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Numerical modelling and experimental validation of percutaneous vertebroplasty

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Percutaneous vertebroplasty is a medical procedure done for treating weakened or damaged vertebrae. In this procedure, a cement-like polymer (bone cement) is injected percutaneously into the inside of the vertebra, which is a porous trabecular structure. Upon curing, the bone cement restores the structural strength of the vertebra. While the procedure is fairly successful, there is a risk of bone-cement leaking outside the vertebra, which could lead to severe problems like pulmonary embolism or paralysis. Towards this, a numerical model that can simulate the flow of bone cement inside the porous vertebra could be useful. Such a model could help mitigate the risk of leakage and help the surgeons determine optimum operating parameters, viz. the injection pressure, the cement viscosity, etc.

However, the problem is particularly challenging due to many factors like the complex geometry of the trabecular structure, the curing of the bone cement, non-Newtonian rheology of the bone cement and the bone marrow, and patient-to-patient variation in material parameters. In order to tackle this, a continuum-mechanical approach based on the Theory of Porous Media is used to develop a multiphase model consisting of bone, bone marrow, and bone cement. The flow is modelled using a fully upwind Galerkin formulation. Rheological modelling of the fluids is done using non-Newtonian (shear-thinning) constitutive equations. The viscosity at the macro-scale is obtained using semi-empirical models to upscale the shear-rate. The curing of bone cement is modelled by adding a time-dependence to its viscosity. Rheological characterisation of the bone cement is carried out to obtain the material parameters. For the validation of the model, an experiment is set up where the bone cement is injected into representative porous media (here, aluminium foam). The evolution of the flow is captured using a dynamic CT imaging setup. The results at the different stages of injection are then compared and studied.

Time Block Preference

Time Block B (14:00-17:00 CET)

References

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