A heat transfer analysis of the cochlea during magnetically-guided cochlear implant surgery

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Motivation

450,000 cochlear implant users worldwide

(http://www.cochlear.com/au/home/connect/cochlear-hearing-ambassador,September 10, 2018)

Cochlear implant (FDA-approved treatment)

Manual insertion

Risk:
intracochlear physical trauma
(33% of insertions)
(Finley et al., *Otology and Neurotology*, 2008)

Magnetically-guided insertion

(Clark et al., *Intelligent Robots and Systems*, 2011)

Reduces risk of intracochlear physical trauma
Risk:
Thermal trauma

Motivation

Department of Mechanical Engineering
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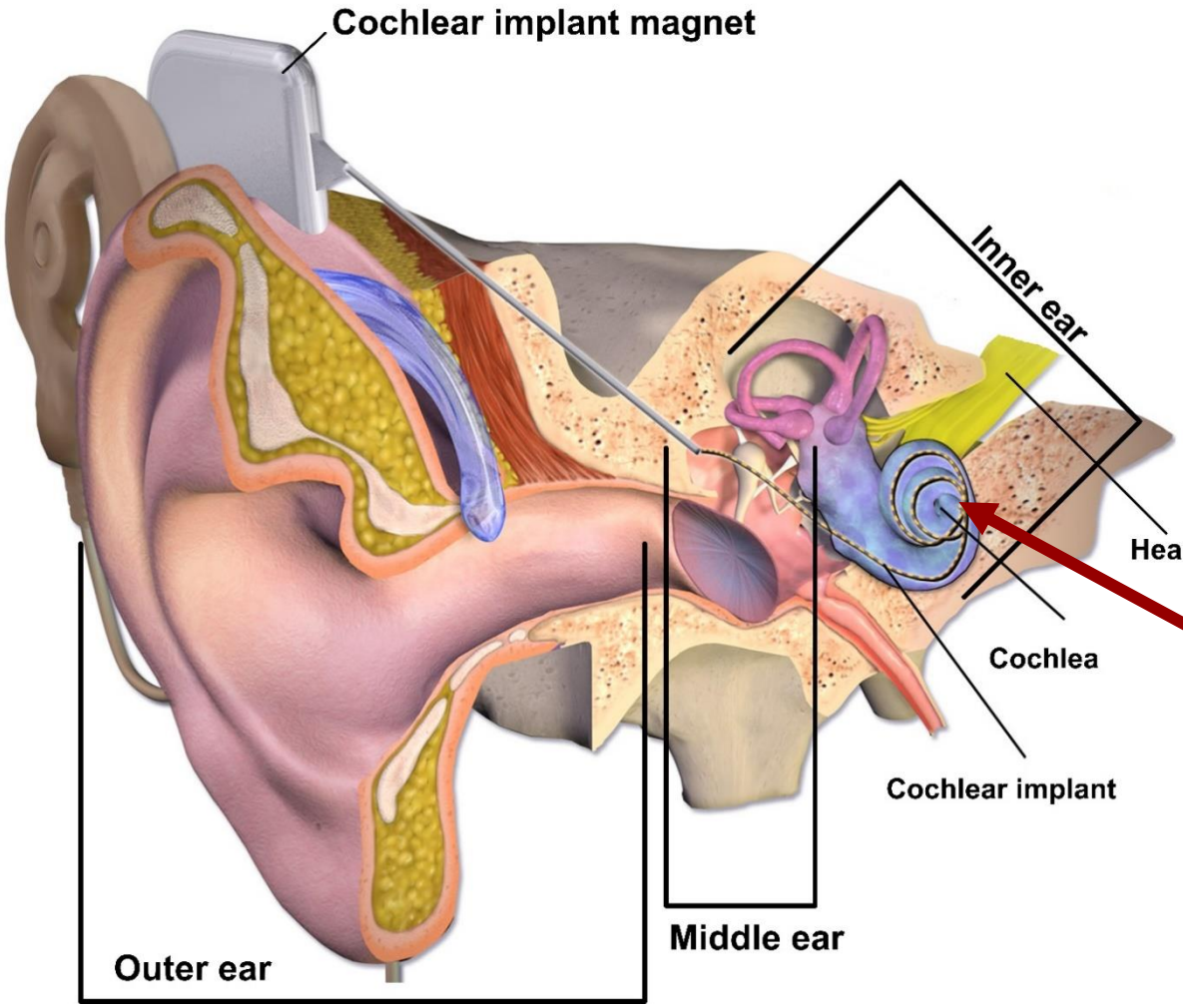
Cochlea

