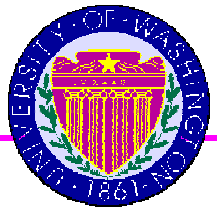
Summer School Surgical Robotics
Montpellier, France, 10-Sept-2009



Tissue Damage

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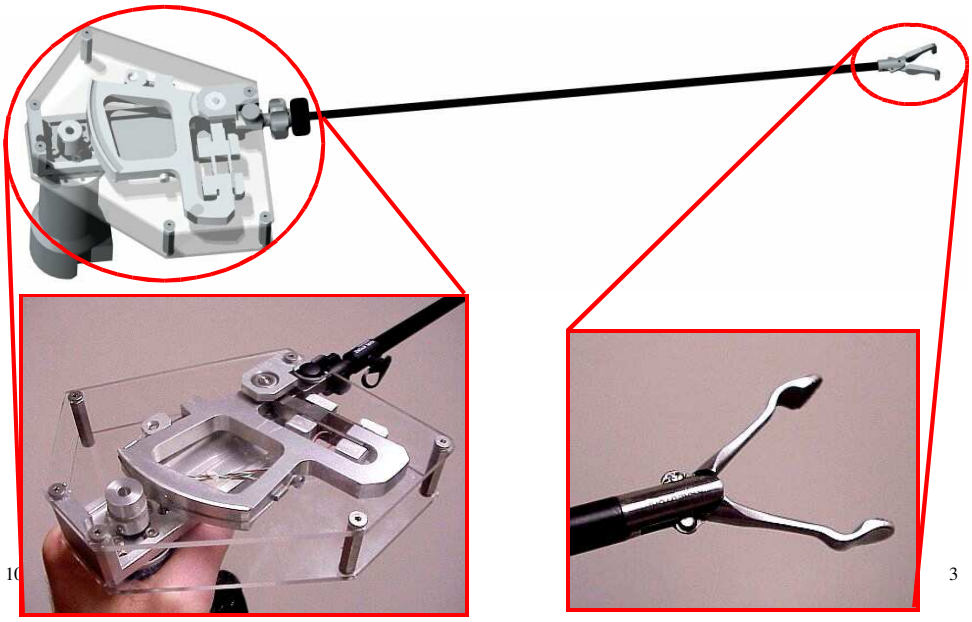
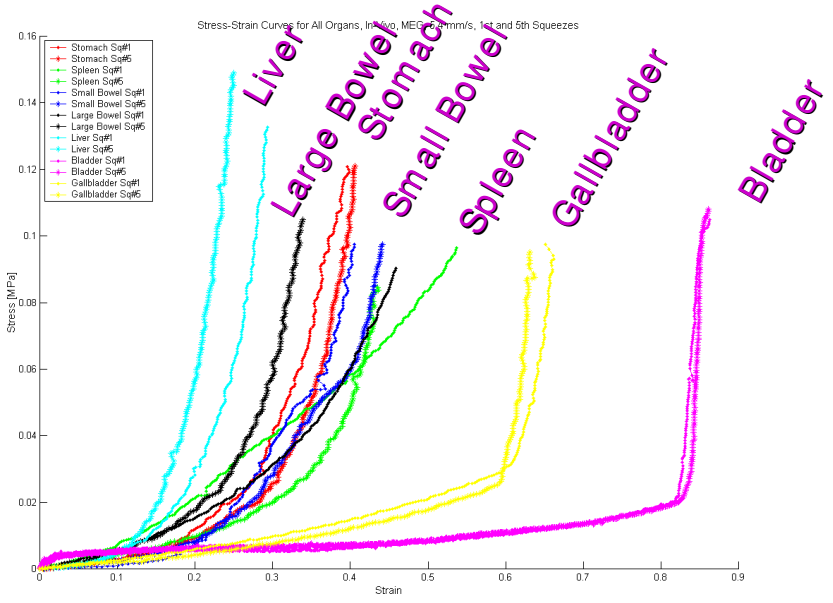
- Mika Sinanan, Jacob Rosen, Paul Swansen, George Turkiyyah
- UW Medical Scientist Training Program (MD/Ph.D.)
- National Institutes of Health (NIBIB)

