Syllabus: Modeling of SAR, Power Deposition, and Implantable Devices

Tamer S. Ibrahim (Email: tsi2@pitt.edu)  
Departments of Radiology and Bioengineering  
The University of Pittsburgh, Pittsburgh, Pennsylvania, USA

Since human MRI was introduced as a clinical diagnostic tool, many safety concerns have been raised regarding the extent of the associated radiofrequency (RF) power deposition in tissue (1-10). Particularly, analyzing the dependence of RF power deposition on the frequency of operation, i.e., Larmor frequency or $B_0$ field strength, has been a topic of research interest over the last half century (3,9-11). As human MRI is currently performed at field strengths reaching 7 (12,13), 8 (14,15), and 9.4 (16) tesla, accurately predicting the RF power absorption associated with such operation has become essential to classify the potential clinical practicality of these systems as well as future ones. The critical health concern is not only associated with RF power deposition in the whole head/body, but with the rise in local temperatures. In practice, one of the important safety concerns is the RF “hot spots” produced by the rise in specific absorption rate (SAR).

The rise of the MRI operating frequency also leads to safety concerns regarding the presence of implantable devices (17-19) in patients imaged with these systems. One of these safety concerns is the intricate issue of characterizing the localized RF heating (20) that implantable devices could cause within the MRI environment. The placement and orientations of implantable devices within tissue can differently (depending on the MRI field strength and on the coil/array utilized) affect the distributions and intensities of the close proximity SAR and temperature rises. The technical difficulty of the experimental assessment of implantable devices compatibility with MRI units makes computational techniques (12,21-24) one of the only viable options to evaluate implantable devices within the MRI environment (25) and to compare the calculated SAR and temperature rises to limits set by the Food and Drug Administration (FDA) and International Electromechanical Commission (IEC). Considering that an accurate assessment of RF heating requires proper electromagnetic characterization of tissue and its physical properties combined with its spatial representation, the choice of the computational method is crucial in the accuracy as well as the feasibility of these calculations.

In this course, we will review some of SAR and power deposition concerns associated with implantable devices and high field MRI.

Questions to be answered:
1. Can SAR and/or electric field distributions be assessed from MR images
   a. Yes
   b. No?
2. From a SAR regulatory point view, implantable devices are safer at
   a. 3 tesla
   b. 7 tesla
   c. This question can not be answered without considering the structure, orientation, and the placement of the implantable device(s) within tissue.

REFERENCES