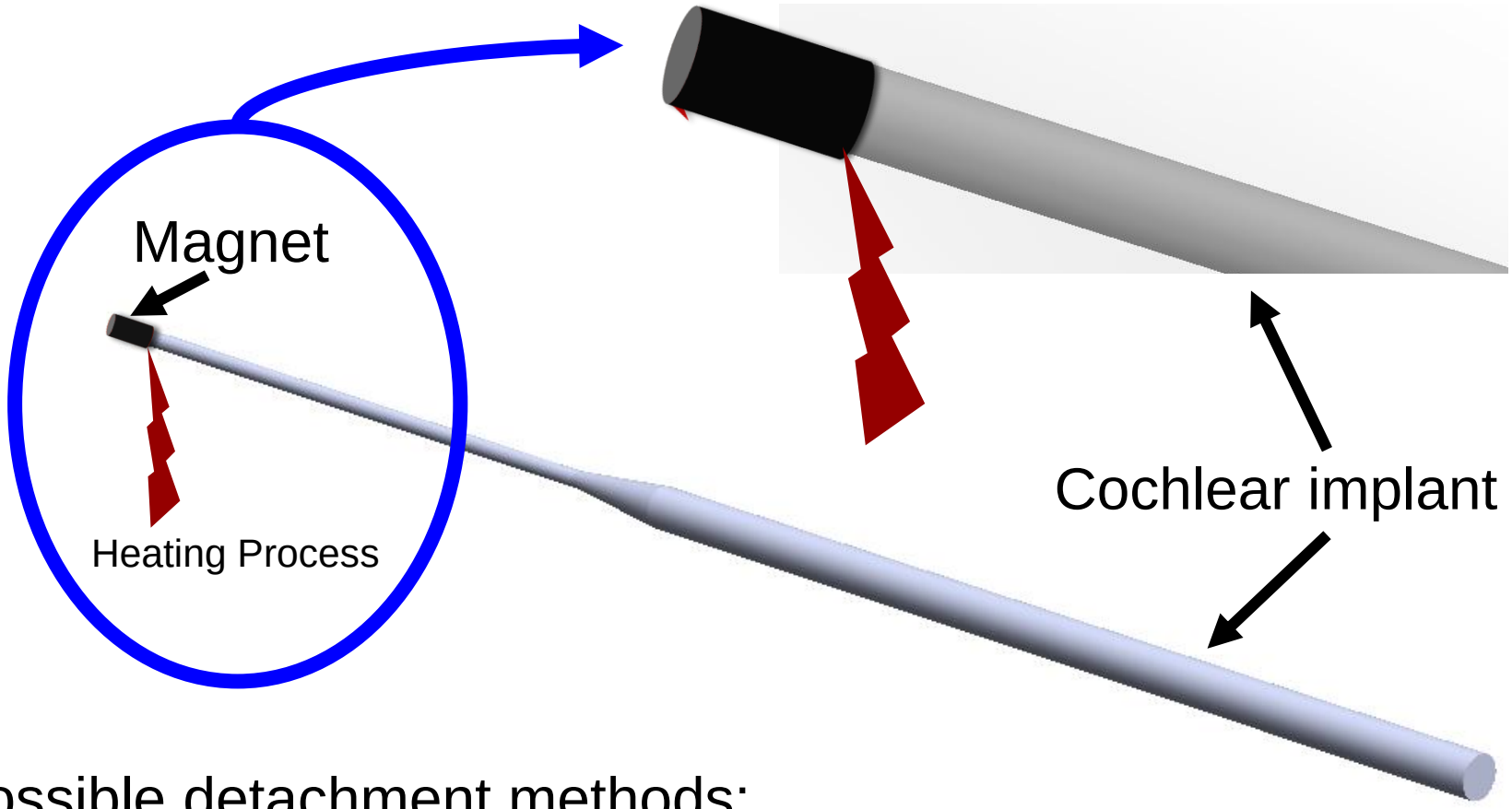


(SICAS Medical Image repository http://doi.org/10.22016/smir.o.207473)

Magnet

Blausen.com staff (2014). "Medical gallery of Blausen Medical 2014".
WikiJournal of Medicine **1** (2). DOI:10.15347/wjm/2014.010. ISSN 2002-4436

Thermal trauma



Possible detachment methods:

- ❑ Joule heating
- ❑ Electrolysis

} cause temperature increase

Objective

Determine a safe range of power input (g_0) for magnet detachment

Criteria

Safe temperature : 316 K,
Maximum exposure time : 1.9 min

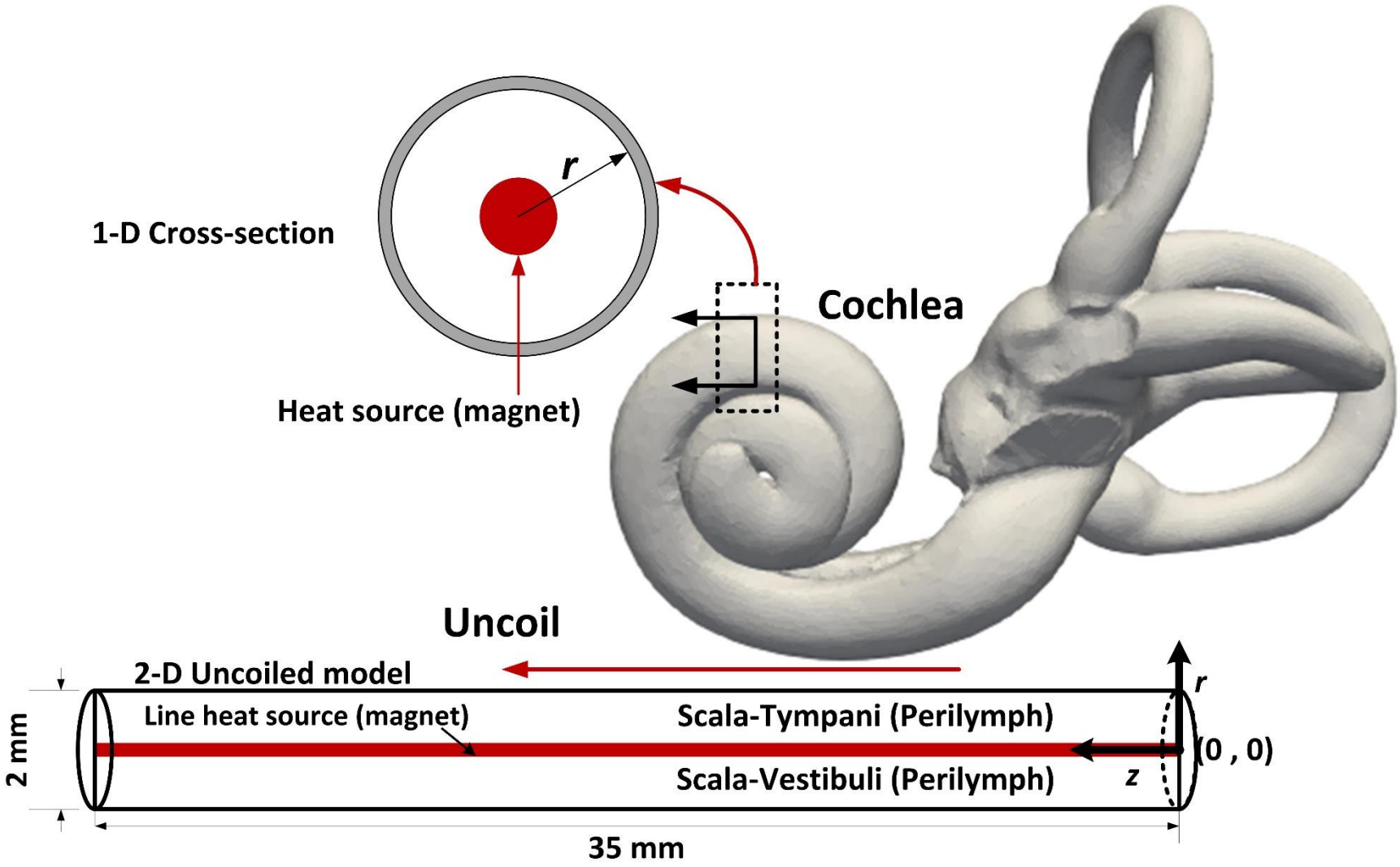
Yoshida et al., *Journal of Neuroscience*, 1999