Motorized Endoscopic Grasper (MEG)



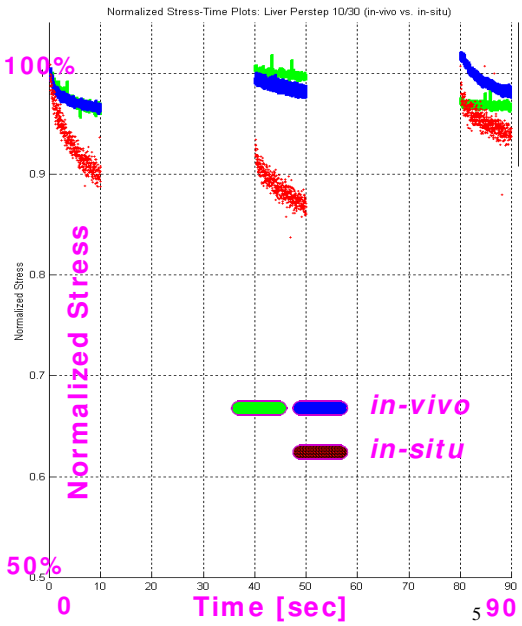
Typical Stress-Strain Curves

All organs, 1st & 5th Squeezes, 5 mm/s, MEG, *in-vivo*



Results — Stress Relaxation

- 1 Liver
- *in-vivo* vs. *in-situ*
- Periodic steps
  - 10 sec on / 30 sec off
- Strains 21% - 51%
- Note:
  - More recovery between squeezes than 10/2.5
  - All squeezes exponential
  - More recovery *in-vivo*
    - Returns to 100%
    - Some >100%
      - Swelling?



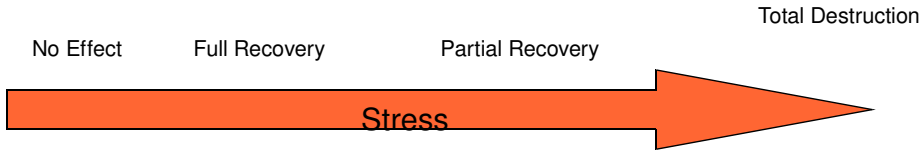
Soft Tissue: conclusions

- In-vivo, surgically relevant data requires a new biomechanics.
- Non-linear and time dependent properties are salient.
- Much work remains to be done!

Tissue Damage: Goals

- What levels of stress are safe for each organ tissue?
- What is “safe”?
- Characterize the spectrum of responses to mechanical stress in terms of clinical signfigance.

Damage “Spectrum”



