JACC: CLINICAL ELECTROPHYSIOLOGY
VOL. ■, NO. ■, 2023

ISSN 2405-500X/$36.00
PUBLISHED BY ELSEVIER

Letters

RESEARCH LETTER

Transcranial/ Transcutaneous Magnetic Stimulation Interacts With But Does Not Damage Implantable Cardioverter-Defibrillators

Transcranial magnetic stimulation (TMS) is an effective therapy in psychiatric and neurologic disorders, and transcutaneous magnetic stimulation (TCMS) of the left stellate ganglion may be a possible therapeutic strategy in refractory ventricular tachycardia.[1,2] Importantly, TMS/TCMS uses temporal gradients of magnetic field exponentially higher than magnetic resonance imaging. Currently, there are no experimental data on direct interaction between TMS/TCMS and implantable cardioverter-defibrillators (ICDs). Possible concerns include: 1) permanent damage to the circuitry of the ICD; 2) heating of the ICD; and 3) oversensing of the magnetic stimulation impulses leading to inhibition of pacemaker stimulation or inappropriate defibrillation. In this proof-of-principle study, we therefore exposed ICDs ex vivo to direct magnetic stimulation and investigated possible signs of interaction, heating, or damage to the ICD.

Included ICDs were connected to a cardiac arrhythmia simulator (ARSI 4; HKP) (Figure 1A) and exposed to magnetic stimulation at increasing output with a gradient of 9 kT/s at a distance from the coil surface of 2 cm and impulse duration of 280 μs. For magnetic stimulation, a MagStim R20+Express Generator and a MagStim C-B60 figure-of-eight coil were used (Figure 1B). Ethics committee approval was not required, because experiments were conducted ex vivo on medical devices.

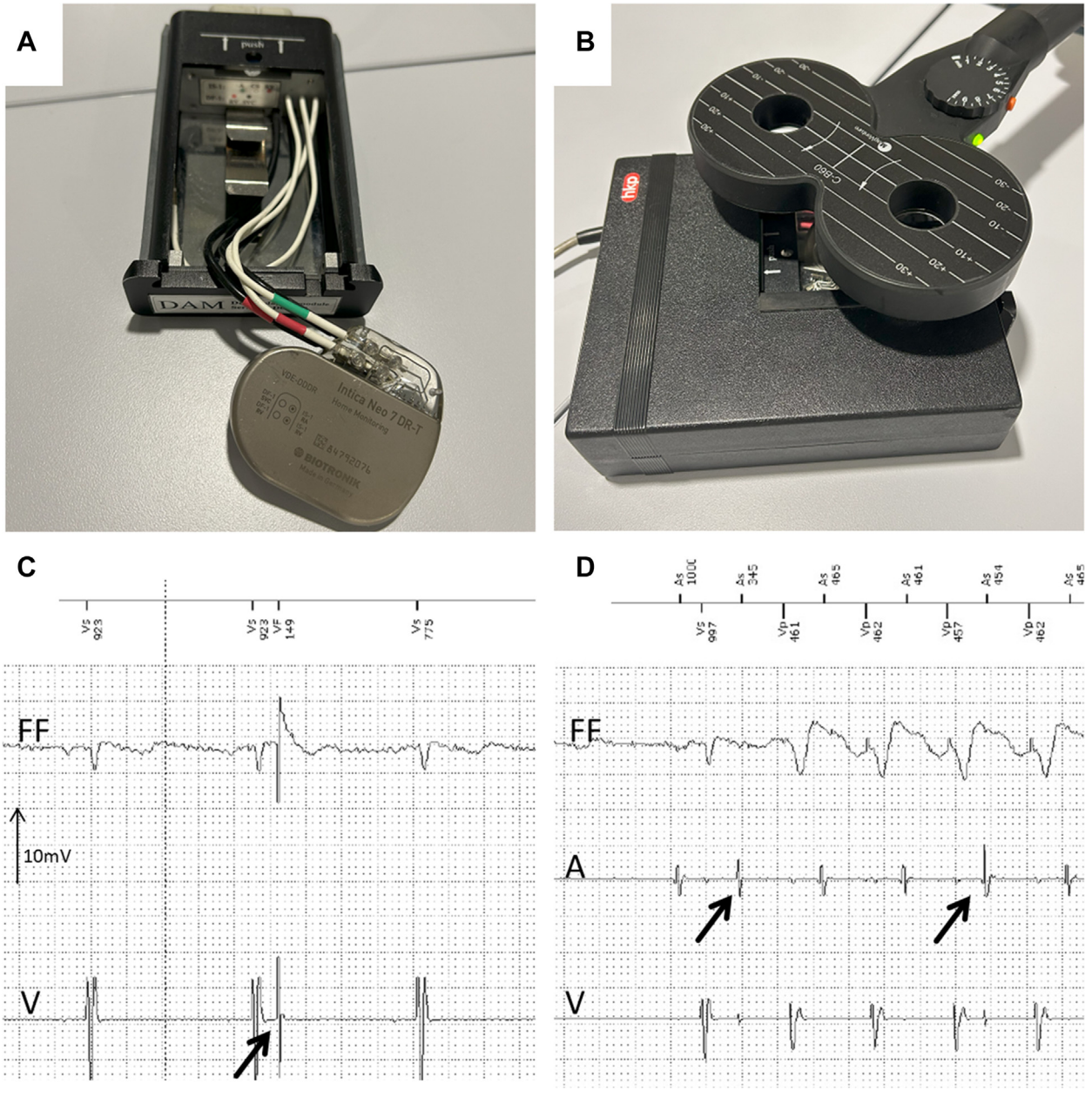
In the first experiment, a Biotronik Itrevia 7 VR-T Dx ICD was connected to the cardiac arrhythmia simulator, programmed in a single-chamber mode (VVI 40/min) and exposed to magnetic stimulation with an increasing gradient during continuous device telemetry. Up to an output of 50% of maximum, no discernible signal interference could be noted. At the maximum possible output, intermittent ventricular oversensing of the stimulation impulse occurred (Figure 1C).

