Revolutionising Preclinical Testing: Computational Modelling of Microbubbles in Patient-Specific Geometry

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Motivation

Nearly 90% of medical therapies entering clinical trials fail, often revealing limitations in how treatments are evaluated during early laboratory testing. This project challenges that gap through computational modelling of microbubble-mediated sonothrombolysis for stroke therapy. Unlike conventional benchtop experiments, computational models enable rapid exploration of treatment conditions that would be costly or impractical to test physically, allowing optimal parameters to be identified earlier in development and improving translation of stroke therapies into effective treatments.

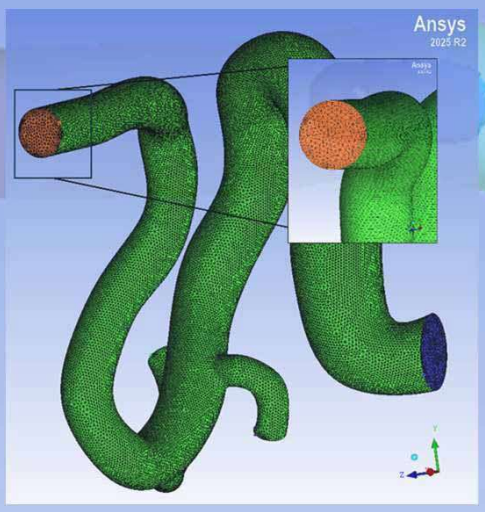

Figure 1 – Meshed Patient-Specific Geometry

Method

- Patient-specific Circle of Willis reconstructed from MRI; rough clot of diameter 1.6mm inserted into MCA (see **Figure 1**)
- Mesh independence at 0.025mm (1.74M elements, <5% convergence)
- Carreau-Yasuda non-Newtonian blood model; steady-state laminar solver in ANSYS Fluent
- Microbubbles modelled as secondary Eulerian phase
- Rayleigh-Plesset acoustic model in MATLAB; 1MHz; MI=0.1-1.0; D=1.25-10.0μm

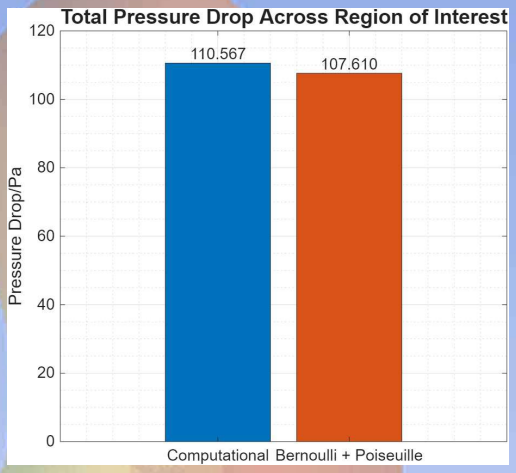

Figure 2 – Computational VS Analytical Pressure Drop

Validation

Combining Poiseuille and Bernoulli analytical estimates gives **<3%** difference from the computational pressure drop (See **Figure 2**), confirming the simulation captures realistic haemodynamic complexity.

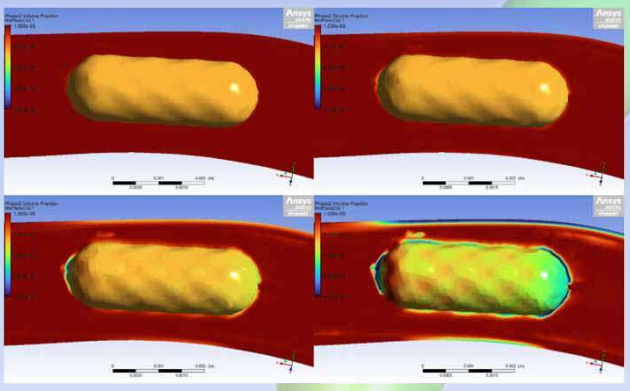

Figure 3 – Volume Fraction of Microbubbles around Clot for Diameters of 1.25μm (Top Left, 2.5μm (Top Right), 5μm (Bottom Left) and 10μm (Bottom Right)

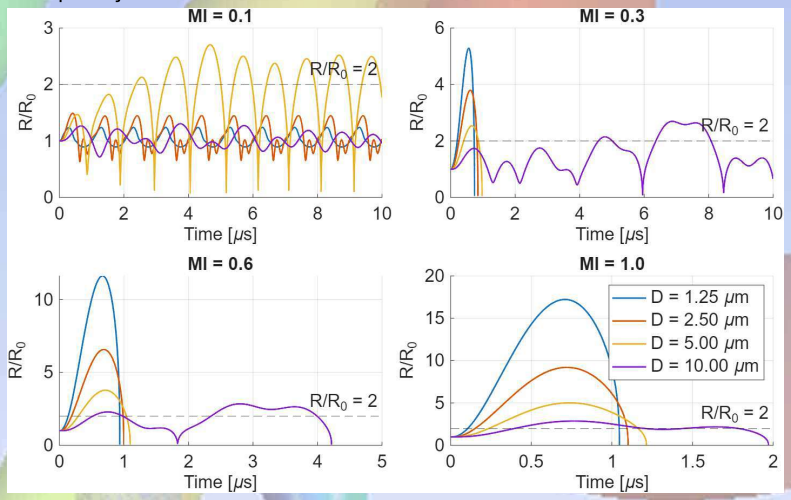

Figure 4 - Normalised Microbubble Radius (R/R_0) against Time. Mechanical indices (MI) of 0.1 (Top Left), 0.3 (Top Right), 0.6 (Bottom Left) and 1.0 (Bottom Right) were tested on varying microbubble diameters, outlined in the legend

Results of Parametric Study

- Smaller bubbles (1.25-5μm) accumulate at the upstream thrombus face (CFD) whereas larger bubbles distribute more broadly due to inertial effects
- Smaller bubbles show greater expansion at therapeutic MI levels (MATLAB) with more aggressive collapse occurs near the clot interface
- This indicates improved localisation and stronger acoustic response
- Therefore, smaller microbubbles may enhance clot targeting while maintaining strong acoustic behaviour
- Next steps include coupling acoustic dynamics with CFD to visualise mechanical effects on the clot

Conclusion

Patient-specific computational modelling systematically isolates microbubble parameters in a way benchtop experimentation cannot replicate. Where experimental sonothrombolysis research has evolved incrementally through costly physical testing, computational parametric modelling represents a genuine revolution in how optimal treatment conditions are identified and translated to the clinic.

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