Mathematical model

Analytical solution
Solution method: Green's function
Programming language: MATLAB R2018a

Numerical solution
Software: COMSOL Multiphysics 5.3a
Physics: Heat transfer in solids
Study: Time dependent

Simplification



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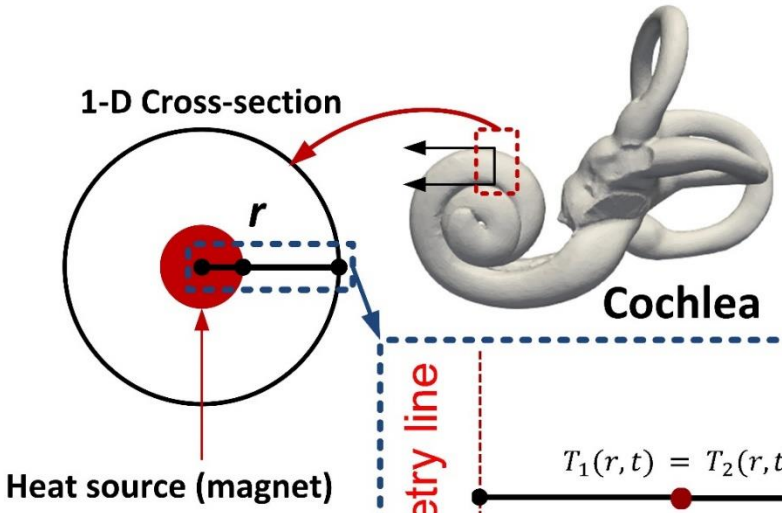
- **Model wizard** : 1-D axisymmetric
- **Physics** : heat transfer in solids (ht) – Magnet (Solid), Perilymph (fluid)
- **Study** : time dependent → setting → times : range(0,0.01,1), range(1,0.1,114)

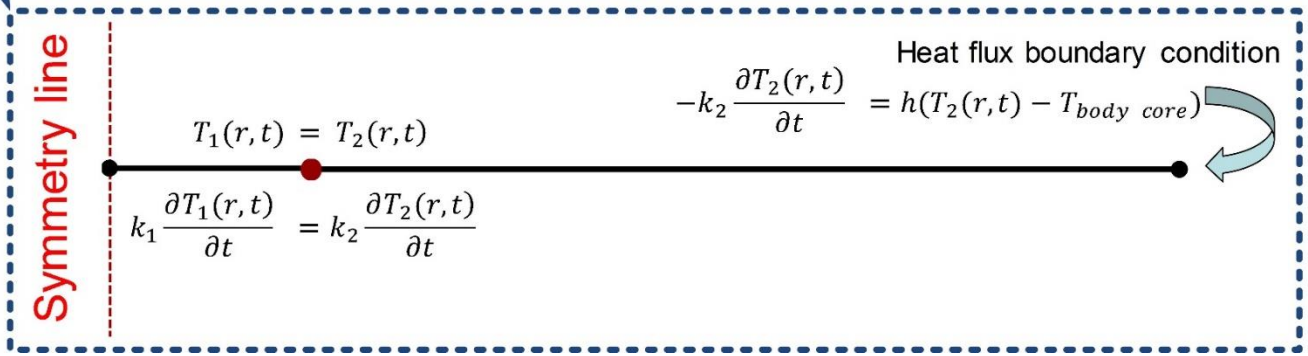
Time-dependent solver → setting → time stepping → steps taken by solver → **Strict**

- **Geometry** : interval1 (0, 0.125 mm), interval 2 (0.125 mm,1 mm)

