RF Induced Heating During MRI:
Evaluation of a Passive Implant in an Anatomical Model using Coupled Multiphysics FEA

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Introduction

- RF induced heating in anatomical models using a coupled Electromagnetic (EM)/thermal FEA approach and NURBS-based geometry is provided
- The FEA approach overcomes the limitations of traditional FDTD that use calculations of local SAR, are computationally expensive and unable to obtain a thermal solution for complex geometries

Objectives

- Develop a coupled FEA approach to predict temperature rise due to RF induced heating of a passive implant in an anatomical model
- Evaluate the effect of the detail of anatomical models and material properties on RF induced temperature rise

Methods

Numerical Approach
- Sequentially-coupled EM/Thermal analysis using COMSOL® Multiphysics; human anatomy with passive implanted device, shielded RF coil and surrounding air domain
- Steady State electromagnetics solution of Maxwell's equations provide heat source for transient thermal problem
- Electromagnetics solved in all domains; conductive heat transfer solved within anatomy and implanted device

RF Coil
- 16-rung high-bypass shielded coil modeled as a perfect electric conductor (PEC), powered with quadrature loading
- Tuned with no load to match characteristic frequency of a Siemens 3T Magnetom Trio clinical scanner (~128 MHz)

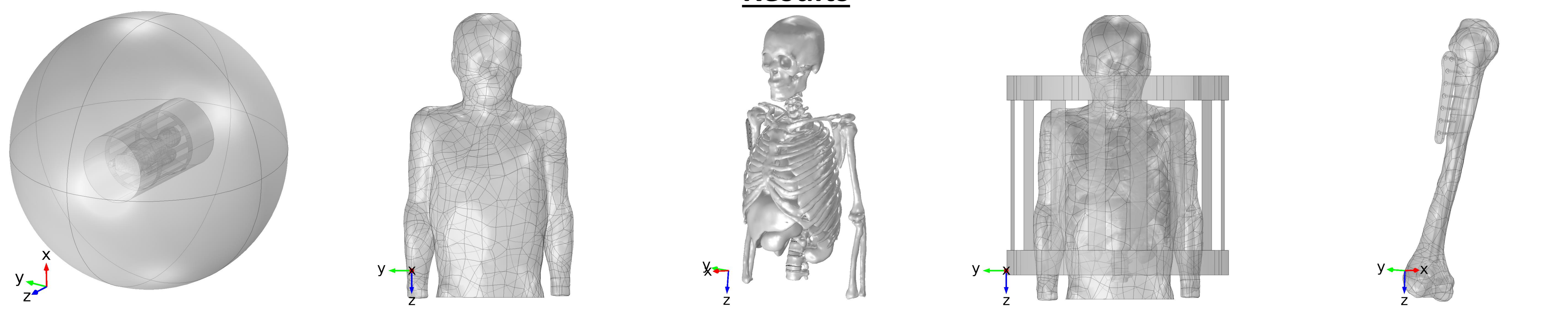
Anatomical Model
- Reconstructed using cryo-sectioned CT data from Visible Korean Human (VKH) project[1] with ScanIP (Simpleware, Exeter UK)
- Upper half of anatomy modeled; three levels of anatomical detail
  - Body cavity only
  - Body cavity with skeletal structure
  - Body cavity with skeletal structure and internal organs

Device
- Generic Humerus locking plate with 8 screws (ϕ 3.5 mm) of varying length; 90mm lengthx3mm thickness

