Real-time reconstruction of high-intensity focused ultrasound focal temperature field based on deep learning

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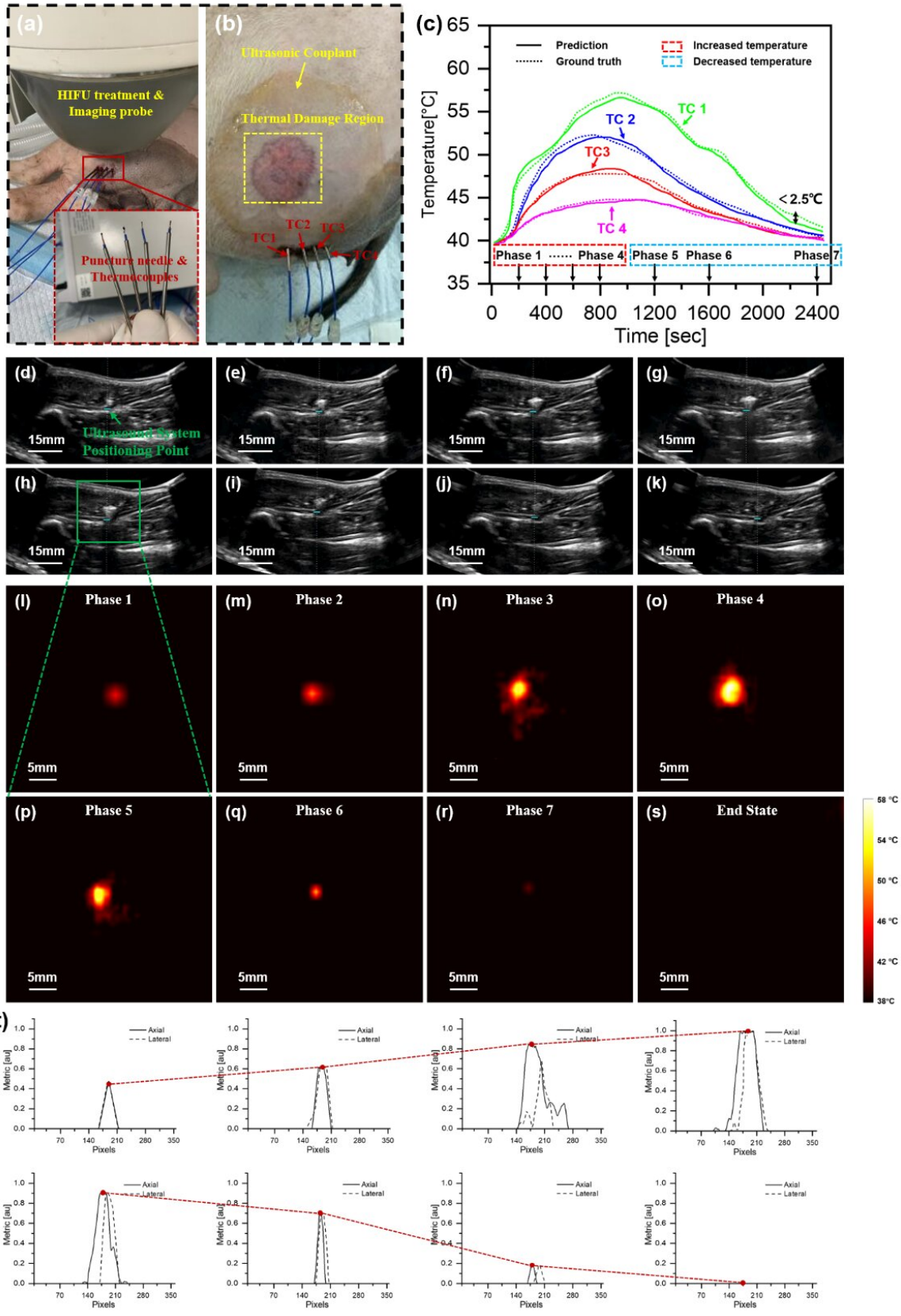
(a)
HIFU treatment & Imaging probe
Puncture needle & Thermocouples
(b)
Ultrasonic Couplant
Thermal Damage Region
TC1
TC2
TC3
TC4
(c)
Prediction
Ground truth
Increased temperature
Decreased temperature
Temperature[°C]
Time [sec]
TC 1
TC 2
TC3
TC 4
< 2.5℃
Phase 1
Phase 4
Phase 5
Phase 6
Phase 7
(d)
(e)
(f)
(g)
(h)
(i)
(j)
(k)
15mm
Ultrasound System Positioning Point
(l) Phase 1
(m) Phase 2
(n) Phase 3
(o) Phase 4
(p) Phase 5
(q) Phase 6
(r) Phase 7
(s) End State
5mm
58 °C
54 °C
50 °C
46 °C
42 °C
38°C
(t)
Axial
Lateral
Metric [au]
Pixels

In*vivo* real-time temperature field reconstruction during HIFU treatment using deep learning. Credit: School of Integrated Circuits @ HUST.

High-intensity focused ultrasound (HIFU) is a non-invasive technique for tumor ablation. During the actual HIFU treatment process, biological tissues absorb acoustic energy and convert it into thermal energy. Measurement and control of tissue temperature within the HIFU focal region are crucial for the effectiveness of treatment.

However, due to the heterogeneous nature of non-uniform biological media (including bone, muscle, fat, and blood vessels), which influence sound propagation and exhibit differences in acoustic absorption, it is currently challenging to achieve accurate and real-time monitoring of the temperature distribution within the HIFU focal region.

As a result, it is difficult to plan effective ultrasound dosages (such as acoustic power and treatment duration) scientifically and precisely for patients. This, to some extent, affects the efficacy of HIFU treatments.

In a recent work published in *BME Frontiers*, a HUST research team developed a deep Multi-Modal Teacher-Student (MMTS) approach, which enables real-time reconstruction of the HIFU focal temperature field.

During HIFU treatment, the research team used the ultrasonic diagnostic system to acquire ultrasonic echo signals and the temperature detection system to acquire real-time temperature data. They further trained a deep neural network that rapidly transforms B-model ultrasonic images into 2D temperature images, revealing accurate color and contrast. This reconstruction process takes only a few milliseconds per frame and does

not need expensive computing resources.

Using only a computer, the reconstruction of the HIFU focal temperature field could be accomplished much faster and cost-effectively, enabling more accurate dose planning.

The physicians from the HIFU Center of Oncology Department, Huadong Hospital, Affiliated with Fudan University, validated this AI-based temperature reconstruction technique in terms of both its reconstruction speed and reconstruction quality.

The physicians confirmed that the deep learning-powered temperature reconstruct approach effectively monitored the distribution of the HIFU temperature field in real-time, laying a theoretical foundation for subsequent personalized treatment dose planning and providing efficient guidance for non-invasive, nonionizing cancer treatment.

More information: Shunyao Luan et al, Real-Time Reconstruction of HIFU Focal Temperature Field Based on Deep Learning, *BME Frontiers* (2024). DOI: 10.34133/bmef.0037

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