Comparison of Ultrasonic Thermometry Based on the Change in Backscattered Energy with MR Temperature Images

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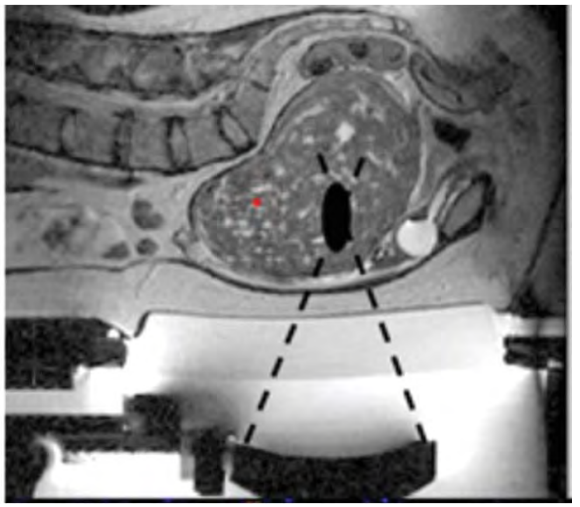
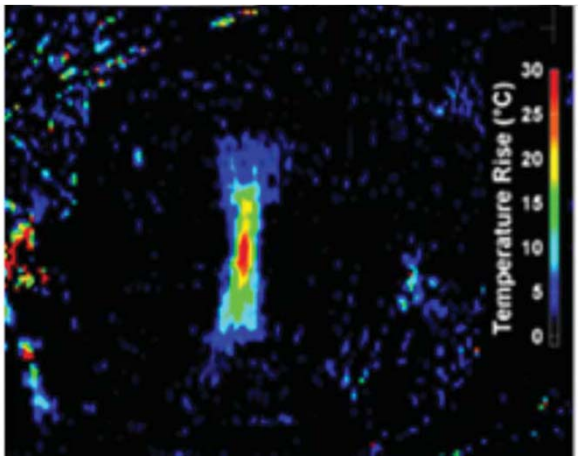
Thermal Therapy

- Applications include
  - Hyperthermia
  - Ablation
  - Drug release
  - Vascular modification
- Temperature Imaging
  - MRI (*de facto* standard)
  - Ultrasound
    (portable, inexpensive,
    high temporal resolution)

Hynynen, J Mag Res 34, 2011



MRI: Uterine fibroid heating



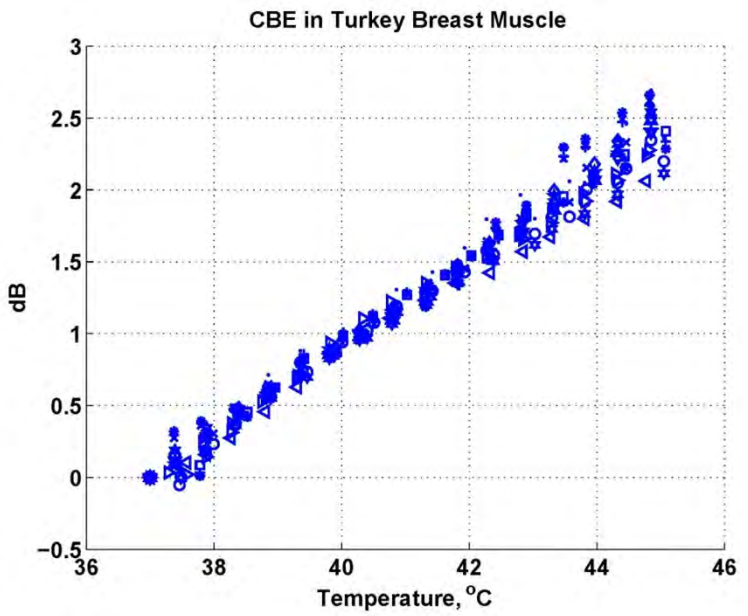
Temperature Elevation Map

CBE: Change in Ultrasonic Backscattered Energy

Ultrasonic backscattered energy increases or decreases with temperature depending on scatterer type as shown in

- Theoretical analyses
- Simulation of scatterer populations
- Measurements in 1D, 2D and 3D
- Monotonic to >60°C

0.300 ± 0.016 dB/°C



CBE thermal sensitivity over 20 1cc volumes from 8 specimens of turkey breast

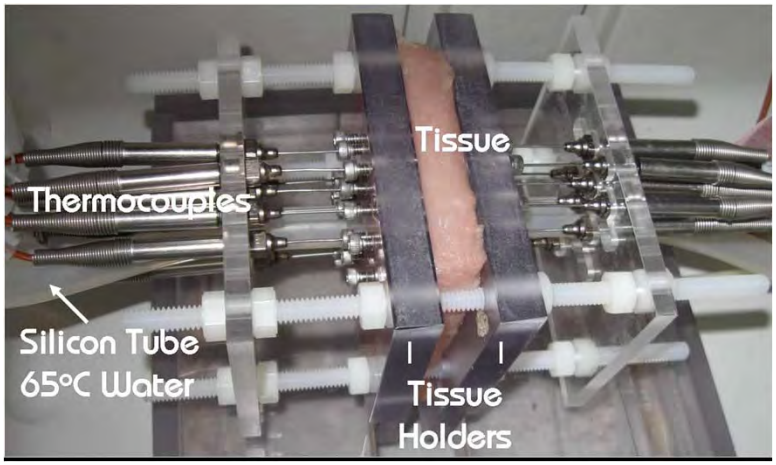
IEEE UFFC 57, 2010.

