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Safety of rTMS in patients with intracranial metallic objects

Dear Editor,

We read with interest the recent letter from Stillman and colleagues [1] discussing the successful application of repetitive transcranial magnetic stimulation (rTMS) in a patient with a titanium intracranial aneurysm clip. We concur with the authors that this is an important topic and that contraindication of metal implants to rTMS can possibly deprive a considerable number of patients with medication-resistant depression from the potential clinical benefits of rTMS treatment. We also appreciate the efforts of Stillman and colleagues to draft safety guidelines for the application of TMS in patients with aneurysm clips. However, we disagree with the conclusion that “TMS can be safely provided to patients with non-ferromagnetic aneurysm clips.” This a priori assumption lacks strong scientific or empirical evidence and may not always be valid.

Our caution is based on the concerns that metallic objects (ferromagnetic or otherwise) are subject to potential heating and mechanical displacement induced, respectively, by the eddy currents and Lorentz forces generated by TMS [2]; they may also guide electric current in such a way that safe current density in brain tissue may be locally exceeded. Although magnetic resonance imaging (MRI) safety studies conclude that many non-ferromagnetic cranial implants are safe for patients undergoing MRI [3,4], the electric fields and eddy currents induced by MRI procedures (mainly by the rapidly switching gradient fields) are typically orders of magnitude smaller than those due to TMS. The TMS-induced eddy currents in the metallic objects result in Lorentz forces and heat these objects, which can potentially be injurious. Hence, Stillman et al.’s [1] statement “if a clip is listed as safe for MRI, it is likely safe for TMS treatment as well”, is misleading. We also note that modern implant materials are often alloys, with a variable proportion of magnetic, paramagnetic and diamagnetic elements, and thus the distinction between “ferromagnetic” and “non-ferromagnetic” objects may be blurred. Further, as the TMS-induced voltage around a loop of wire is proportional to its area, the size of any conducting path in the aneurysm clip should be considered, independent of its composition. Thus, both heat and forces generated by TMS depend on the detailed geometry of the clip and on the degree of electrical contact between different arms of the clip.

Moreover, when metal is inserted in tissue, it provides a low-resistivity path for current to flow. In this scenario, when TMS induces an electric field in both tissue and the metal, the current will tend to flow along best-conducting paths (i.e., along the metal). If the metal object has narrow or pointed ends, the density of current flow into the tissue can be far higher than without the metal, which can, in principle, cause tissue damage.

As no clinical safety data are available, systematic and comprehensive ex vivo studies are needed to better understand (and mitigate) the effects of rTMS on aneurysm clips or other metallic objects implanted in patients. For instance, our group previously measured the distance-, size- and orientation-based heating effects of a common clinical rTMS protocol with a figure-8 coil on a frequently used aneurysm clip made of a cobalt-chromium-nickel alloy [5], while Varnerin et al. [6] assessed the degree of heating of MRI-compatible vascular stents resultant from various geometric, orientation and location parameters relative to the coil. Similarly, we also evaluated the capacity for rTMS to heat or displace titanium skull plates [7].

The value of testing a range of materials is underscored by discrepant published results. For instance, while Pridmore and Lawson [8] found no movement of titanium aneurysm clips due to TMS in a ballistic pendulum experiment, we found subtle but measurable movement of titanium skull plates in a similar experiment [7]. Such discrepancy may be explained by differences in mass, shape and orientation of the tested objects.

The above-mentioned experiments notwithstanding, no study has systematically addressed the dependence of TMS-induced heating or forces on implanted intracranial material characteristics such as size, geometry, conductivity and specific heat in a way that would enable reliable assessment of health risk without additional testing. That is, a catalog of TMS-safe materials and implantable objects and devices is not available. Such efforts are desirable, since from our perspective MRI compatibility is insufficient to predict safety in the TMS setting. We encourage ex vivo studies, to better define the safety parameter space as it relates to rTMS in patients with metallic cranial implants.

Author contributions

Conceptualization, Writing - SD, RI, MT, LC, APL, AR; Supervision – AR.

Conflict/Declaration of interest

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