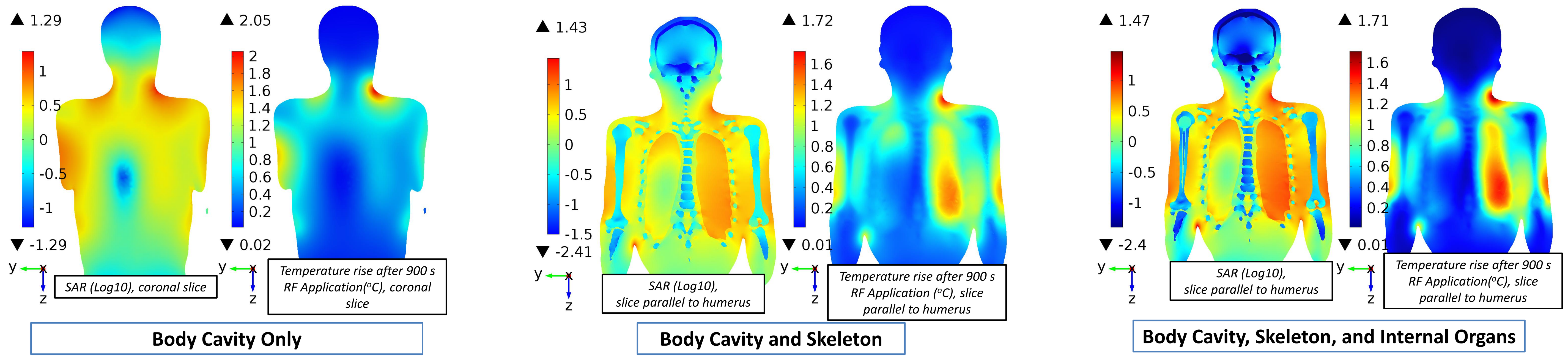
Material Properties
- Tissue property values at 128 MHz obtained from IT'IS database[2]
- Organs and skeletal structures assigned individual material properties; Body cavity treated as average tissue, with properties similar to gel used in ASTM F2182 phantom[3]
- Humerus modeled with marrow, trabecular, and cortical regions

Property	Unit	Tissue										
		Bone (Compact)	Bone (Spongy)	Bone Marrow	Heart	Kidney	Liver	Lung	Stomach	Brain	Intervertebral Disc	Avg. Tissue
Specific Heat	J/Kg.K	2065	2274		3686	3587	3540	3886	3690	3630	3568	4170
Relative Permittivity	1	14.7	26.3	6.23	84.3	89.6	64.3	29.5	74.9	79.7	49.7	80
Electrical Conductivity	S/m	0.07	0.2	0.02	0.77	0.85	0.51	0.32	0.91	0.83	0.86	0.47
Density	Kg/m^3	1908	1178	980	1081	1066	1079	394	1088	1046	1100	1000
Thermal Conductivity	W/m.K	0.32	0.31	0.2	0.56	0.53	0.52	0.39	0.53	0.51	0.49	0.6