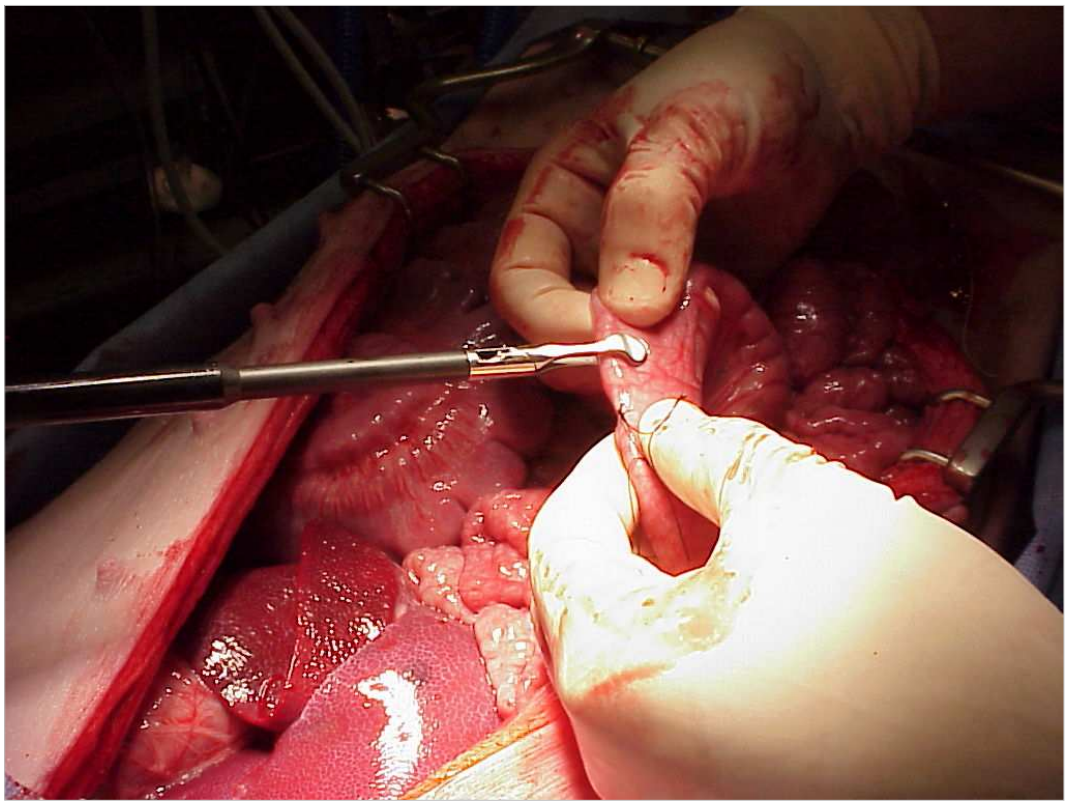
Liver:	20kPA	100kPa	300kPa
Small Bowel:	???		
Other Organs:	???		

Other effects

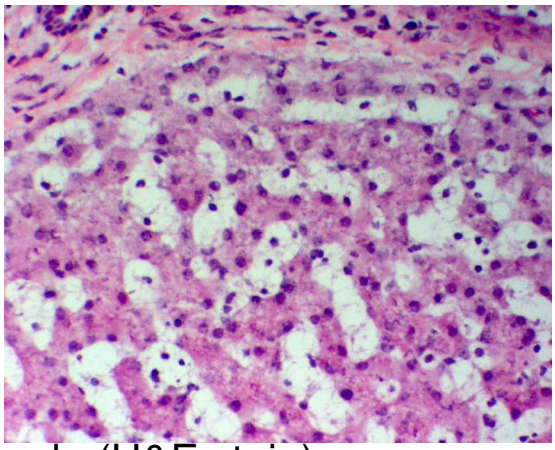
- Recovery time
- Patient condition
- Pathology
- Duration of stress

Experimental Protocol

- Apply known stress with MEG for 10 sec.
- Allow tissue to respond for 90 min.
- Acquire tissue samples, freeze in liquid nitrogen.
- Section samples and stain with H&E stain.

