Poroviscoelastic Modeling of Stress Relaxation of Porcine Liver to Investigate Injury Response

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ABSTRACT

Background: *Highly vascular tissue is a combination of solid and fluid components. The interaction between these two phases during deformation creates a viscoelastic or rate-dependent behavior. To understand how fluid and solid components contribute to the injury response of liver tissue, a constitutive model is needed which reflects the biphasic nature of the material. This study aims to capture the stress relaxation response of porcine liver in unconfined compression using biphasic poroviscoelastic (PVE) modeling.*

Methods: *Seventeen fresh porcine liver specimens (19mm diameter, 10mm thick) were compressed to 5% strain at varying strain rates (.001s-1, .01s-1, .1s-1) using a Bose Electroforce Test Instrument. Relaxation response was monitored for 2000 seconds until equilibrium was achieved. Abaqus (v6.8-2, Simulia) SOIL analysis was used to create a PVE axisymmetric finite element model for each strain rate group. Rate dependent and independent responses of the solid phase were modeled with a three-term Prony series and a hyperelastic material model respectively. Best fit parameters were determined using nonlinear least-squares algorithms. Poisson's ratio was selected as 0.49, the initial void ratio 0.2, and material permeability 3.09x10-13m4/Ns[1,2].*

Results: *Compression data showed rate dependence of the peak reaction force (Fig. 1). Best fit Prony series parameters were g1=0.5026, g2=.1848, g3=0.1418, τ1=2.1s, τ2=47.1s, τ3=380.1s and the initial shear modulus was 795Pa. Linear regression analysis between model and experiment resulted in R2 values of 0.997, 0.988, and 0.989 for 0.001s-1, 0.01s-1 and 0.1s-1 respectively ($p<0.05$).*

Discussion & Conclusions: *The PVE model accurately predicted the stress relaxation behavior of porcine liver tissue. Advantages of the PVE model include the ability to simulate both the overall mechanical response and the fluid pressure changes in response to loading (Fig. 2). Future studies will validate pore fluid pressure model predictions and incorporate higher strain rates to examine interstitial fluid pressure as an injury severity indicator [3].*

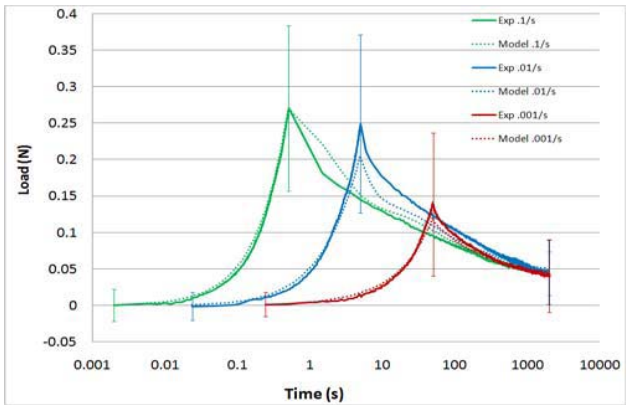

Figure 1: Experimental (solid lines) and model (dashed lines) results

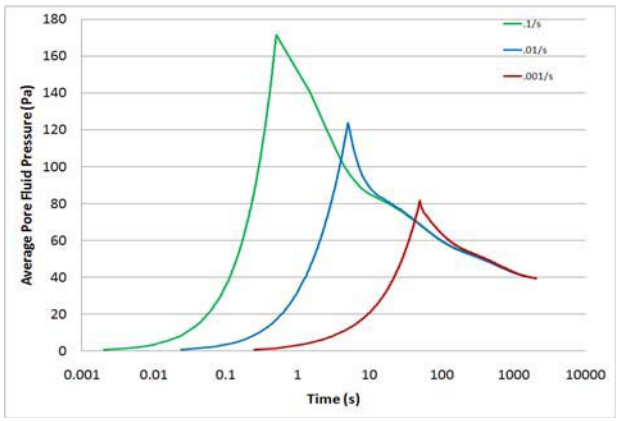

Figure 2: PVE model average pore fluid pressure outputs.
for .1s-1 (green), .01s-1(blue) and .001s-1 (red).