Objective

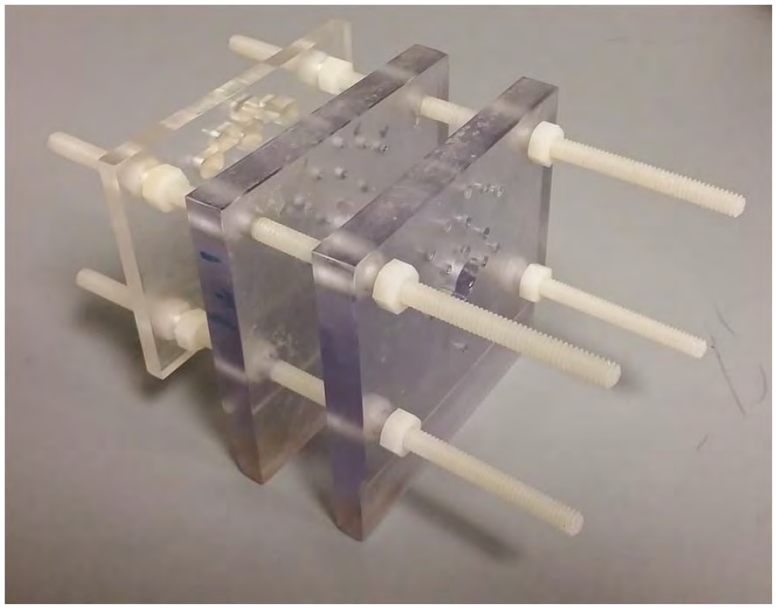
- Produce CBE-based temperature images *in vitro* @ 30 sec intervals with MRI compatible heating source