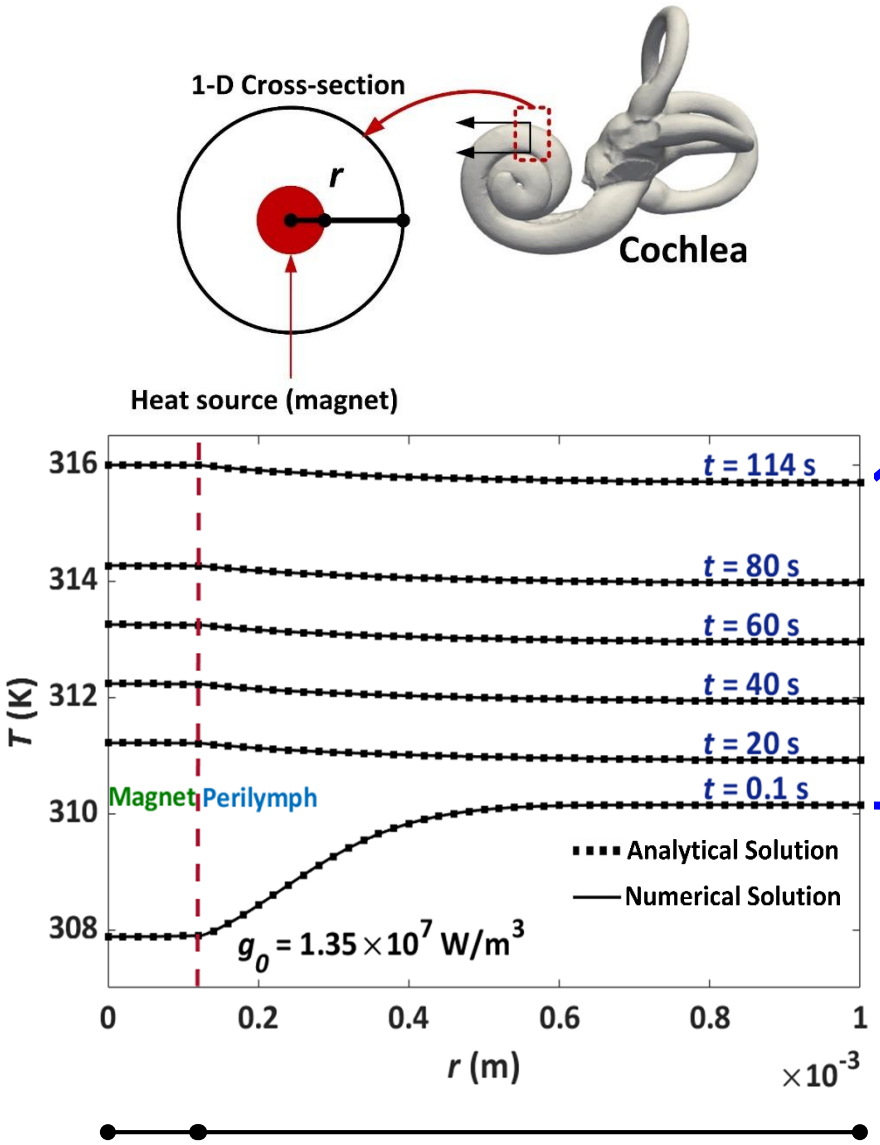


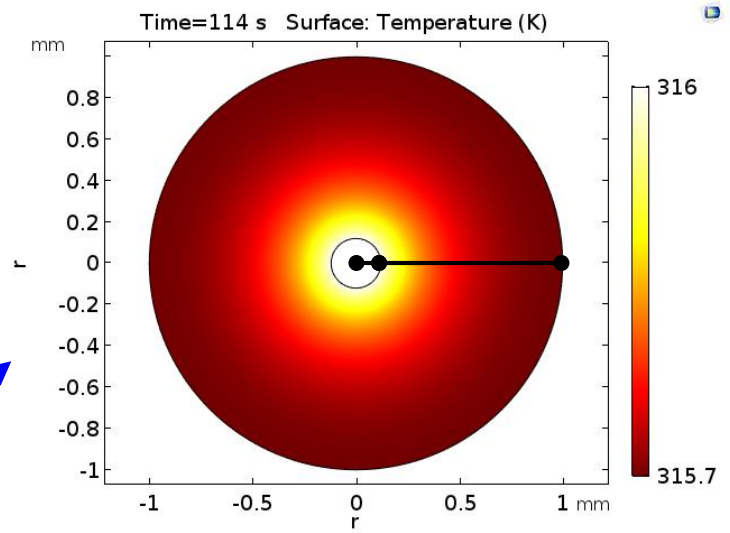
Materials : Water, Neodymium magnet (blank material)

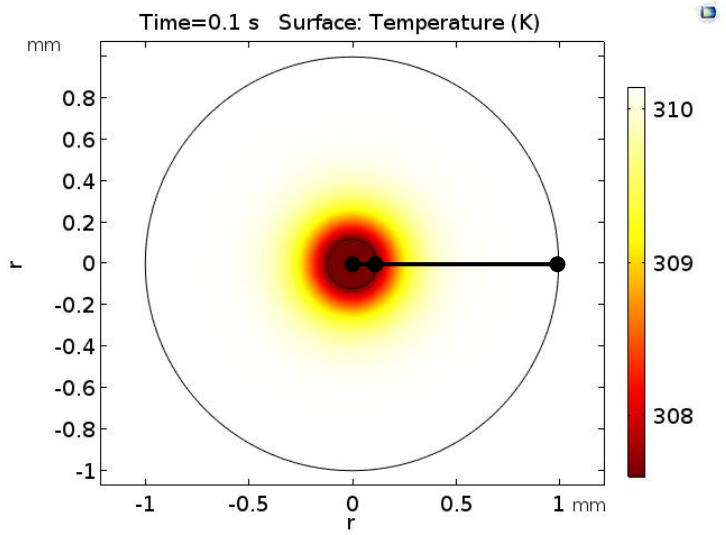
Mesh : user-controlled mesh – finer mesh close to boundaries



