Power to temperature transfer function derivation for AIMD local tissue heating

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1 Introduction

The region of high tissue-heating is located where the electric field is expected to be concentrated due to the presence of the active implantable medical device (AIMD). These at-risk regions are likely in the vicinity of the stimulation electrodes of the AIMD. The local tissue-heating can be evaluated in three steps: 1) quantify the incident radio frequency (RF) fields to the implants, 2) estimate a conservative RF power deposited in the tissue by the AIMD due to the RF fields of 1), and 3) assess the corresponding in vivo temperature increase in the tissue due to the absorbed RF energy, by which guidelines for 1) and 2) are established in ISO/TS 10974 [1]. In this study, we demonstrate that the conversion factor between power deposition to a temperature metric can be used in 3) and can be determined without the knowledge of incident conditions to the AIMD and complete geometry of the AIMD.

2 Method

The distributions of the local induced power deposition and temperature within the high-heating region are dominated by the AIMD electrode geometry, and there is a static transformation from power deposition to a temperature metric that is independent of the incident conditions to the implant. To verify this hypothesis, we derive the conversion factor between power deposition and the maximum local temperature rise (p2\(\Delta T_{\text{max}}\)) from 90 generic AIMD samples of various lengths. The computational electromagnetics (Maxwell’s equation) and thermal (Penne’s bioheat equation) simulations are conducted using the simulation platform, Sim4Life (ZMT, Zurich, Switzerland).

3 Results and Discussions

The generic AIMDs are insulated wires of different lengths. p2\(\Delta T_{\text{max}}\) is derived for five electrode geometries: 2, 4, 6, 8, and 10 mm-long. We demonstrate that for small electrodes, p2\(\Delta T_{\text{max}}\) are independent of the AIMD complete geometry and can be evaluated without the full knowledge of the AIMD incident conditions or lead geometry. p2\(\Delta T_{\text{max}}\) can be used to convert the estimated in vivo power deposition into the maximum tissue temperature increase. Tissue perfusion [2] will be considered in future work to provide better estimates of the in vivo scenarios.

Figure 1. p2\(\Delta T_{\text{max}}\) numerically derived for 90 generic AIMD samples of different electrical length (h/\(\lambda\)).

References