- Compare to MR temperature images *in vitro* @ 30 sec intervals

Non-uniform Heating Fixture

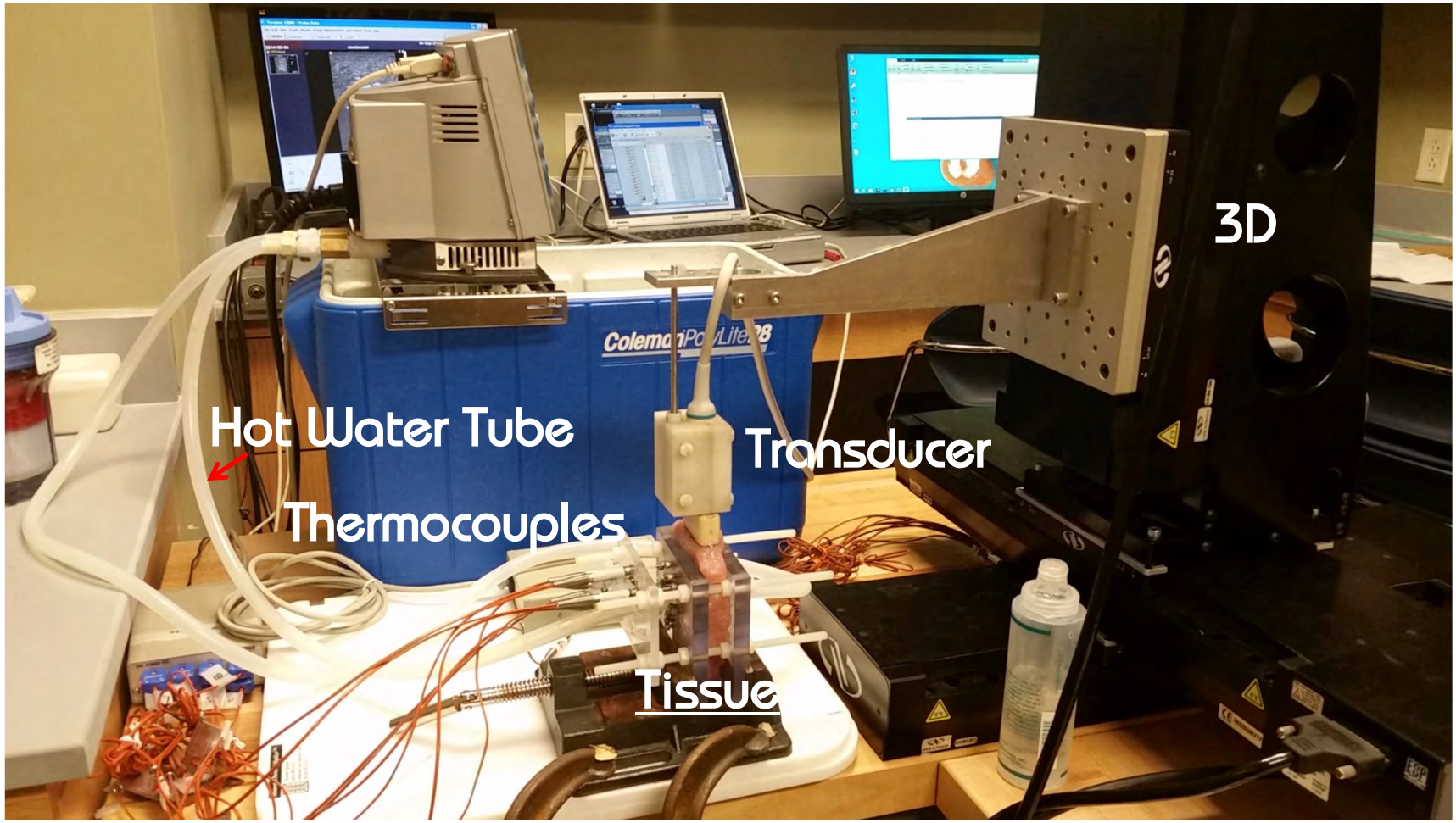


Tissue Fixture
For CBE TI



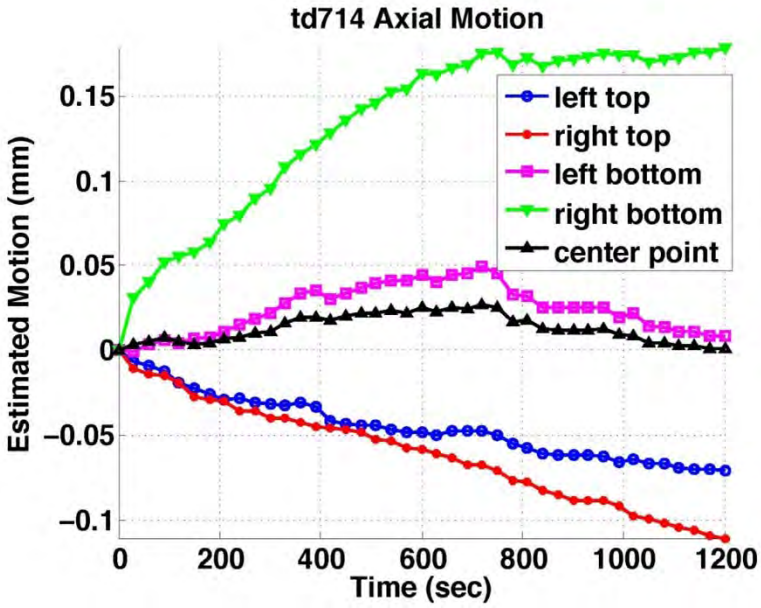
Tissue Fixture For MR TI
(CBE fixture without
thermocouples
& guides)

