded 1 mT the sensor was activated and programmed monotonous acoustic alert signal occurred, indicating initiation of telemetry mode. Owing to compromised mobility, the patient was dependent on a wheelchair and thus body position additionally promoted closer proximity of the implanted devices (Figure 3). Changing of body position, eg, erect position with straight back, was not sufficient to prevent interaction. Finally, surgery was necessary to reestablish a working ICD system. In this specific case, the patient initially rejected an operative revision. This decision put him in danger, as tachyarrhythmia detection and all ICD therapies were
suspended each time the magnetic sensor of the ICD was activated. The patient habituated to the acoustic alert signal and—although demonstrated beforehand—could not distinguish the magnet-induced alert from the melodic elective replacement indicator alert occurring later. Therefore, no premature visit was arranged with our outpatient clinic.

Interestingly, telemetry communication of the ICD and the respective programmer, which was previously described as main target of (electromagnetic) device-device interactions, was not affected in this case in any of the performed controls.

Conclusion
Device-device interferences between LVAD and ICD systems emerge not only in the context of telemetry communication failure, but also in the context of uncontrolled activation of the ICD magnetic sensor by a permanent magnet of a neighboring LVAD and may lead to premature EOS of the ICD. As this is favored by spatial proximity of both implanted devices, size of generator pocket and location of ICD should always be carefully reevaluated in these patients during generator replacement and before wound closure.

Acknowledgments
This case report has been carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) and written informed consent of the included patient was obtained in advance.

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Figure 3 Photographs of the patient’s typical body position in the wheelchair promoting closer proximity of the implanted devices.