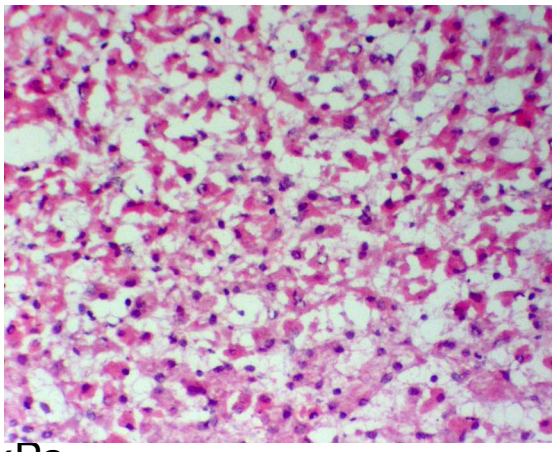


Preliminary Results: Liver



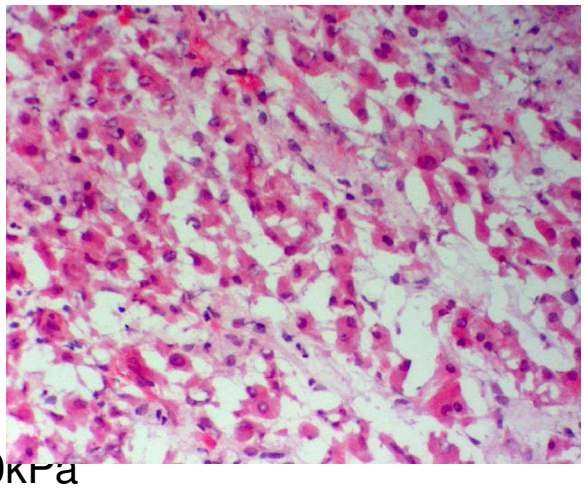
- Normal (H&E stain)