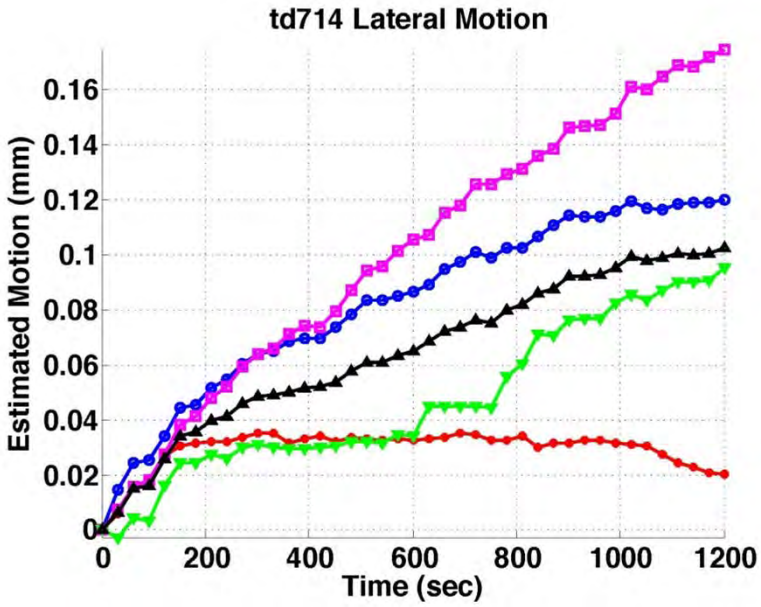
CBE Temperature Imaging Experiment



In vitro Experiments with Turkey Breast

Non-rigid 3D Motion Compensation

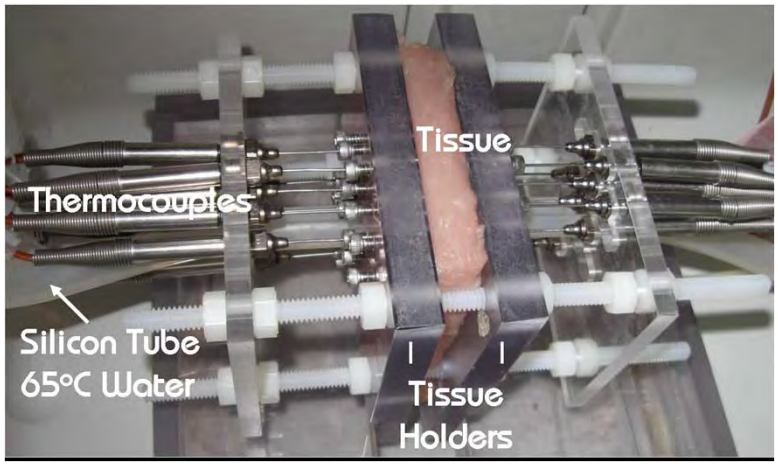




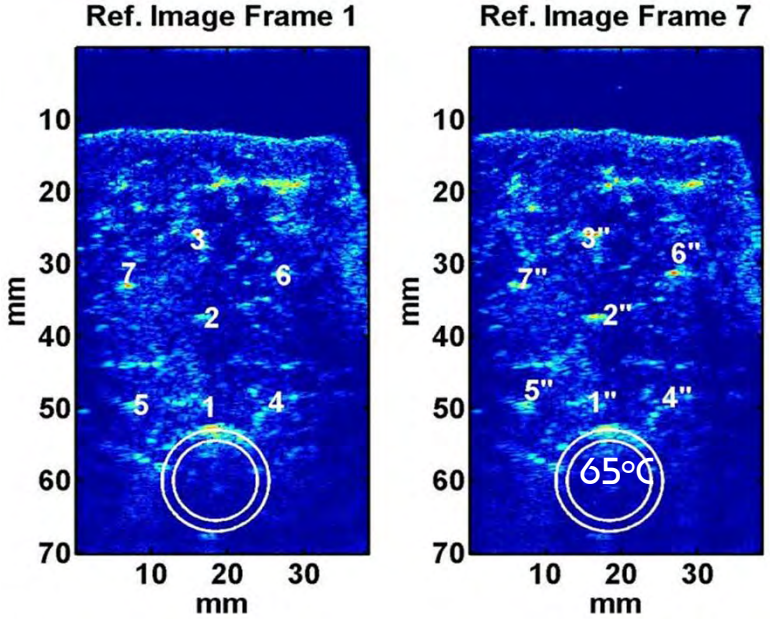
Motion in turkey breast over 20 minutes
Apparent Motion Between Images < 15 μm

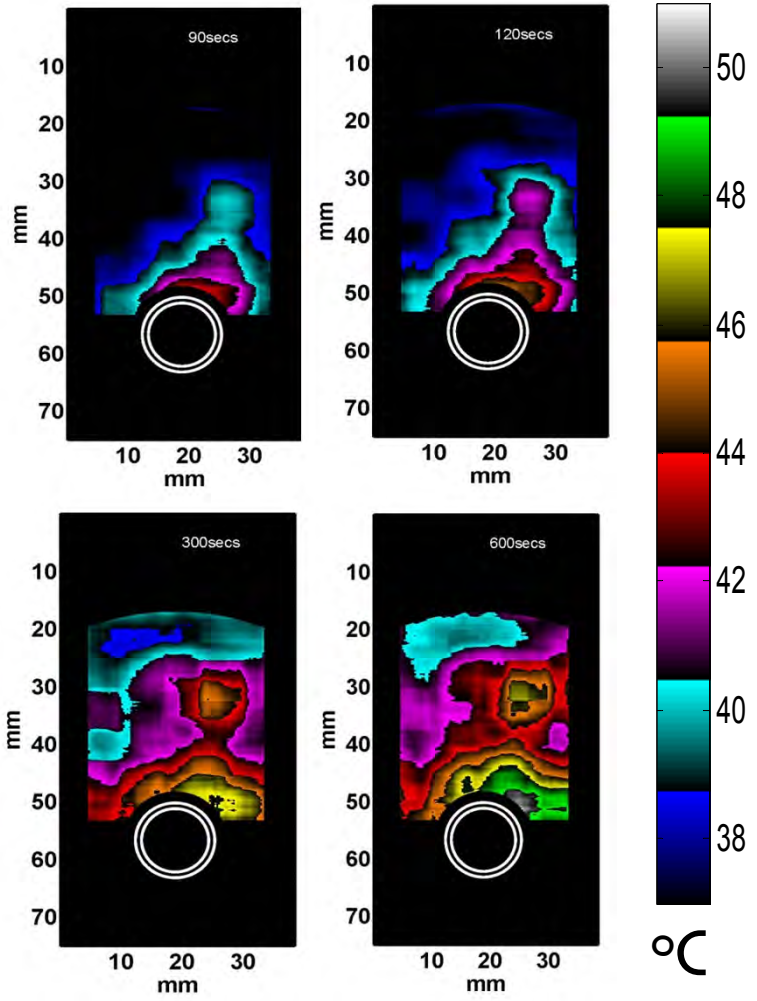
CBE Temperature Imaging with during Non-uniform Heating in Turkey

