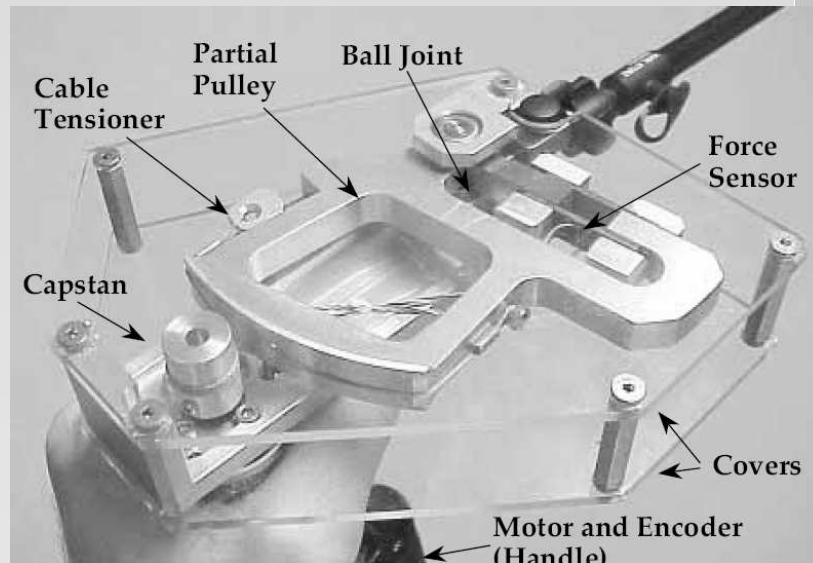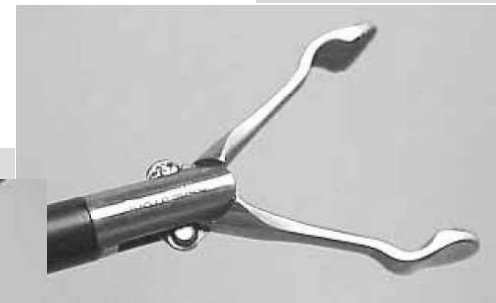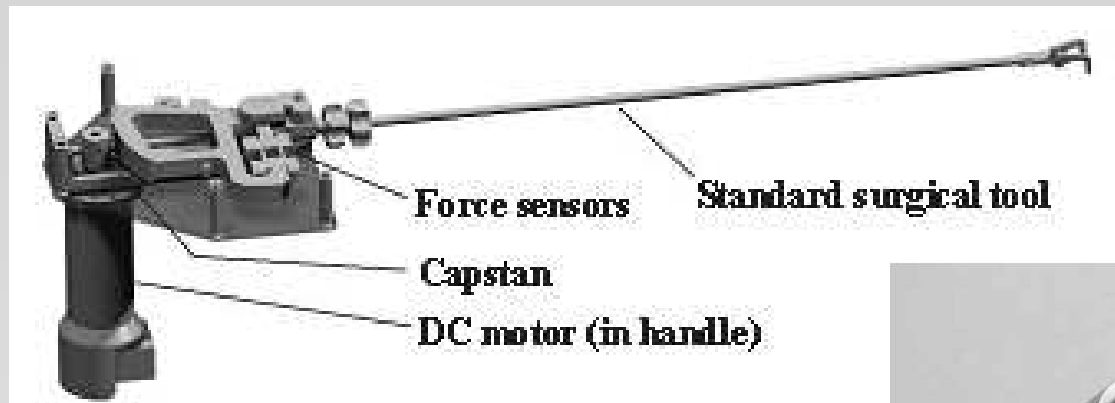# Experimental Design

- Apply compressive forces to abdominal organs within the ranges typical to MIS (as identified in Blue Dragon Experiments)

- Measure indicators of cell death as a function of stress (=force/area)

- Identify thresholds for safe limits of stress application

Motorized Endoscopic Grasper

Force sensors   Standard surgical tool
Capstan
DC motor (in handle)

Cable Tensioner   Partial Pulley   Ball Joint   Force Sensor   Capstan   Covers   Motor and Encoder (Handle)

