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BENCHMARKING CIVA HEALTHCARE PLATFORM FOR TRANSCRANIAL ULTRASOUND SIMULATION

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BACKGROUND

Recent work presented benchmarking and intercomparison of several transcranial acoustic modelling tools. We expand on that work with benchmarking of the CIVA Healthcare Simulation platform.

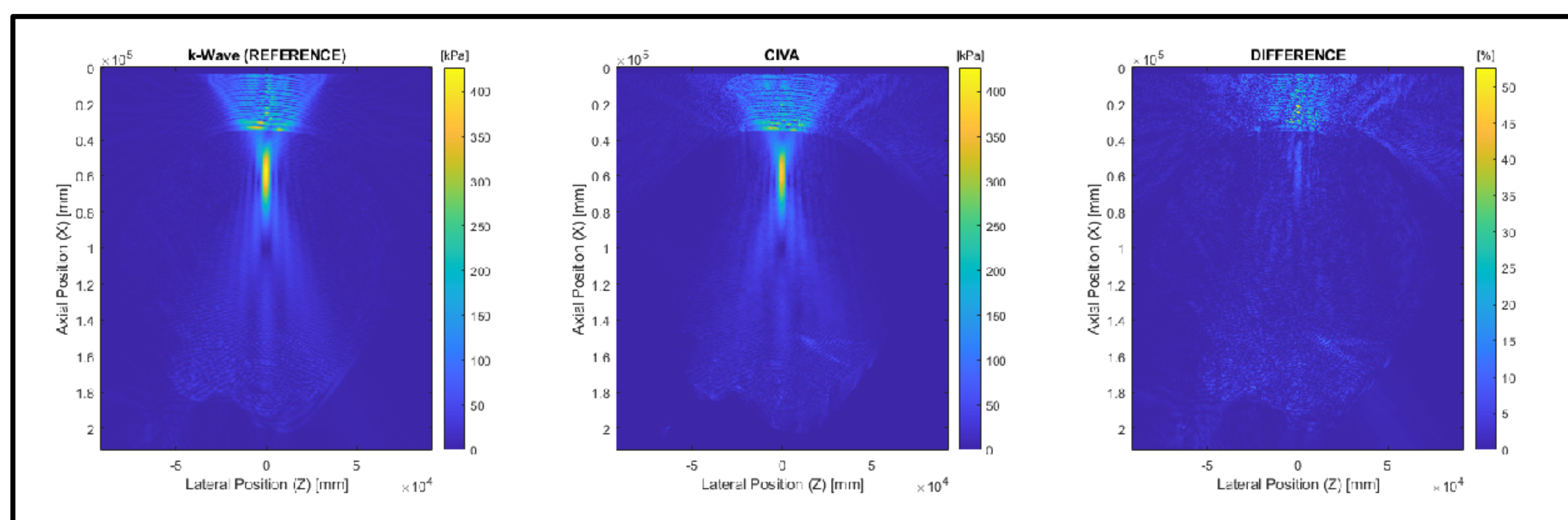


FIGURE 1: Benchmark #9 comparison - 3D curved transducer with a human skull. (left) Results obtained using the CIVA Simulation Platform. (center) Results obtained using k-Wave (right) difference map.