Fixture



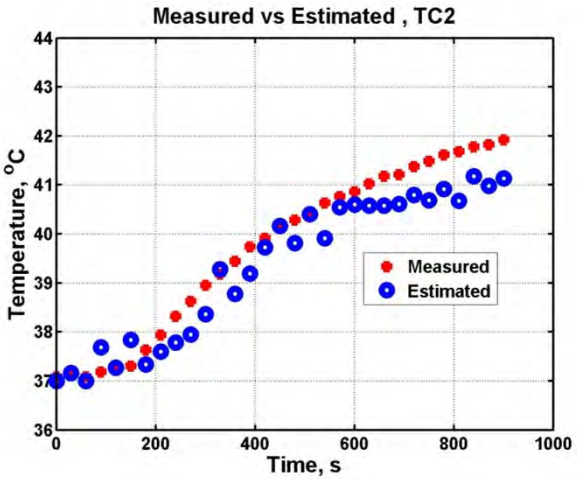
Thermo-couple locations

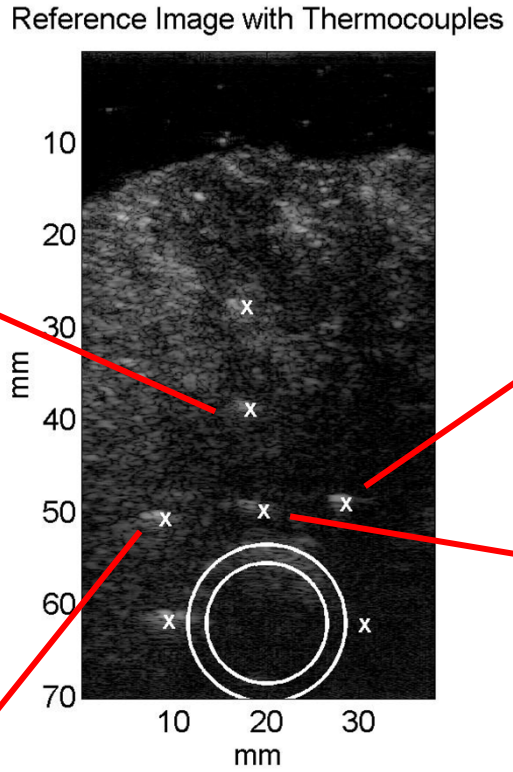


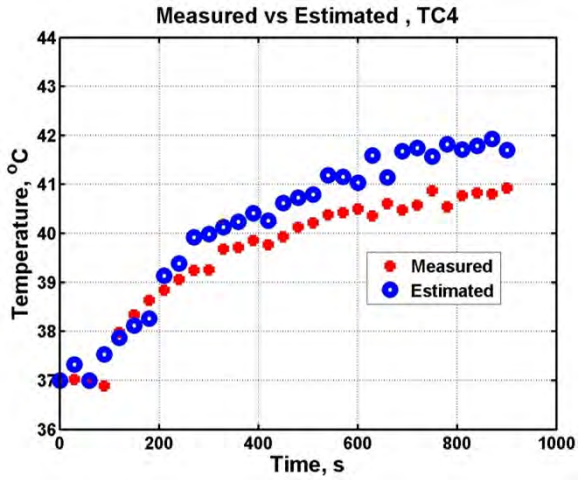


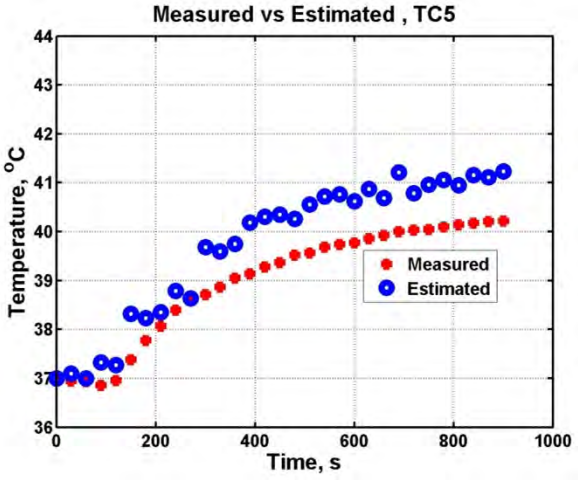
~1 °C accuracy

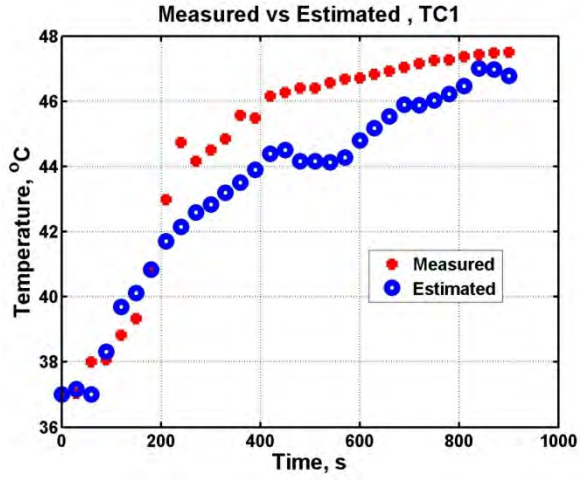
CBE Temperature Imaging with during Non-uniform Heating in Turkey











Estimated temperatures at the indicated thermocouples was tracked to within ~1° C.

