# Numerical Calculation of Temperature Increase During MRI due to the Presence of Total Hip Replacement Implants

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# Temperature increase of tissue due to hip implants inside an MRI birdcage coil

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## Background

- Active or passive implants can heat the surrounding tissue when inside the MRI scanner
- This leads to exclusion of patients from MRI scanning due to implants, unless heating can be assessed and mitigated

## Objective

- To demonstrate the possibility of assessing worst-case temperature rise from implants with numerical methods

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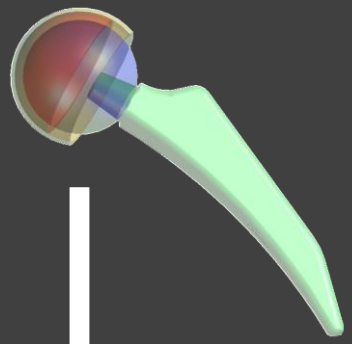
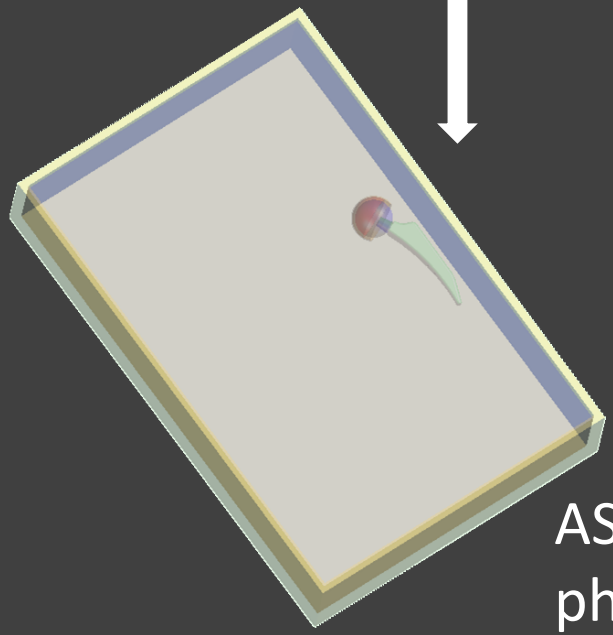
## Materials and methods