In a second experiment, a Biotronik Intica Neo 7 DR-T ICD was connected to the cardiac arrhythmia simulator and programmed to a dual-chamber mode (DDD 50-130/min). It was then exposed to magnetic stimulation according to the above-described protocol. At an output of 25% of maximum, atrial oversensing occurred, leading to a pacemaker tachycardia which was correctly identified and terminated by the device (Figure 1D). In a third experiment, the same ICD was programmed into the device's MRI mode and programmed to asynchronous pacing (DOO 80/min). No further interaction between magnetic stimulation and the ICD occurred up to the maximum output. No significant changes in lead impedance, sensing amplitude, or thresholds were found after each of the 3 experiments.

In a fourth experiment, a Biotronik Rivacor 5 VR-T Dx ICD was connected to a Medtronic Sprint Quattro Secure MRI SureScan 6947M (62 cm) dual-coil defibrillator lead and immersed in a plastic container with 1.5 L 0.9% NaCl normal saline solution. Subsequently, the device was programmed to a single-chamber mode (VVI 40/min) and exposed to magnetic stimulation at an output of 70% of maximum and a repetition rate of 0.9 Hz for 15 minutes. The temperature of the normal saline bath containing the ICD did not change during stimulation (21.8 °C at 0 min, 21.8 °C at 5 min, 21.7 °C at 10 min, and 21.3 °C at 15 min). After the end of magnetic stimulation, there was no sign of damage to the ICD.