MR Temperature Imaging Experiment

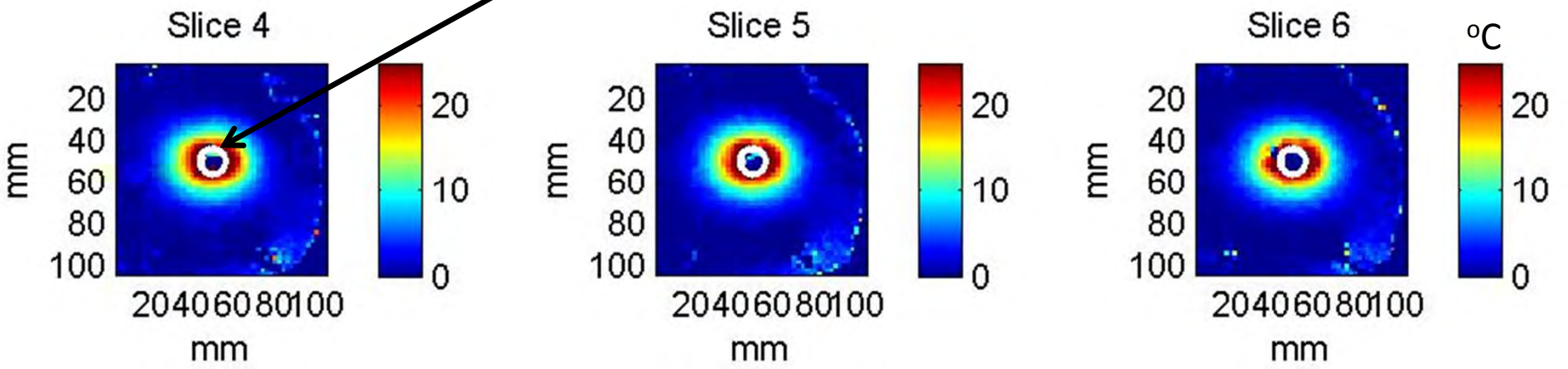
Preparation for hot-water heating

Hot-water tank with pump for delivery to tissue in MR room

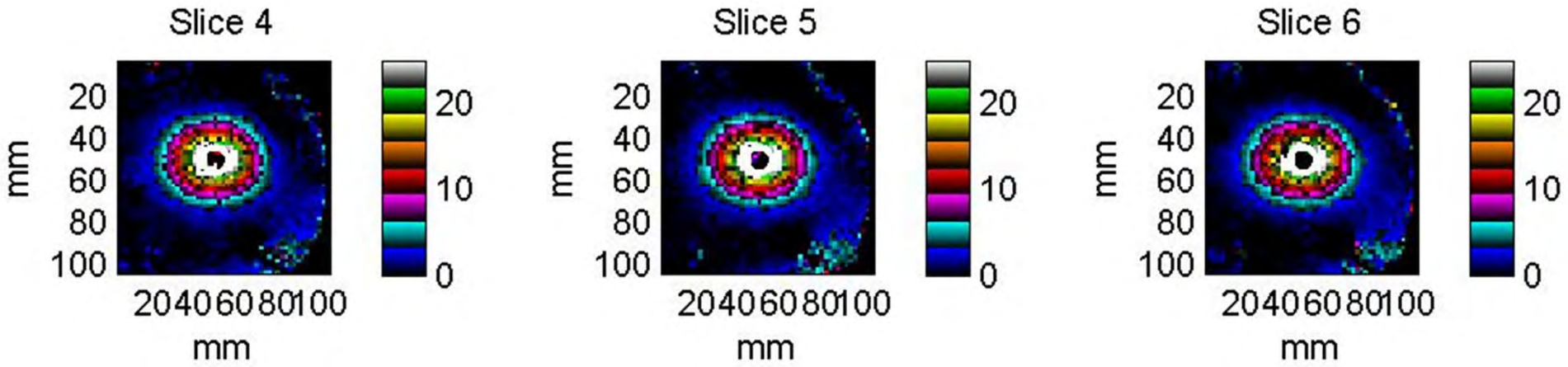
Tissue in fixture under sand bags with silicon tubes from hot-water tank

Drift correction for MR TI (Ari Partanen, Philips Corp)

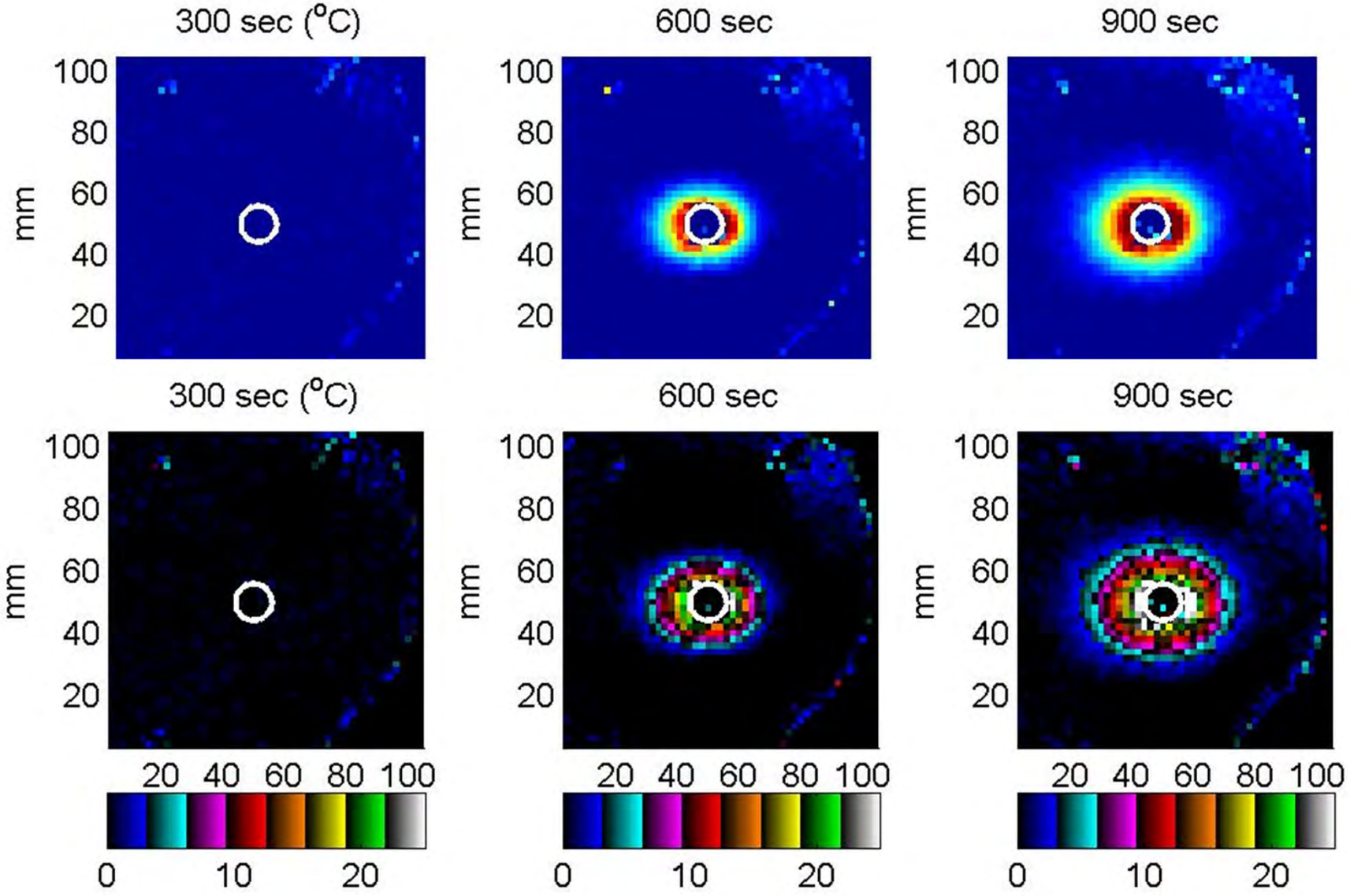
MR Temperature Elevation Images in Turkey Heated by 75°C Water in Central Tube