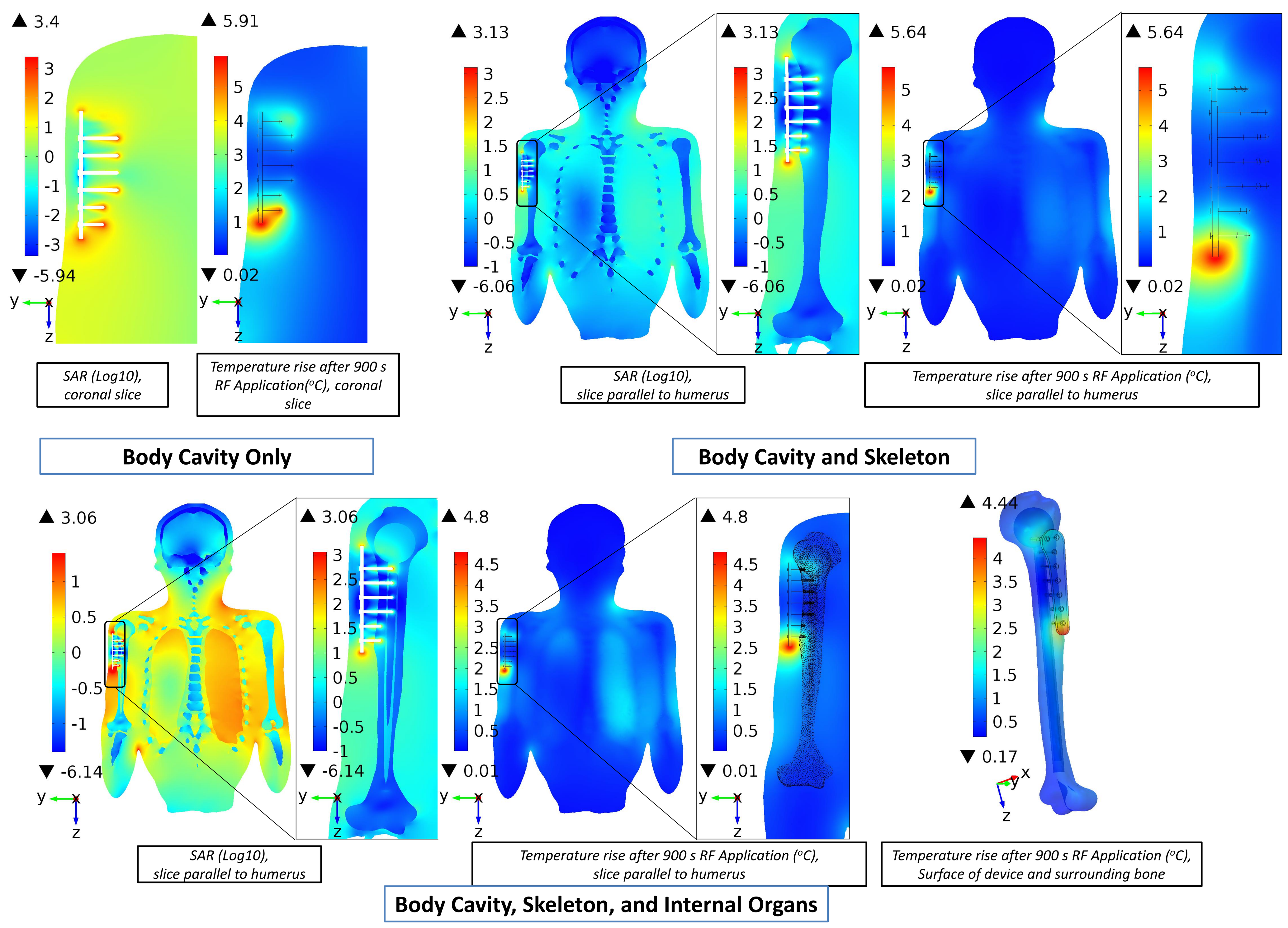
Results



Modeling space, consisting of outer air domain, shielded RF coil and anatomical phantom — *NURBS based solid model of Body Cavity used for FEA* — *Skeletal structure and internal organs included in anatomical model* — *Anatomical model placed in RF coil with coil centered in the "Chest" position* — *Humerus with generic orthopedic implant used for analysis*



Background SAR and temperature rise after 900 s RF application (without device) for anatomical models with varying levels of detail



Background SAR and temperature rise after 900 s RF application (with device) for anatomical models with varying levels of detail

Note: All Results are normalized to a Whole Body SAR (WBSAR) of 2W/kg

Conclusions

- A sequentially coupled Multiphysics FEA approach is demonstrated for directly calculating temperature rise due to RF heating in an anatomic phantom with a passive implanted device
- Methodology enables consideration of virtual human anatomy and high fidelity geometric representation of a passive implant
- The Model has been used to evaluate the temperature rise in and around the implant, and the local SAR
- The results indicate that variations of local maxima in SAR may not correspond to temperature maxima at the same locations
- Detail of the anatomical model influenced the temperature predictions; however a less detailed model resulted in a more conservative estimate of temperature rise

References

1. Visible Korean Human: Its Techniques and Applications, Park JS, Clinical Anatomy, 2006, 19:216-224
2. http://www.itis.ethz.ch/itis-for-health/tissue-properties/database/
3. ASTM F2182-11a Standard Test Method

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