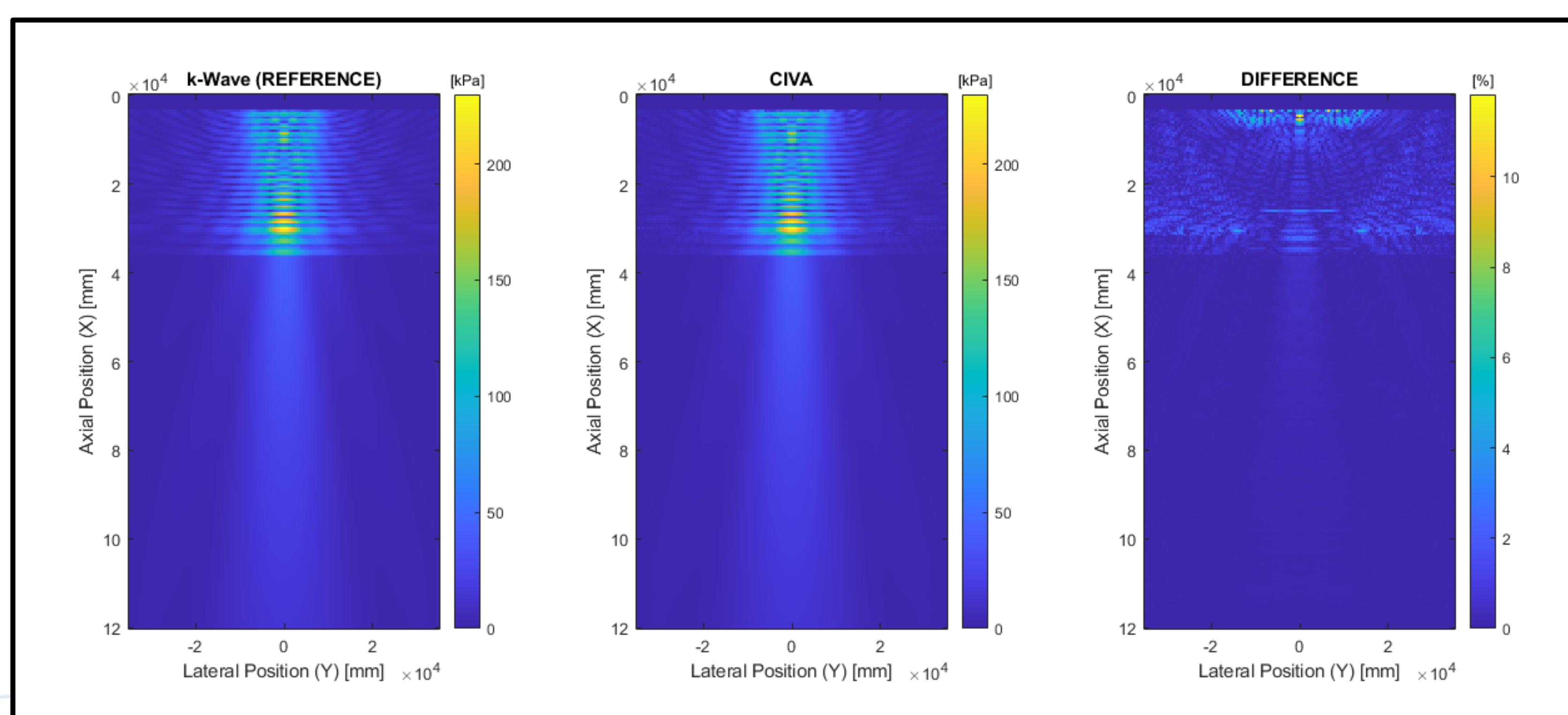


FIGURE 2: Benchmark #4 comparison - 2D piston transducer with skin, three-layered skull, water, and brain. (left) Results obtained using the CIVA Simulation Platform. (center) Results obtained using k-Wave (right) difference map.

FIGURE 3: Summary of relative L2 difference metric compared to KWAVE computed across the entire field taken from the exit plan of transducer.

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METHODS

The 18 unique numerical benchmarks provided in [1] were reproduced in the CIVA Healthcare simulation platform, which uses a ray-tracing model to provide rapid calculation of acoustic fields. All simulations were performed using a desktop PC. Benchmark values and intercomparisons were generated using the MATLAB code provided in supplemental material, with the CIVA results being appended to the existing comparisons.

RESULTS

Good agreement was found between the results obtained by CIVA and those obtained through other methods. Two results are shown in Figures 1 and 2. The most significant differences being observed in large 3D calculations through a real skull. These large 3D simulations used a lower number of rays and internal reflections to decrease computation time in order to accommodate the atypically large simulated domain, without significant deterioration of the results.

The relative L² difference metric was computed as

$$L^2 = \sqrt{\frac{\sum (p_1 - p_2)^2}{\sum p_1^2}}$$

Where p_1 is the amplitude of the pressure field from k-Wave simulations, and p_2 is the amplitude of the pressure field from the comparison field. The relative L² metric is shown for all models in Figure 3.

In contrast with full-wave methods, the ray-tracing model provides fast calculation of the acoustic field only at specified points, typically near the focal target, without simulation of the field in the intervening or surrounding space.

CONCLUSIONS

The CIVA Healthcare Simulation platform shows strong agreement with other models of transcranial ultrasound modelling. These results serve to validate the CIVA ray-tracing method, and further build confidence in the use of computational modelling to support transcranial ultrasound therapies.

REFERENCES

[1] Aubry et al (2022). JASA, 152(2)