Preliminary Results: Liver



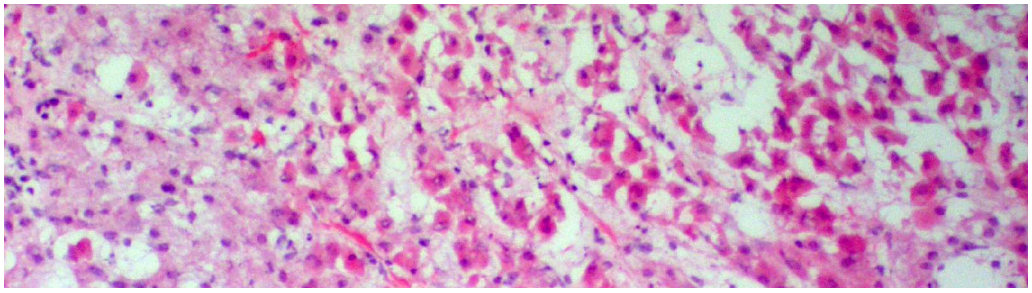
- 100kPa

Preliminary Results: Liver



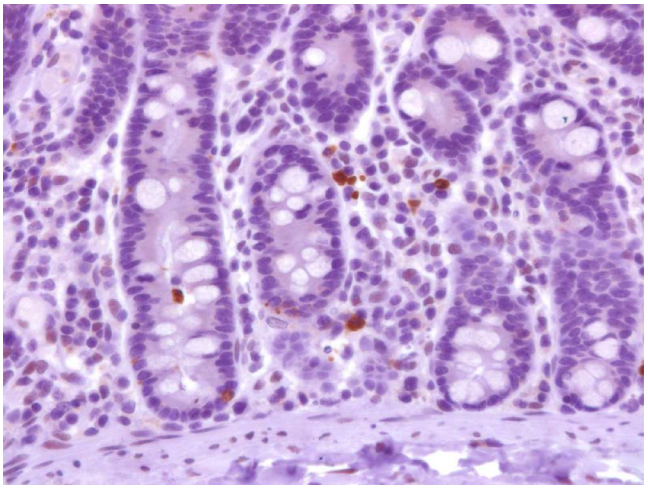
- 200kPa

Preliminary Results: Liver



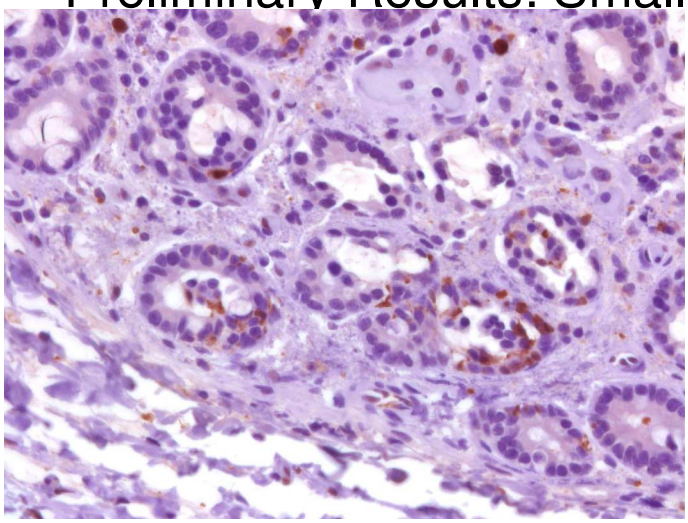
- Edge of compression zone

Preliminary Results: Small Bowel



- Normal: Activated Caspase 3

Preliminary Results: Small Bowel



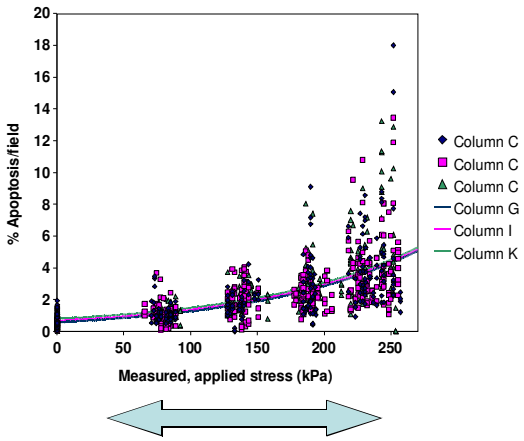
Increased Apoptotic Cells

Presence of apoptotic bodies

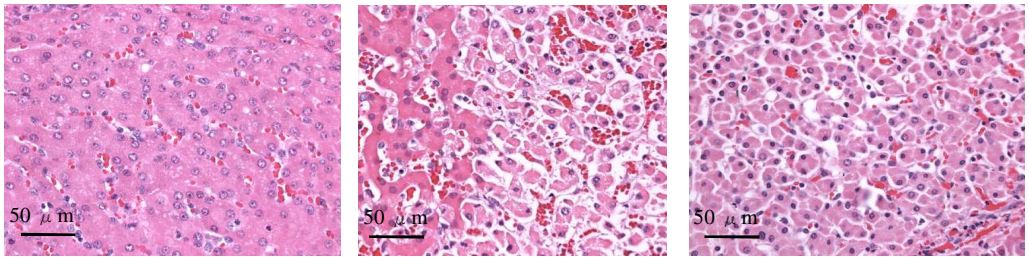
Dilation of crypt lumens

- 251kPa: Activated Caspase 3

Apoptosis in the Bowel



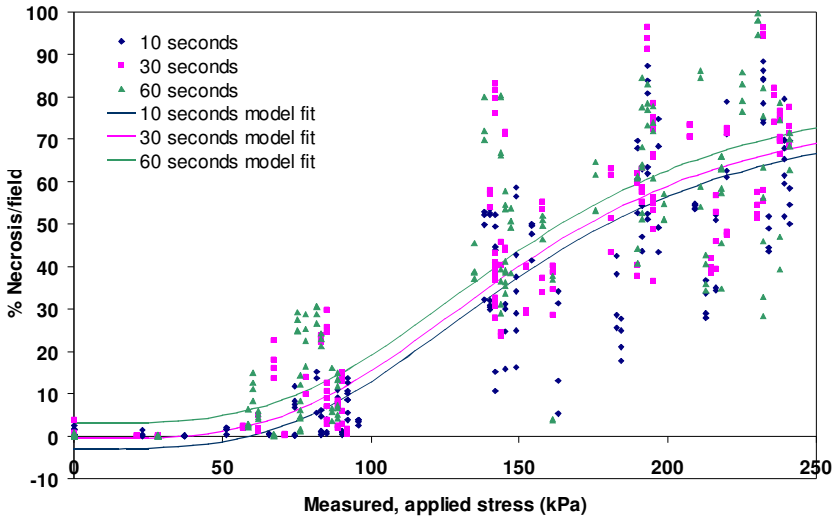
Necrosis



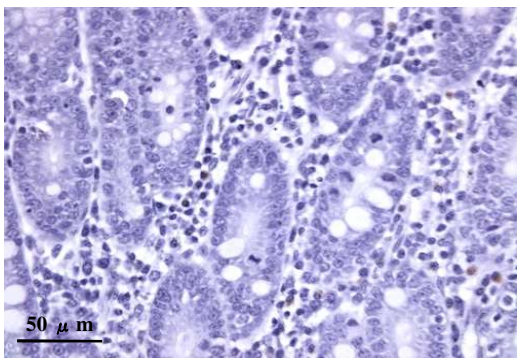
Control 120 kPa 240 kPa

- Necrosis – disorderly cell death, causes inflammation
- Use H&E stain to look at tissue architecture and cell morphology
  - Pyknotic nuclei
  - Blanching or eosinophillia of cytoplasm
  - Congested sinuses (bleeding in sinusoids)
  - Loss of hepatic chord structure.

