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Acoustic and Thermal Numerical Modelling of Transcranial Ultrasound Thermal Therapy

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Abstract

Objectives:

This work presents a rapid and accurate numerical model of intra-cranial acoustic and thermal fields, and quantifies the effect of model complexity on clinically relevant parameters.

Methods:

The CIVA simulation platform provides rapid simulation of acoustic and thermal fields arising from transcranial focused ultrasound therapy using the INSIGHTEC ExAblate clinical system. Acoustic simulations were performed to quantify the effect of mode conversion and internal reflection within a layered skull model on the resultant acoustic field at the focus. Simulated acoustic fields were then combined with the CIVA thermal model to predict temperature rise at the focus, which was compared to experimental temperature rise measured using MR thermometry.

Results:

The results quantify the effect of mode conversion and internal reflection as a function of skull heterogeneity within a ray-tracing model of transcranial acoustic propagation. Results demonstrate the necessity of including the effects of shear wave mode conversion within the skull when using ray-tracing models, while the contributions of internal reflection do not significantly alter the position or amplitude of the maximum acoustic field near the focus. The comparison of simulated temperature rise produced using transcranial focused ultrasound demonstrated a high degree of agreement with experimentally measured temperatures across a range of acoustic power levels.

Conclusions:

This work quantifies the importance of various acoustic wave behaviour and skull heterogeneity in transcranial focused ultrasound modelling, which may help guide the use and required complexity of numerical models. Comparison of simulated and experimentally measured temperature fields demonstrates that the CIVA Healthcare platform can provide rapid and accurate prediction of temperature rise.

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