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Towards a clinically relevant porous media model for vertebroplasty

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More than 1.4 million clinical vertebral fractures occur annually, making them a common occurrence worldwide. The cause of vertebral fractures could be injuries resulting from accidents or osteoporosis in old age. Vertebroplasty is a commonly used procedure to treat and prevent vertebral fractures. The procedure involves injecting bone cement inside the vertebra and letting it harden by curing. One of the risks associated with the procedure is leakage of bone cement into blood vessels or the spinal canal, leading to complications like pulmonary embolism, paralysis, etc. The outcome of the procedure is often hard to predict because of uncertain factors like the unknown trabecular structure, non-Newtonian nature of the bone cement and the bone marrow, curing of the bone cement, etc. A computational model that can simulate the procedure could be a useful tool for surgeons.

We have developed a multiphase continuum-mechanical macro-scale model based on the Theory of Porous Media for simulating vertebroplasty. The related governing equations were discretized using a combined Finite Element - Finite Volume approach by the so-called Box discretization. Different rheological models for upscaling the non-Newtonian rheologies were used to compare and determine the most suitable one for this application. The model was validated using a benchmark experiment that was set up physically and in simulation. The influence of bone marrow and parameters like permeability, porosity, etc. was investigated to study the effect of varying conditions on vertebroplasty. We found that the presented model could realistically simulate the injection of bone cement in porous materials when used with the correct rheological upscaling models.

Going forward, we want to use this model to identify and investigate the critical parameters that affect the outcome of the vertebroplasty procedure. Furthermore, the model could be extended to include the temperature effects and fractures, as well as to account for the uncertainties arising from the patient-specific nature of the various parameters. Using this model to develop a clinically relevant tool for practitioners could help them make better decisions regarding the operating parameters and conditions for each patient.

Participation

In-Person

References

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