Pressure-related deep tissue injury coincides with areas of high maximum shear strains

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Introduction

Deep tissue injury has recently been recognized as a specific type of pressure ulcer, and was defined as pressure-related damage to subcutaneous tissues under an intact skin. These wounds often require long hospitalization because of poor healing and they seriously decrease quality of life.
Prevention and early detection are hampered by incomplete understanding of the underlying damage pathways. Previous animal experiments demonstrated that the ischemic area was much larger than the damaged area and suggested that strains were directly responsible for tissue injury (Stekelenburg et al. 2007):

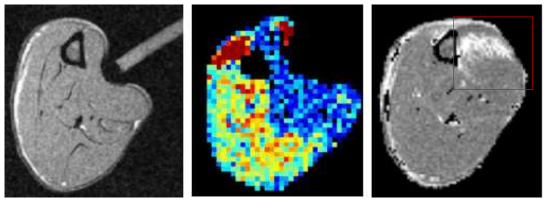

Figure 1: MR-image of cross-section of rat hindlimb during 2h compression (left), perfusion during compression (blue = low, red = high perfusion)(center), T2-weighted MR-image 4h after unloading (high intensity = damage)(right).

Is there a relation between tissue deformation and deep tissue injury?

MR-tagging can be used to measure internal deformations during compression, but these measurements provoke damage. Therefore they cannot be combined with measuring damage due to compression. A dedicated 2D plane stress finite element model was developed to calculate experiment-specific internal strains and compare them with measured damage. MR-tagging experiments were used to validate this model.

Validation

Numerical and tagging displacements were interpolated on a grid in the region of interest (red square in figure 1) and then processed to obtain strains. Correlation between numerical and experimental maximum shear strains and strain energy densities was good:

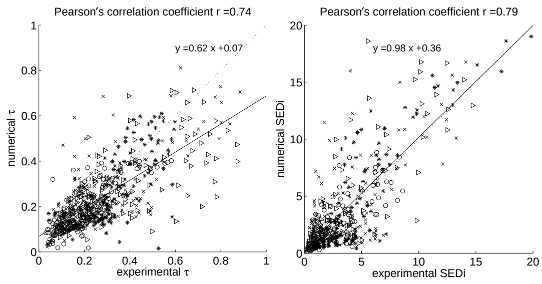

Figure 3: Correlation of model and tagging strain quantities (n = 4).

Damage correlation

The model was then used to simulate damage experiments and the overlap between damage locations and maximum compressive and shear strains was analyzed:

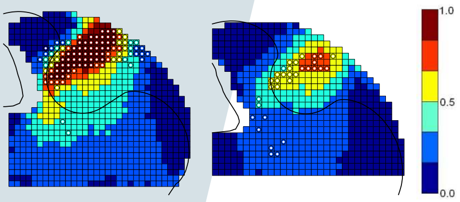

Figure 4: Maximum shear strains in region of interest (red square in figure 1) of 2 different experiments with damage (white cross/black circle) and deformed contours (black curves) superimposed.

The area of high maximum shear strains coincides with the damage, and the amount of damage increases as the size of the area with high maximum shear strains increases:

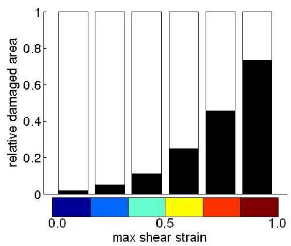

Figure 5: Relative damaged area in each category (n = 9).

Yes, internal shear strains cause deep tissue injury.

- High shear strains cause muscle damage within 2 hours, while ischemia does not cause damage until after 4 hours.
- Defining a strain damage threshold would be a major leap forward in prevention and early detection of deep tissue injury.

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