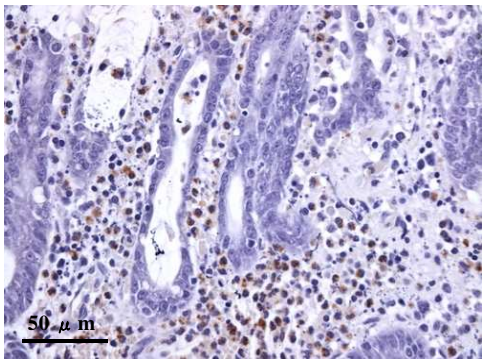
Necrosis in the Liver



Inflammation (Neutrophils)



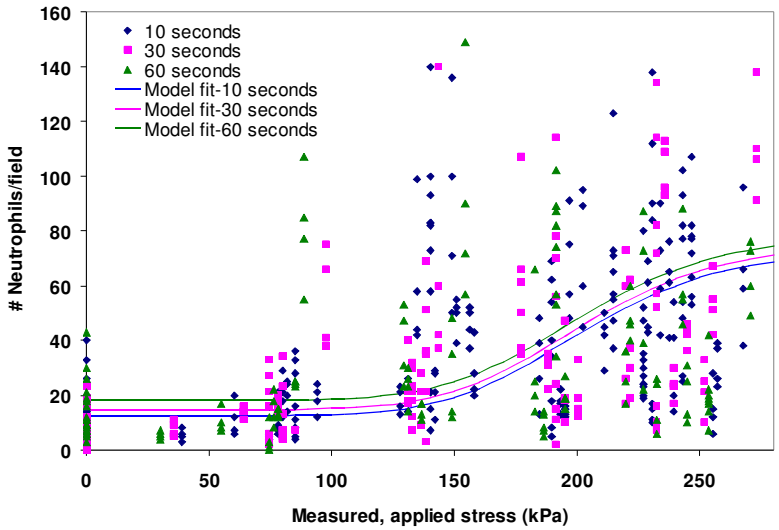
Control



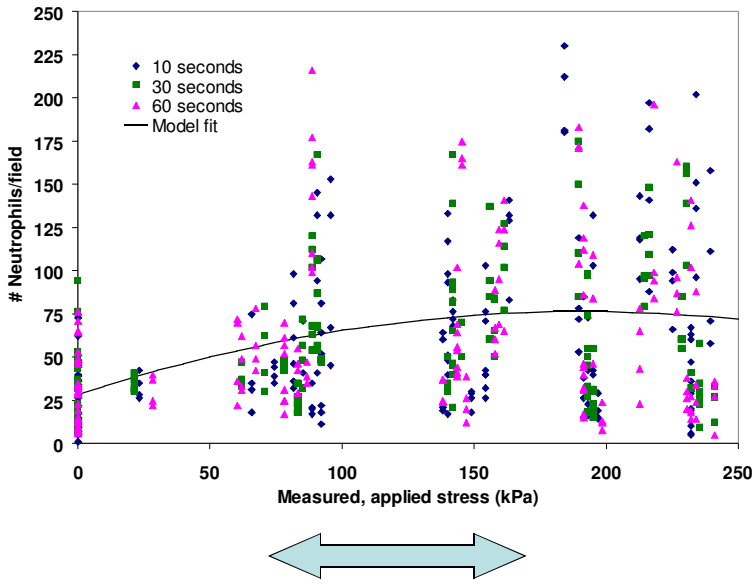
Stressed Region (120 kPa)

- Neutrophils indicate acute inflammation
- Anti-myeloperoxidase immunohistochemistry (brown)
- Count cells in digital images to quantify inflammatory cell infiltration

