Numerical Investigation of Vortex-Induced Mechanical Stresses in the Microbubble-Free Blood–Brain Barrier Opening

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Objectives (25 words)

To investigate whether the torsional stresses resulting from the angular momentum of acoustic vortices may contribute to the opening of the BBB without microbubbles.

Methods (75 words)

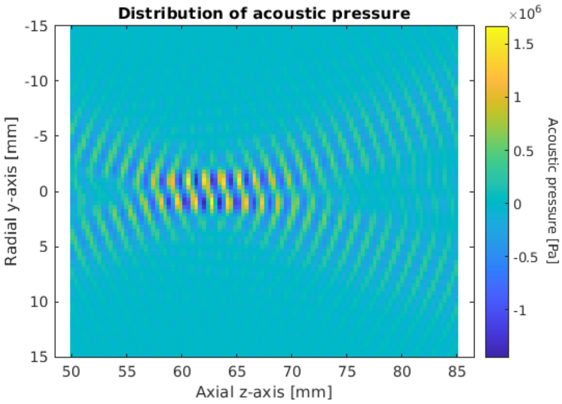
We performed numerical simulations of a bowl-shaped therapeutic transducer (1.05 MHz) operating in standard and vortex modes. Model of a capillary-sized elastic tube was positioned at the calculated acoustic focus, and a finite element analysis was used to determine the maximum deformations and the corresponding shear stresses for different orientations of the elastic tube. The simulations were performed in COMSOL Multiphysics and k-wave, with k-wave serving as the reference.

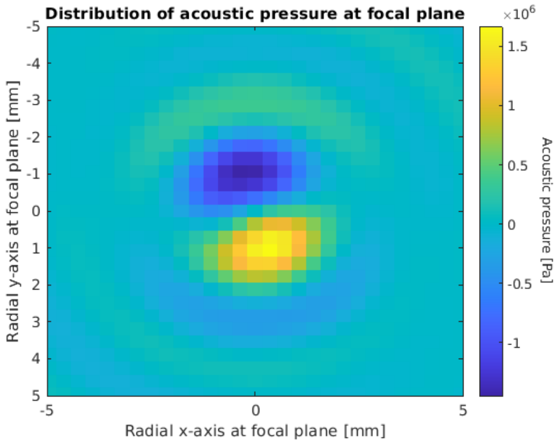
Results (100 words)

The spatio-temporal distributions of acoustic pressure obtained using k-Wave and COMSOL Multiphysics—for both conventional focused acoustic fields and focused vortex fields—show agreement within 10% of the acoustic pressure amplitude. The results were compared with those obtained for non-vortex excitation, as well as with literature data on local vascular deformation during ultrasonic opening of the blood-brain barrier using microbubbles, and with numerical simulations of shear stress generated in a blood vessel by an oscillating microbubble.

Conclusions (50 words)

Preliminary findings provide qualitative insight into the microbubble-free BBB opening mechanisms and may support the development of safer and more controllable neurotherapeutic strategies.





3D Visualization of the distribution of the acoustic pressure