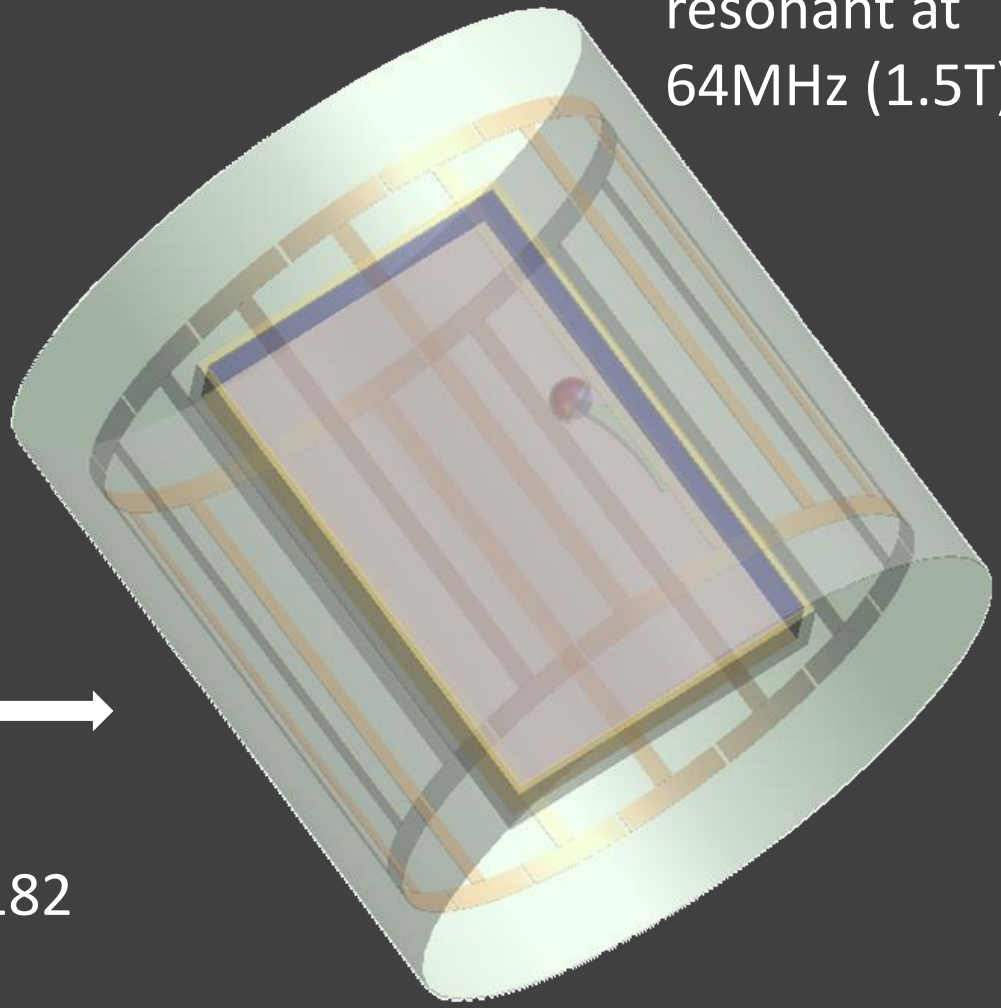
CAD model of hip implant





ASTM F2182 phantom

Birdcage coil resonant at 64MHz (1.5T)



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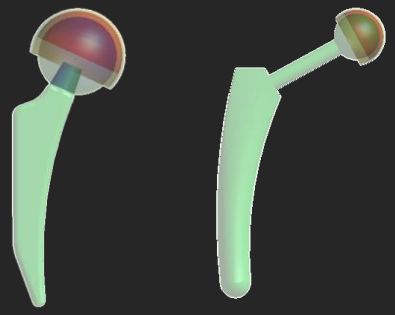
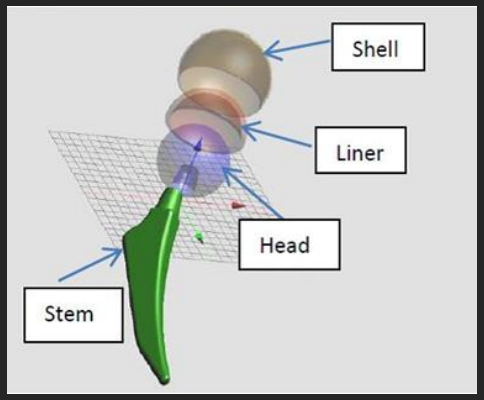
# Materials and methods

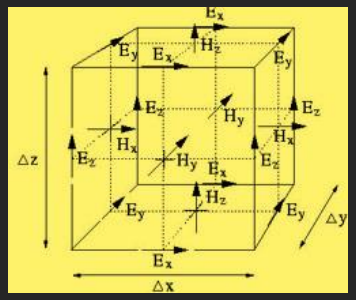
Two implant models



Various parts/materials




FDTD technique




SEMCAD X

Software used

- Coupled electrothermal problem
- Results normalized to 2W/kg in phantom (normal mode)

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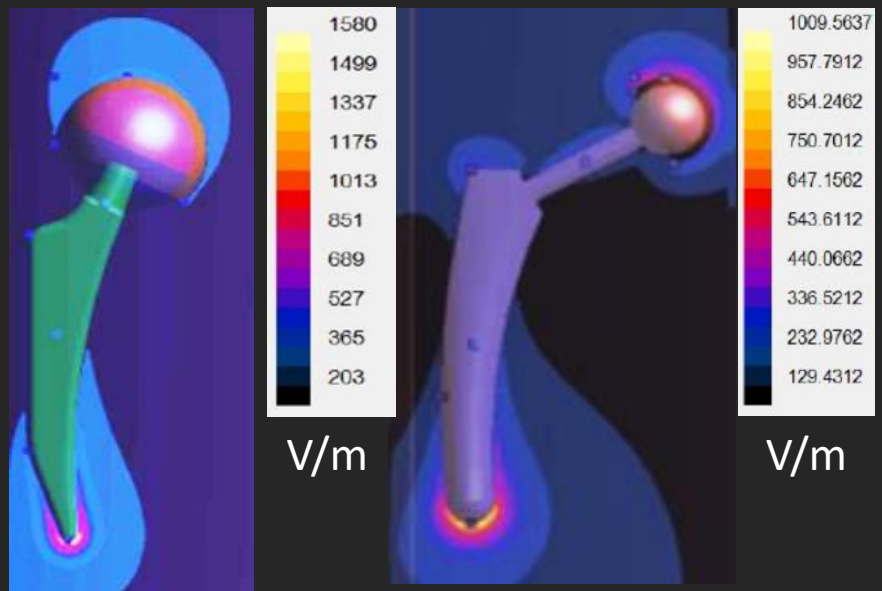
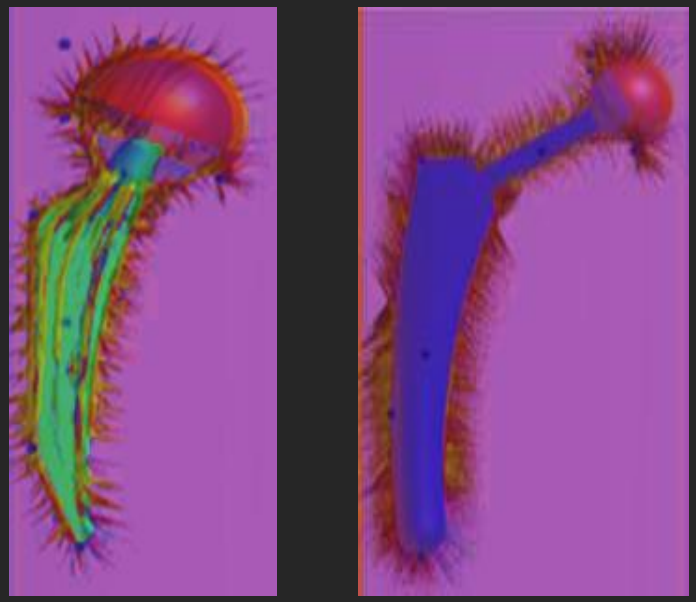
# Results