Brown, 2003

Animal Experiments

- *In Vivo* porcine model
  - 40kg female swine
  - IACUC protocol approval
- Liver and small bowel
- Apply and measure stresses using MEG
  - Stress range: 0 - 300 kPa
  - Corresponds to 99% confidence interval of mean forces applied
  - Duration: 10, 30, 60 seconds
- Allow injury to develop ~3 hours
- Histology and immunopathology
  - Small Bowel: Apoptosis
  - Liver: Necrosis
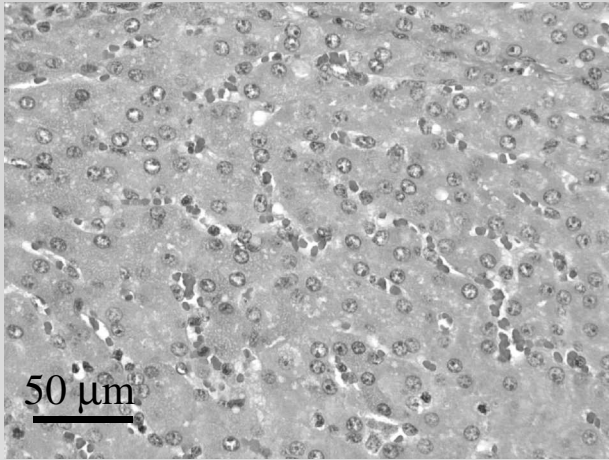
Apoptosis

