# A Heat Transfer Analysis of the Cochlea During Magnetically-guided Cochlear Implant Surgery

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## Abstract

Approximately 450,000 people worldwide suffering from hearing problems use cochlear implants (http://www.cochlear.com/au/home/connect/cochlear-hearing-ambassador, June 12, 2018). Manual insertion of the cochlear implant during surgery can potentially damage the delicate tissues within the cochlea, which can lead to deterioration of residual hearing ability and mitigation of the cochlear implant functionality. In order to improve the accuracy of the insertion and diminish the risk of permanent damage, Abbott's group proposed to magnetically guide the implant in the cochlea in lieu of manual insertion (Leon et al., Journal of Medical Devices 8, 041010, 2014). In this paradigm, a magnet attached to the cochlear implant is guided through the cochlea under the driving force of a magnetic field. To prevent any future damage to the cochlea, which may be caused by exposing the patient to a strong external magnetic field (e.g. MRI), the magnet has to be detached from the implant and removed from the cochlea. However, the detachment process generates heat that may be harmful to surrounding tissues. The objective of this research is therefore to study heat transfer within the cochlea and determine conditions for which thermal trauma are avoided.

The cochlea is a long semi-conical, spiral-shaped channel with two and one-half turns consisting of three sub-channels (Fig. 1.a) (SICAS Medical Image repository http://doi.org/10.22016/smir.o.207473). For the transient thermal analysis, simplified 1-D and 2-D geometries of an uncoiled cochlea are modeled in COMSOL Multiphysics 5.3a. The inner ear fluids are approximated as water. Results from the 1-D and 2-D COMSOL models are verified with analytical solutions in a 1-D geometry. To validate the 2-D model with 1-D results, the temperature profile in a cross-section of the 2-D model is compared with the 1-D model. The thermal damage threshold of in-vivo tissues depends on temperature, type of tissue, and the length of exposure to the heat source. Cumulative equivalent minutes at a fixed temperature (CEMT) is a parameter that combines the effects of temperature and length of exposure. As such, CEMT is used to determine a safe range of power input (g0) for magnet detachment from the implant. Yoshida et al. (Journal of Neuroscience 19, 10116-10124, 1999) reported that exposing mouse ear tissues to a temperature of 43°C for 1.9 min does not affect ear functionality.

As depicted in Fig. 1.b, the maximum temperature difference between the analytical and numerical solutions does not exceed 2%. By applying the Parametric Sweep Study Module of COMSOL, it is found that the maximum safe allowable power input for magnet detachment from the cochlear implant is 1.35×107 W/m3 based on a CEM43 of 1.9 minutes. In addition, the time (tmax) required for the cochlea to reach a maximum temperature (T) of 43°C is shown in Fig. 1.c as a function of the power input. Validation of a

2-D COMSOL model (Fig. 1.a) is shown in Fig. 1.d. These results (and others) will eventually help assess the accuracy of a complex 3-D transient heat transfer model of the cochlea.

## Figures used in the abstract

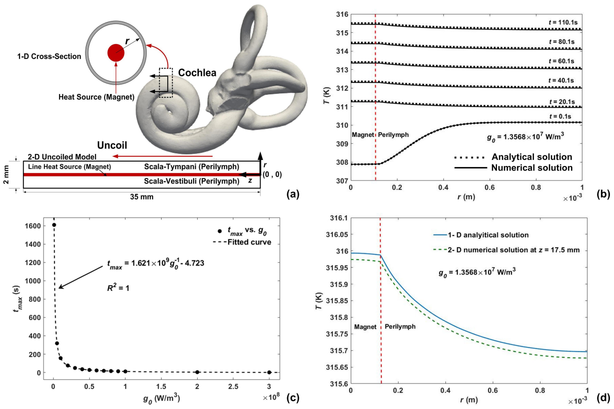


**Figure 1**: Figure 1. a) Geometry b) Transient temperature (T) vs. radius (r) c) Maximum operation time vs. power input d) Validation of the 2-D results with 1-D.