## Electric field distribution




## Induced electric currents



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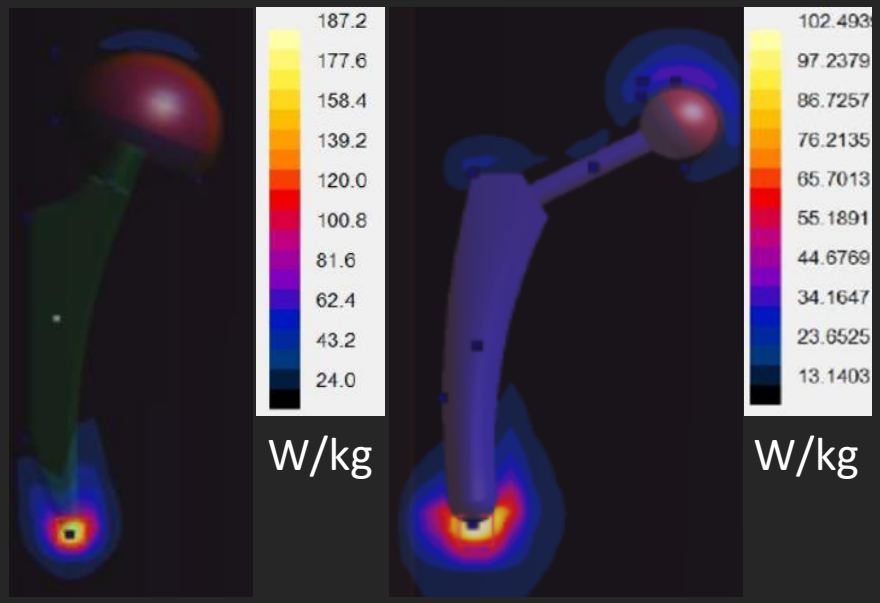
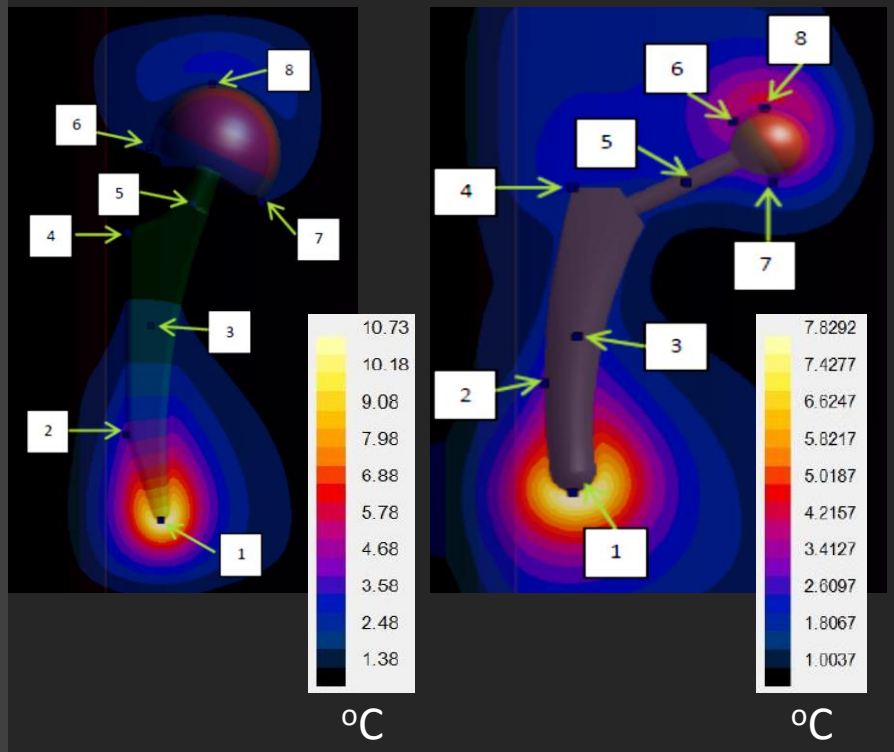
# Results