In summary, our proof-of-principle experiments indicate that the risk of damage to an ICD and heating of an ICD may be low during magnetic stimulation, even when stimulation is delivered directly to the device. We consistently used a far greater output at a far closer distance to the ICD than would be realistic for TMS/TCMS. Because only Biotronik ICD and Medtronic defibrillator leads were studied, research on ICD, pacemakers, and magnetic stimulation coils and generators of all types and manufacturers in

FIGURE 1 **Representative Images of Magnetic Stimulation in ICD**



(A) Explanted implantable cardioverter-defibrillator (ICD) connected to the cardiac arrhythmia simulator. (B) Placement of the magnetic stimulation coil directly above the cardiac arrhythmia simulator. (C) ICD electrogram during magnetic stimulation at maximum output leading to ventricular oversensing. Arrow indicates stimulation-induced artefact. (D) Magnetic stimulation at 25% of maximum output leading to atrial oversensing and inducing a pacemaker tachycardia in a dual-chamber ICD (arrows). Atrial sensitivity: 0.4 mV; ventricular sensitivity: 0.8 mV.

more physiologic models of magnetic device interference is warranted. However, our data could encourage investigators using TMS/TCMS to include device patients in future studies after careful individual risk/benefit analysis. This approach may be supported by case reports documenting apparent safety of TMS in patients with cardiac pacemakers.[3-5] In light of the high comorbidity of depression in cardiovascular disease and its distinct effect on outcomes and prognosis, this might add therapeutic

options for a significant proportion of cardiac patients.

ACKNOWLEDGMENTS The authors thank Ulrich Franke (Biotronik), Hannes Conrad (MagVenture), and Andreas Wollbrink (IBB, University of Muenster) for their support.

*Felix K. Wegner, MD[a]
Michael Bietenbeck, MS[b]
Sonja Suntrup-Krueger, MD[c]
Timothy M. Markman, MD[d]
Lars Eckardt, MD, PhD[a]
Carsten Wolters, PhD[e]

*Department of Cardiology II-Electrophysiology,
University Hospital Muenster,
Albert-Schweitzer-Campus 1,
48149 Muenster, Germany
E-mail: felix.wegner@ukmuenster.de

From the [a]Department of Cardiology II-Electrophysiology, University Hospital Muenster, Muenster, Germany; [b]Department of Cardiology I-Cardiovascular Imaging, University Hospital Muenster, Muenster, Germany; [c]Institute of Translational Neurology, Department of Neurology, University Hospital Münster, Muenster, Germany; [d]Cardiovascular Division, Perelman School of Medicine at the University of Pennsylvania, Philadelphia, Pennsylvania, USA; and the [e]Institute for Biomagnetism and Biosignal Analysis, University of Muenster, Muenster, Germany.

https://doi.org/10.1016/j.jacep.2023.10.021

Dr Suntrup-Krueger is supported with an endowed professorship by the Else-Kröner-Fresenius-Stiftung. Dr Markman has received nonfinancial research support from MagStim. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.
The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

REFERENCES

1. Lefaucheur J-P, Aleman A, Baeken C, et al. Evidence-based guidelines on the therapeutic use of repetitive transcranial magnetic stimulation (rTMS): an update (2014-2018). *Clin Neurophysiol*. 2020;131(2):474-528.

2. Markman TM, Pothineni NVK, Zghaib T, et al. Effect of transcutaneous magnetic stimulation in patients with ventricular tachycardia storm: a randomized clinical trial. *JAMA Cardiol*. 2022;7(4):445-449.

3. Jammigumpula A, Joseph JT, Manibettu V, et al. Safety of repetitive transcranial magnetic stimulation in patients with cardiac pacemakers: a case report. *J ECT*. 2023;39(3):e15-16.

4. Stultz DJ, Pitch R, Tuttle C, et al. Pacemaker and transcranial magnetic stimulation (TMS) use in H-1, figure-8, and single-pulse coils. *Brain Stimul*. 2022;15(3):803-805.

5. Wei DY, Greenwood FS, Murgatroyd FD, Goadsby PJ. Case report of the safety assessment of transcranial magnetic stimulation use in a patient with cardiac pacemaker: to pulse or not to pulse? *Headache*. 2018;58(2):295-297.