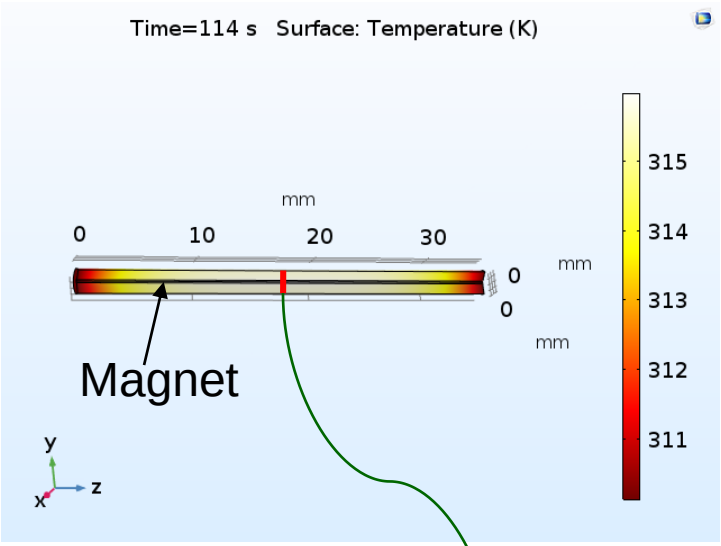
1-D verification

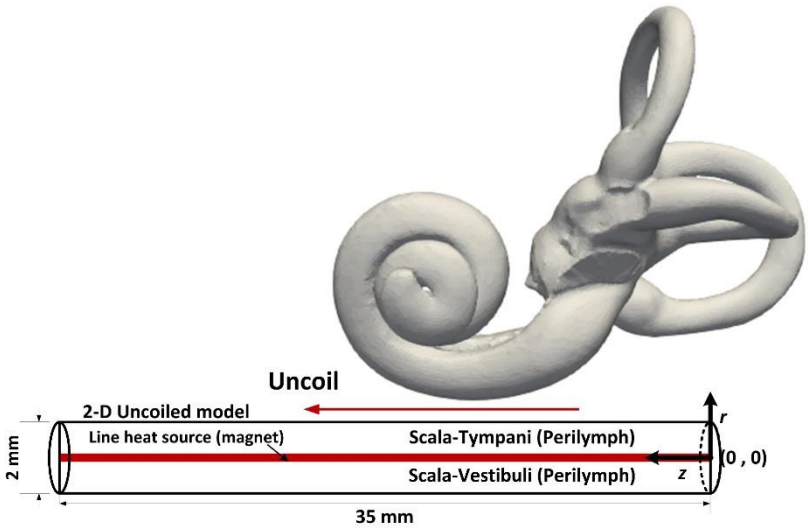


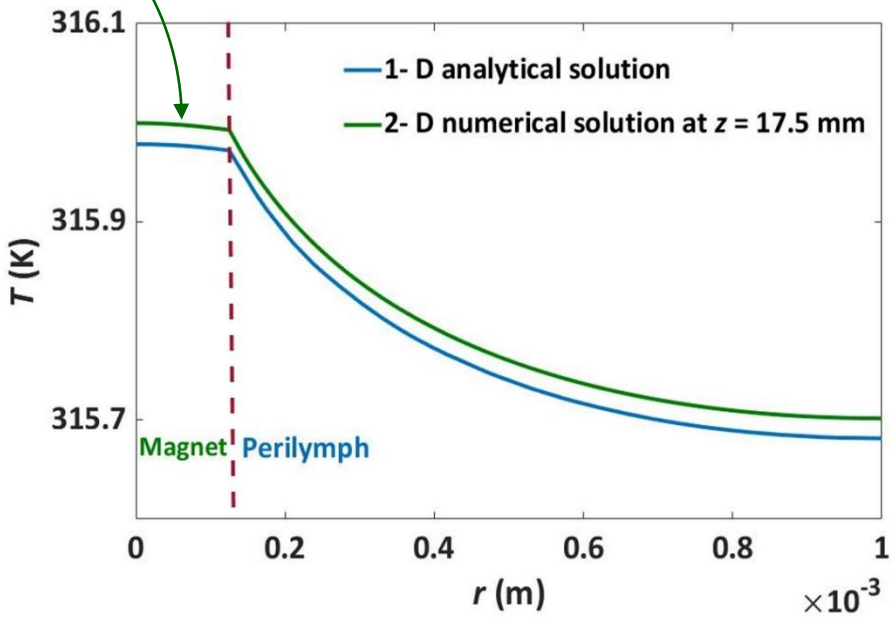




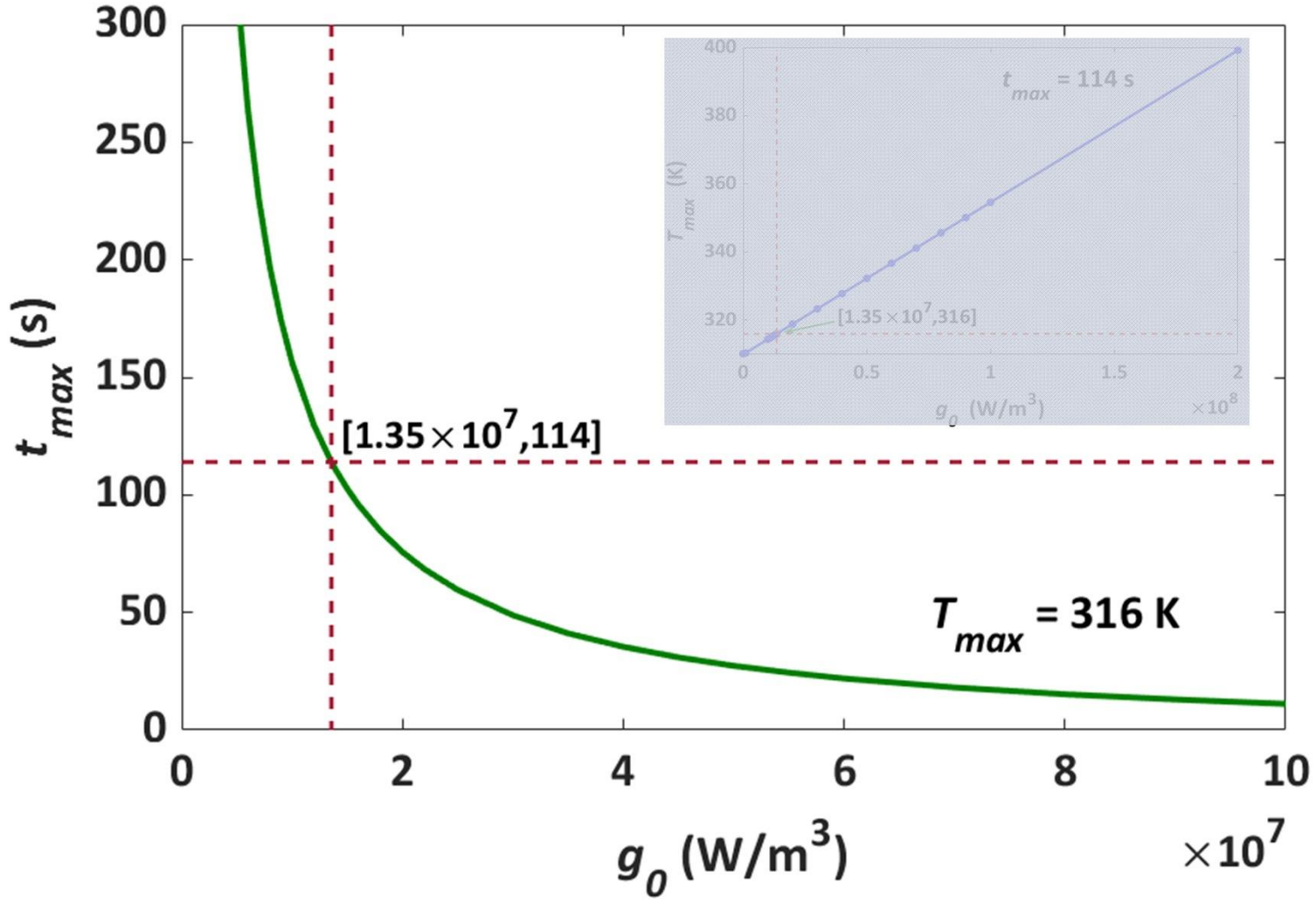