Neutrophils in the Bowel



Neutrophils in the Liver



Simulation of Grasping

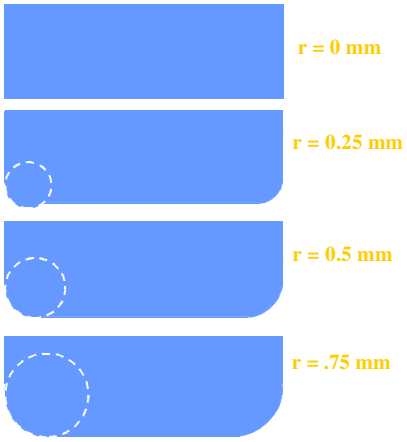
- Finite element modeling (FEM)
  - Numerical method for complex problems
- FEM of actual tissues from *in vivo* study
  - 2D-Plane strain assumption
  - Material properties based on *in vivo* measurements**
- Compared stress distributions in model to damage in tissue

(See FEM slides)

Aim III

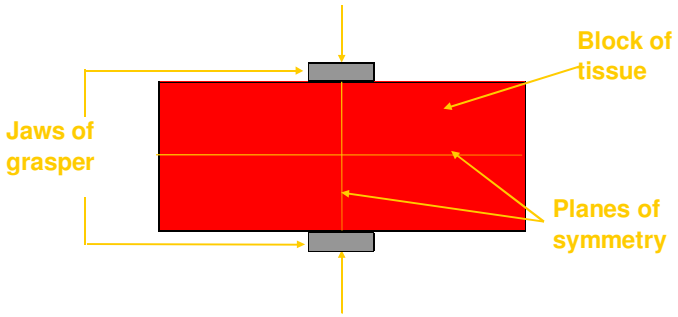
- Use computational methods to determine if rounding the edges of a grasper reduces stress on tissues during compression

Test grasper edges



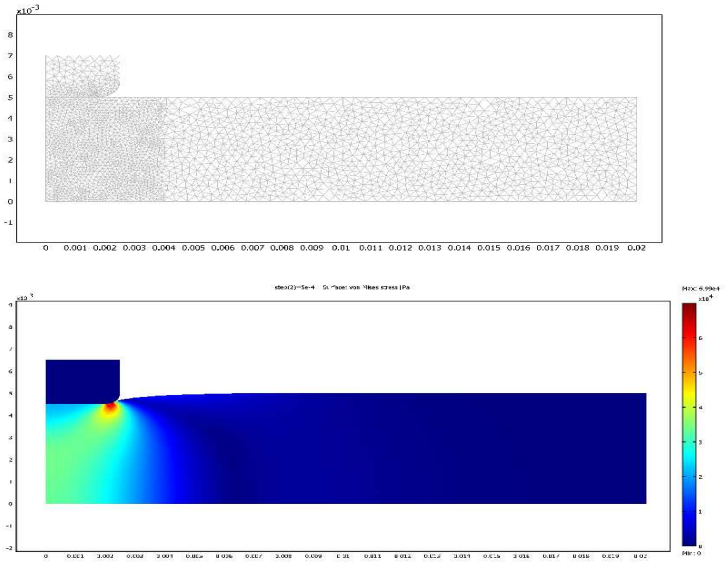
- Little published data
- Sharp corners lead to high stress concentrations
- Test rounded grasper edge
  - peak stress, integrated stress, predicted damage

