



Pacemaker and Transcranial Magnetic Stimulation (TMS) use in H-1, figure-8, and single-pulse coils

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1. Introduction

Rossi [1] reported that Transcranial Magnetic Stimulation (TMS) use was safe with VNS systems, cardiac pacemakers, and spinal cord stimulators if the coil was not activated too close to where the device is implanted. Specific distance parameters were often unclear, resulting in many studies excluding these situations in clinical trials and device labels issuing warnings for their use [2]. Updated guidelines by Rossi [3] clarified that TMS with figure-8 coils is considered safe if the TMS coil is not activated less than 10cm from the electronic components. However, many TMS clinicians remain hesitant to treat patients who have cardiac pacemakers.

With respect to TMS coils used in TMS, the strength of a magnetic field decreases as it travels from its source at a rate of R^{-3} or $1/R^3$, where R is the distance from the center of the coil. For a typical figure-8 TMS coil, the peak source field is about 15,000 gauss (1.5 Tesla); this diminishes to about 0.55 gauss at 30 cm from the center of the coil. The H-1 coil produces a much broader magnetic field that is less uniform but still results in an acceptably low field level at 30 cm. The location of an implanted device in the anterior chest wall is more than 30 cm for most patients. Thus, TMS coil magnetic field level is sufficiently low enough not to induce meaningful currents in conductors exposed to it when used correctly.

Two previous case reports were found on TMS in patients with pacemakers. Hizli Sayar [4] described a 72-year-old male with a dual-chamber pacemaker for sick sinus syndrome whose depression was successfully treated with a figure-8 coil to the left dorso-lateral prefrontal cortex at 10 Hz, 110% MT and 1000 stimuli for six sessions/week, demonstrating improvement on his Hamilton Rating Scale for Depression [5] from 32 to 6.

Wei [6] reported on a 78-year-old woman with a pacemaker whose 25-year chronic resistant migraines were safely and effectively treated with single-pulse TMS to the occipital cortex. She was initially studied in the cardiac lab with the support of

cardiology and EKG monitoring with no effect on her EKG or pacemaker. She was then switched to outpatient treatment of two pulses in the morning and evening without side effects or effects on the pacemaker.

Here, we describe two patients with cardiac pacemakers treated in two independent clinics with two different coil types. In each case, the patient was made aware of the potential risks related to the use of TMS with pacemakers, and the procedure was coordinated with the patient's cardiologist.

2. Methods

Before the first TMS session, each patient was evaluated with a baseline EKG and interrogation of the pacemaker function. This was also done after the final TMS session. A Medtronic donut magnet was taped to the patient's chest wall over the pacemaker device during each TMS session (See Fig. 1). A pulse oximeter was placed on the left hand in view of the TMS operator because some right-hand movements might be expected during stimulation of the left cerebral cortex. An alarm indicator was set for a pulse outside 50–100 beats per minute.

A donut magnet (See Fig. 2) is a ring-shaped permanent ferrous magnet that is strong enough (more than 10 Gauss) to alter pacemaker function. The Medtronic pacemaker blue donut magnet model 9466 has a minimum field strength of 90 Gauss when measured 1.5 inches from either side of the magnet [7]. Since it is dense and ferromagnetic, it redirects an outside electromagnetic field away from the underlying tissue. When placed over the pacemaker, it converts the pacemaker into an asynchronized mode, which means it no longer senses the intrinsic heart rhythm. Thus, the implanted pacemaker will now discharge at a fixed rate. Once the magnet is removed, the pacemaker reverts to its original pacing programming [8].

Our first patient was a 55-year-old man with severe treatment-resistant depression. He had chronic atrial fibrillation requiring a cardiac pacemaker and an implantable defibrillator. He had previously failed medication trials, including fluoxetine, sertraline, escitalopram, venlafaxine, duloxetine, bupropion, mirtazapine, lithium, valproic acid, lamotrigine, topiramate, levetiracetam, quetiapine, olanzapine, aripiprazole, lurasidone, and cariprazine. Due to the severity and persistence of his depression, he requested a trial of TMS before consideration of ECT. The patient was treated using an H-1 coil over the left DLPFC at 18Hz, 120% MT, 55 trains for 2 seconds with a 20-s intertrain interval for 1980 pulses per session. He received 28 sessions. His post-treatment Beck Depression [9] and PHQ-9 [9] scales demonstrated remission (5 and 4, respectively), with the patient stating, "I have not felt this good in 16 years".



Fig. 1. Patient with donut magnet and pulse oximeter.



Fig. 2. Medtronic donut magnet.

The second patient was a 68-year-old woman with a 38-year history of treatment-resistant major depression superimposed upon dysthymic disorder. She had inadequate responses to the following medications: fluoxetine, sertraline, escitalopram, bupropion, venlafaxine, duloxetine, levomilnacipran, mirtazapine, vortioxetine, lamotrigine, quetiapine, and aripiprazole. She also had unsatisfactory results with ECT and participated in many years of psychotherapy. She had a complete heart block and was 98% pacemaker dependent with a Medtronic device in the upper left chest wall near the clavicle. She was turned away by several TMS centers closer to her home because they were hesitant to treat a pacemaker-dependent patient with TMS. We treated her with a figure-8 coil stimulating the left DLPFC at 10Hz, 120% of SMT, 4 seconds with an 11-s intertrain interval, 3000 pulses/session for 36 sessions. She achieved full remission for the first time in 30 years. The pre-and post-treatment BDI-II [9] scores were 35 and 5, respectively.

3. Conclusions

With the simple procedure described above, we delivered TMS therapy to two patients with cardiac pacemakers who were refractory to numerous other treatments. Based on safety recommendations by Rossi et al., 2021 and the four previously mentioned cases, it appears pacemaker use in TMS is well tolerated.

Conflicts of interest

The authors have no conflicts of interest to report for this article.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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