2-D verification



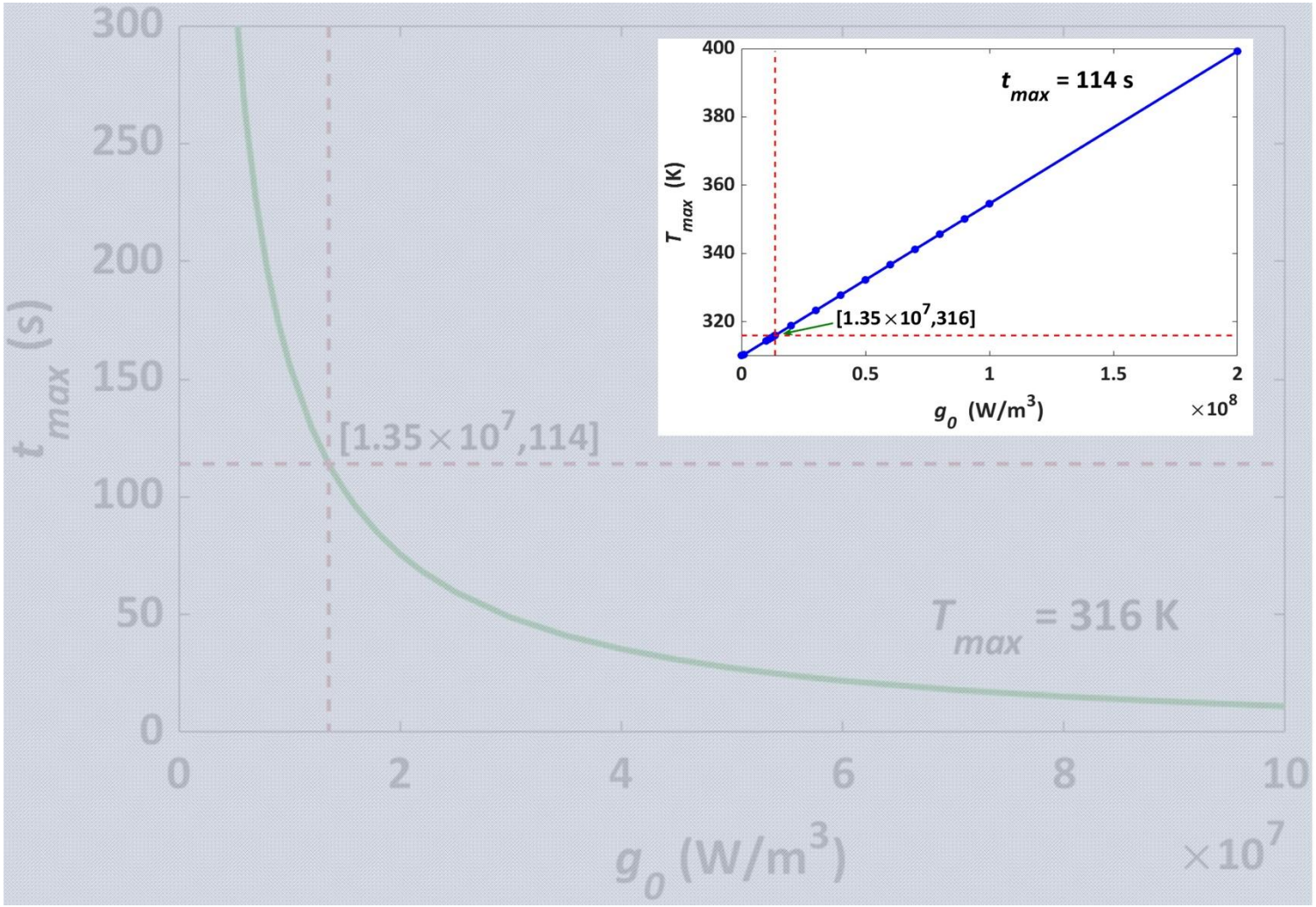




Results – Fixed maximum temperature



Results – Fixed maximum time

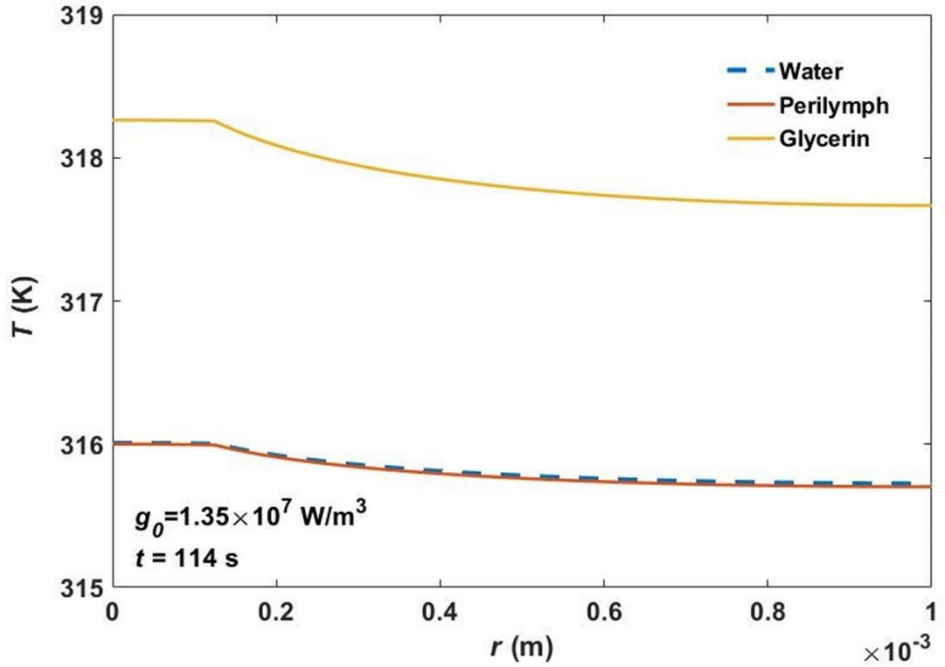