## Peak spatial $SAR_{1g}$




## Temperature rise



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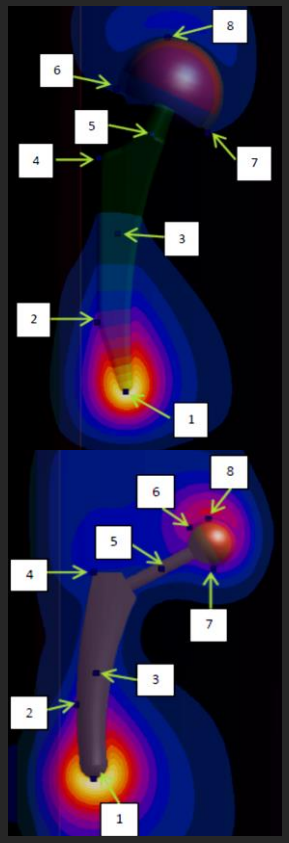
## Results

### Temperature rise at various points with different materials




| Top Implant | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Point :** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| **Co-Cr-Mo** | 11.3 | 3.4 | 0.9 | 0.6 | 0.7 | 0.9 | 0.8 | 1.2 |
| **Stainless Steel 316L** | 11.0 | 3.3 | 0.9 | 0.6 | 0.7 | 0.9 | 0.8 | 1.1 |
| **Ti Alloy Grade 5** | **12.7** | 3.5 | 0.7 | 0.5 | 0.7 | 1.0 | 0.9 | 1.5 |
| **Steel + Alumina Liner** | 11.0 | 3.3 | 0.9 | 0.7 | 1.2 | 1.7 | 1.5 | 1.6 |
| **Steel + Zirconia Liner** | 11.1 | 3.3 | 0.9 | 0.7 | 1.0 | 1.5 | 1.3 | 1.7 |
| **Steel + Polymer Liner** | 10.9 | 3.2 | 0.9 | 0.8 | 1.2 | 1.9 | 1.6 | 2.1 |
| **Bottom Implant** | | | | | | | | |
| **Point :** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| **Co-Cr-Mo** | 8.2 | 2.5 | 1.7 | 1.6 | 1.7 | 3.3 | 2.6 | 3.2 |
| **Stainless Steel 316L** | 8.0 | 2.5 | 1.7 | 1.6 | 1.7 | 3.2 | 2.5 | 3.1 |
| **Ti Alloy Grade 5** | **9.0** | 2.5 | 1.5 | 1.7 | 1.6 | 3.5 | 2.6 | 3.5 |
| **Steel + Alumina Liner** | 8.3 | 2.6 | 1.8 | 1.8 | 2.3 | 4.2 | 3.6 | 3.8 |
| **Steel + Zirconia Liner** | 8.3 | 2.6 | 1.8 | 1.7 | 2.2 | 4.1 | 3.3 | 3.9 |
| **Steel + Polymer Liner** | 8.2 | 2.5 | 1.8 | 1.8 | 2.4 | 4.5 | 3.7 | 4.2 |

## Conclusions

- Modern numerical tools allow for the prediction of temperature rise in tissue next to an implant inside the MRI
- The comparison of measurements in the literature with present numerical results shows very good agreement
- Computer simulations can be used for parametric analysis of tissue heating with implant shape, material used, etc.
- Costly, lengthy and tedious measurements in an experimental setup could be replaced in the future by calculations