Grasper Testing FE model

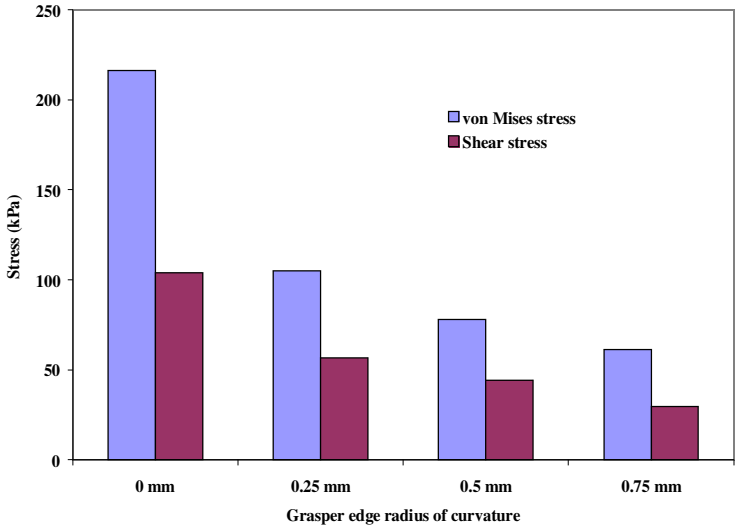


- 2D-plane strain assumption
- 2 loads
  - Low and high strain
- Tissue with properties of liver
- Predict damage
  - Map *in vivo* necrosis to calculated stress

Mesh and Example Model



Peak stresses @ 10% strain



Integrated stress @ 10% strain

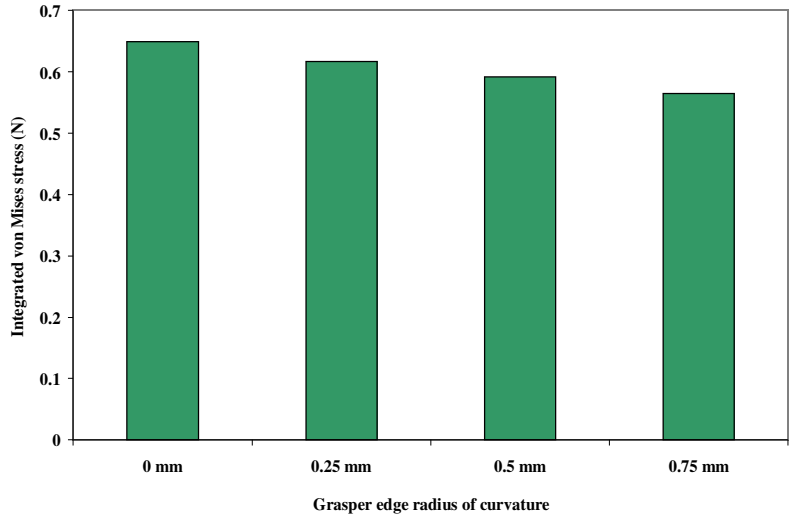
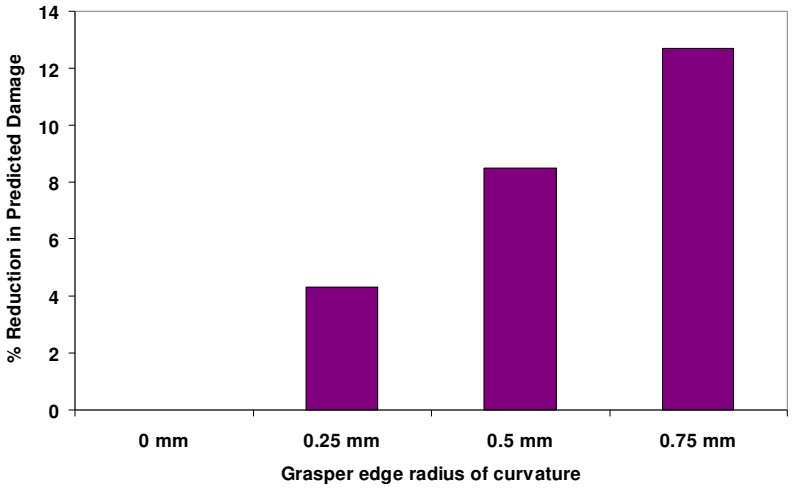


Figure 6.6: Percent overall damage predicted in the tissue block after a 30 percent strain

Reduction in predicted damage @ 30% strain



Conclusions Aim III

- Rounded edges reduce peak stresses
  - Correlates to previous sensor-based study
- Small reduction in overall predicted damage
  - Future studies may indicate clinical relevance of reduction