Results – Scala-Tympani fluid

- High viscosity Glycerin decreases the potential of physical trauma

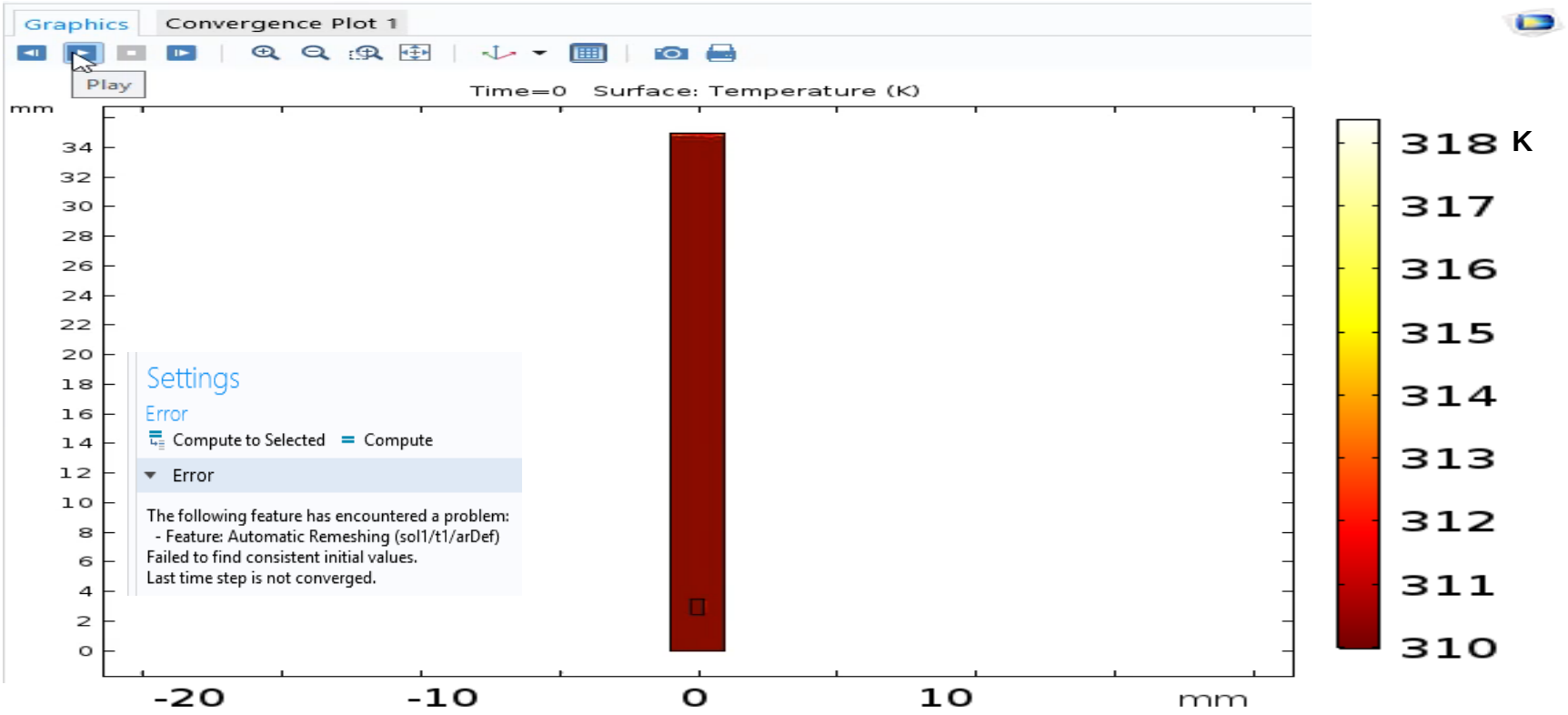
Kontorinis et al., *Otology & Neurotology*, 2011