Parallel images (separated by 2 mm) after 1200 sec

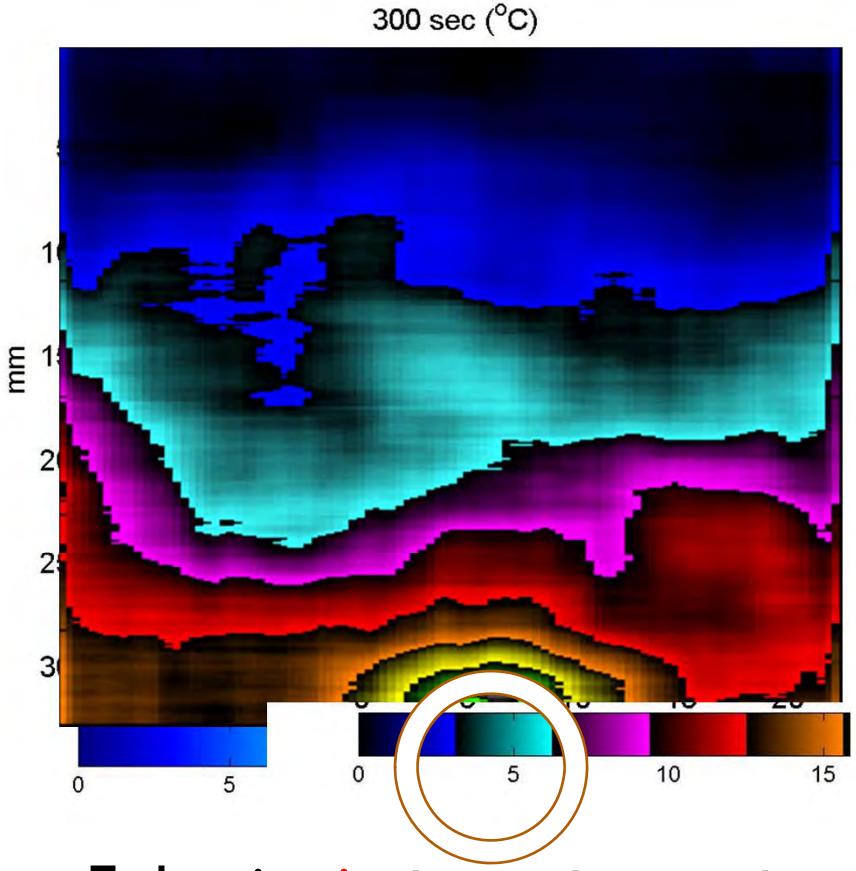


MR Temperature Elevation over Time



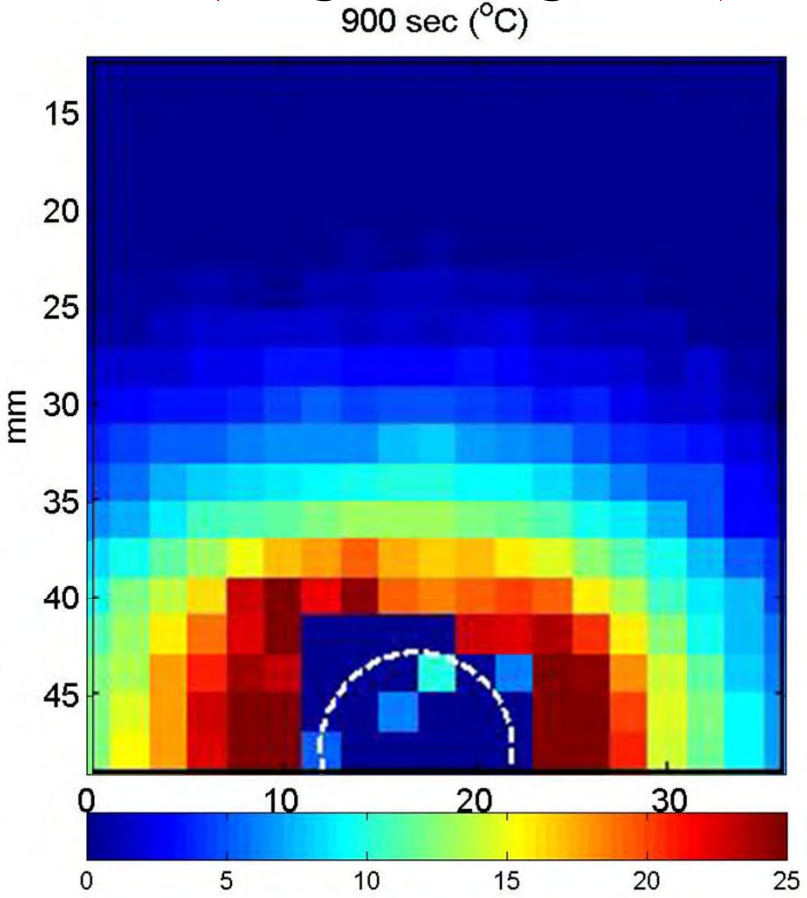
Temperature Images during Non-uniform Heating of Different Turkey Specimens

