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

R. Martin Arthur¹, William L Straube², Michael Gach², Michael Altman² & Hong Chen²,³

¹Electrical & Systems Engineering, ²Radiation Oncology & ³Biomedical Engineering
Washington University in St. Louis

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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. Magn. Res. 34, 2011
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

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

Thermocouple locations

~1 °C accuracy

Washington

2016 ICHO

AM Arthur

April 15, 2016
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

Philips Ingenia 1.5T system

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

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

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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)

MR (long heating tube)

Turkey in air at room temperature

Turkey in water at room temperature

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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 ultrasonic 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