Fluid	Average force (N)	Maximum force (N)
Glycerin	0.095 (SD, ±0.02)	0.203 (SD, ±0.02)
Water	0.139 (SD, ±0.034)	0.367 (SD, ±0.068)



Future work

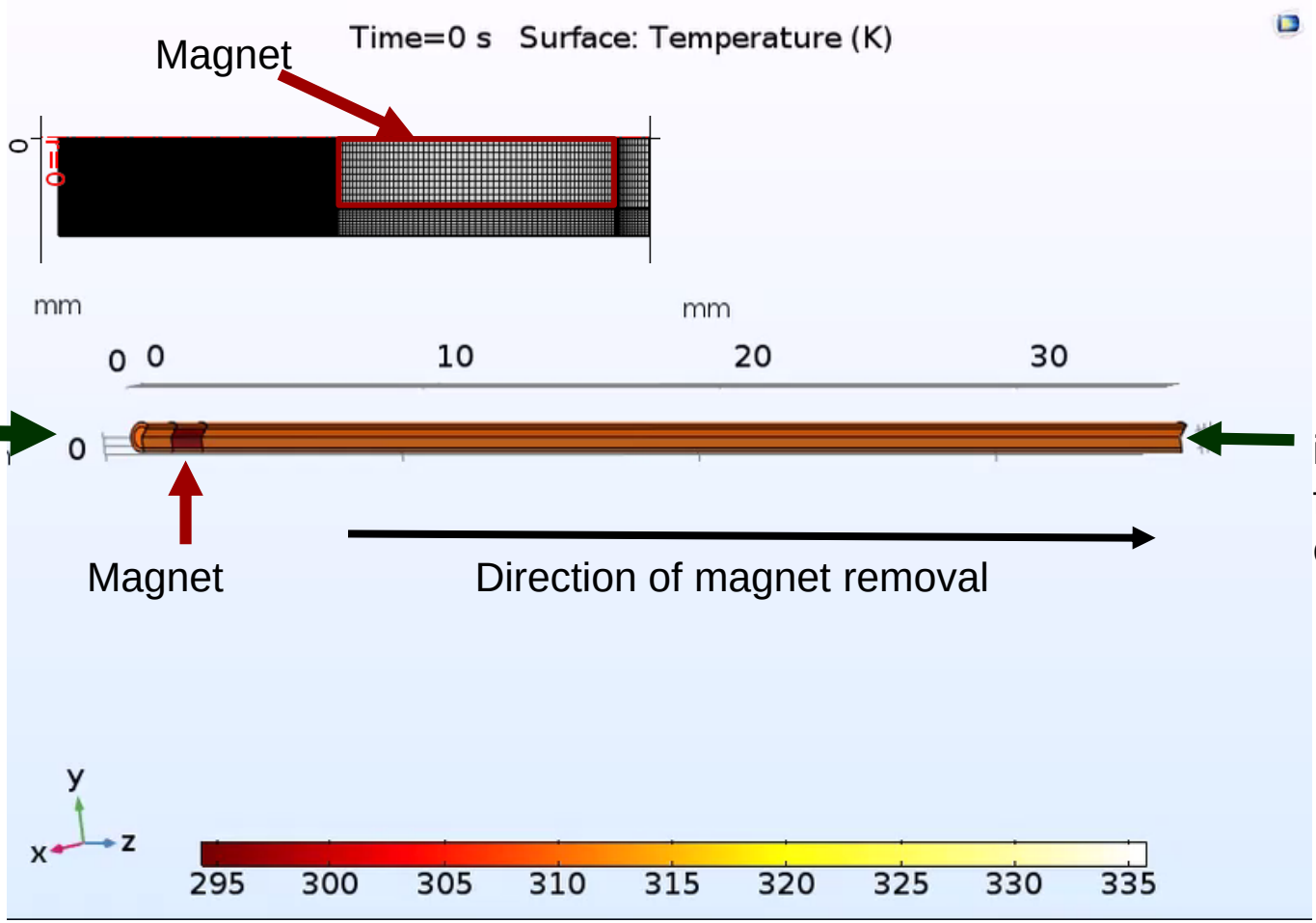
- Heat transfer in solids + moving mesh (ale) – with auto remeshing



Current issue: all moving mesh simulations crash at some point

Future work

- Heat transfer in fluid + laminar flow (spf) + moving mesh (ale)



The cochlea apex

Implant is inserted from this end

Future work and acknowledgment

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- 2-D analysis with a combination of magnet and cochlear implant
- Bioheat transfer (ht) + laminar flow (spf) + moving mesh (ale)
- Repeat all steps for the 3-D model

(SICAS Medical Image repository http://doi.org/10.22016/smir.o.207473)

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Questions?

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