CBE (short heating tube)



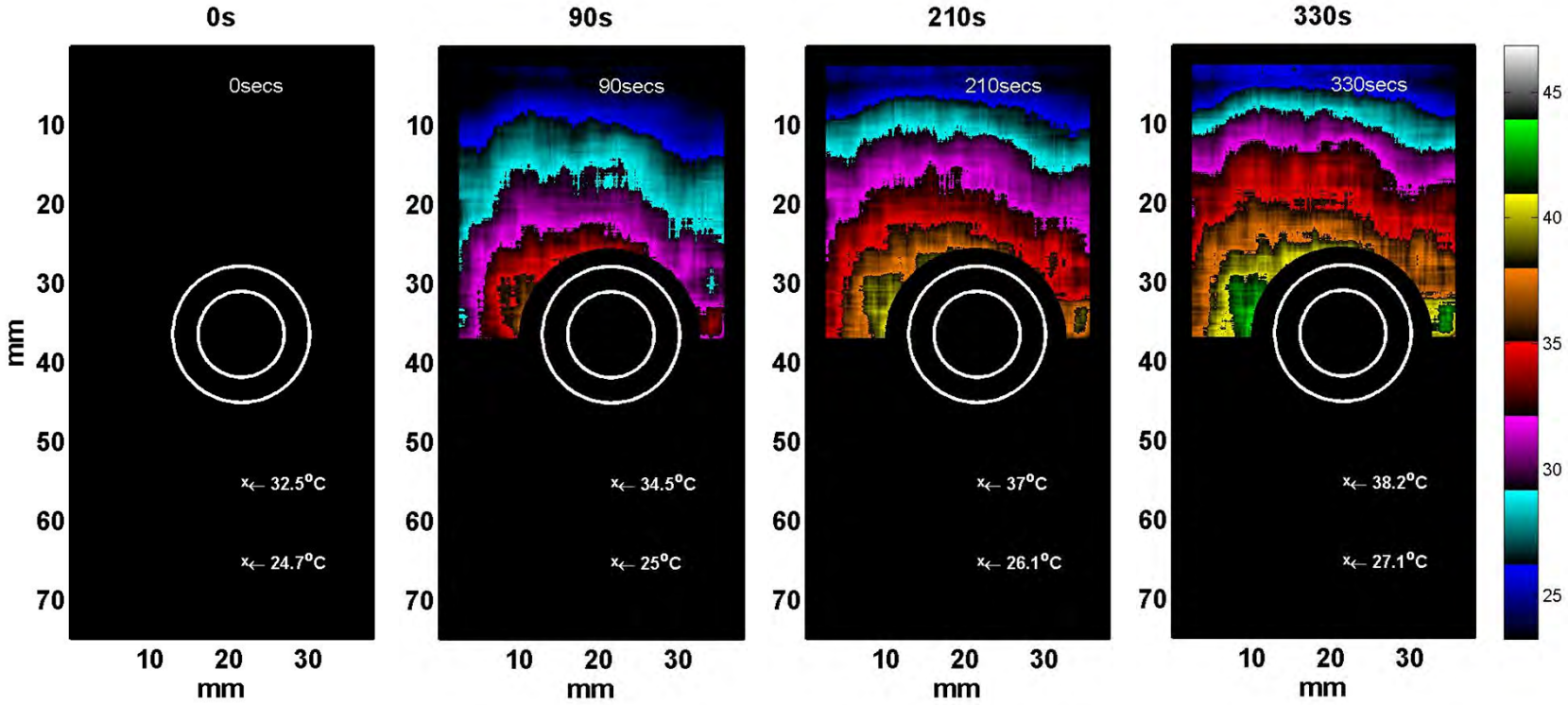
Turkey in air at room temperature

MR (long heating tube)



Turkey in water at room temperature

CBE Temperature Images during Non-uniform Heating in Gelatin Phantom



- Phantom in air at room temperature
- Thermocouples outside of the field of view
- CBE temperature within ~1°C of thermocouple readings

Summary & Conclusions

- Volumetric temperature distributions were estimated in turkey breast using
  - CBE ultasonic temperature imaging
  - MR temperature imaging
- Both modalities are subject to motion artifact, but are accurate to about 1°C
- In this preliminary study both modalities had
  - Similar temperature elevations, but
  - Differences in heating patterns with distance from heat source
- Further studies comparing both are planned with temperature validation using fiber optics sensors