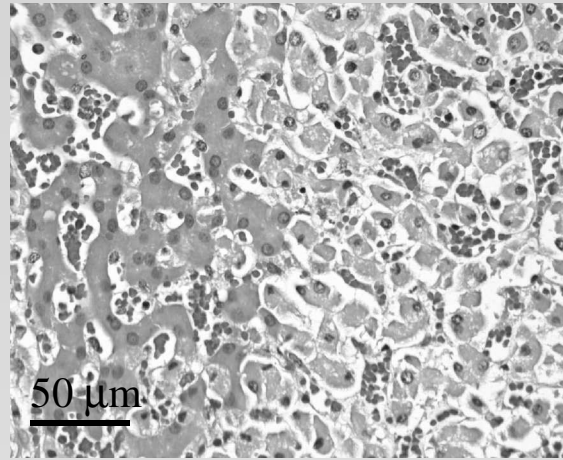50 μm   50 μm
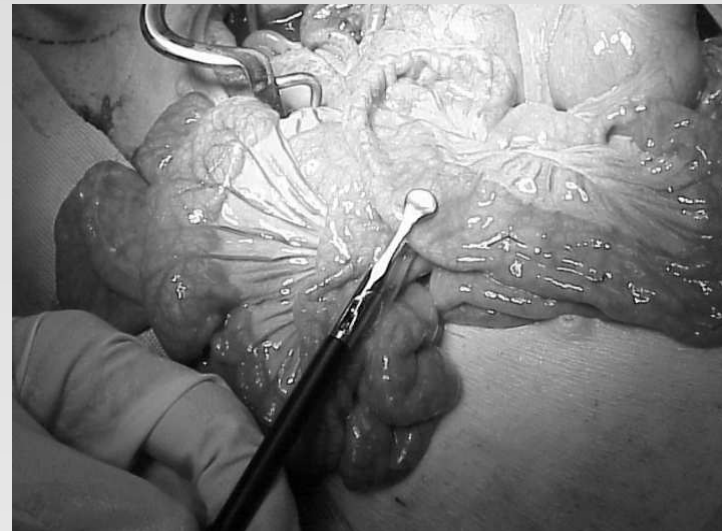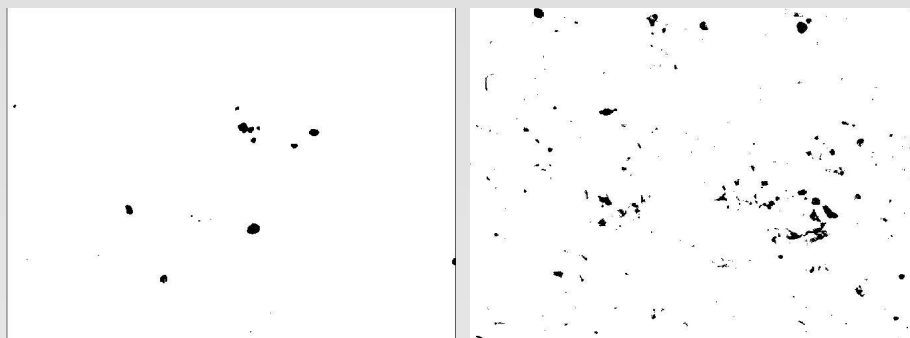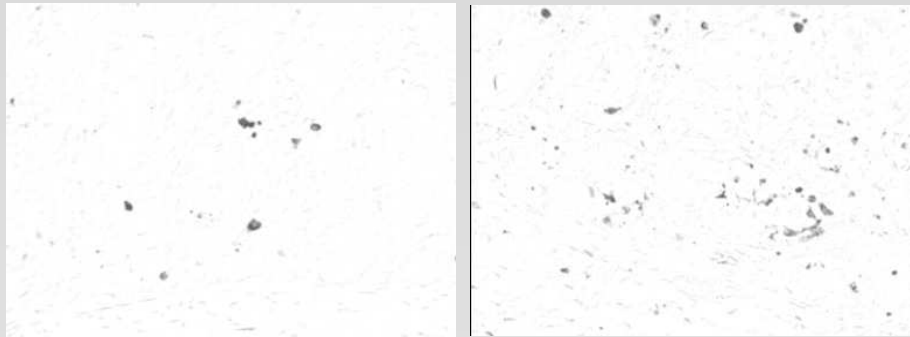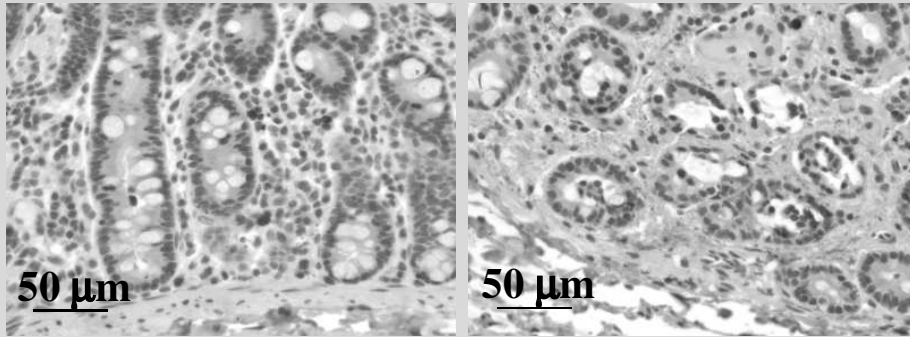
Control (0.38%)   285kPa (1.51%)

- Programmed cell death
- Identify apoptotic cells using anti-activated caspase-3 immunohistochemistry
- Cells stain brown
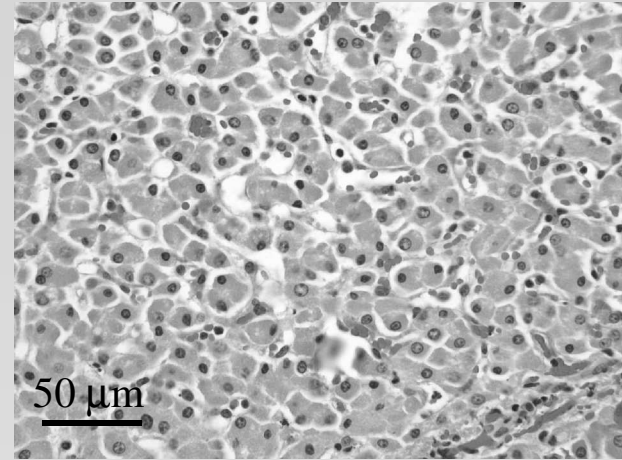- Quantify % apoptotic cell area using image analysis techniques
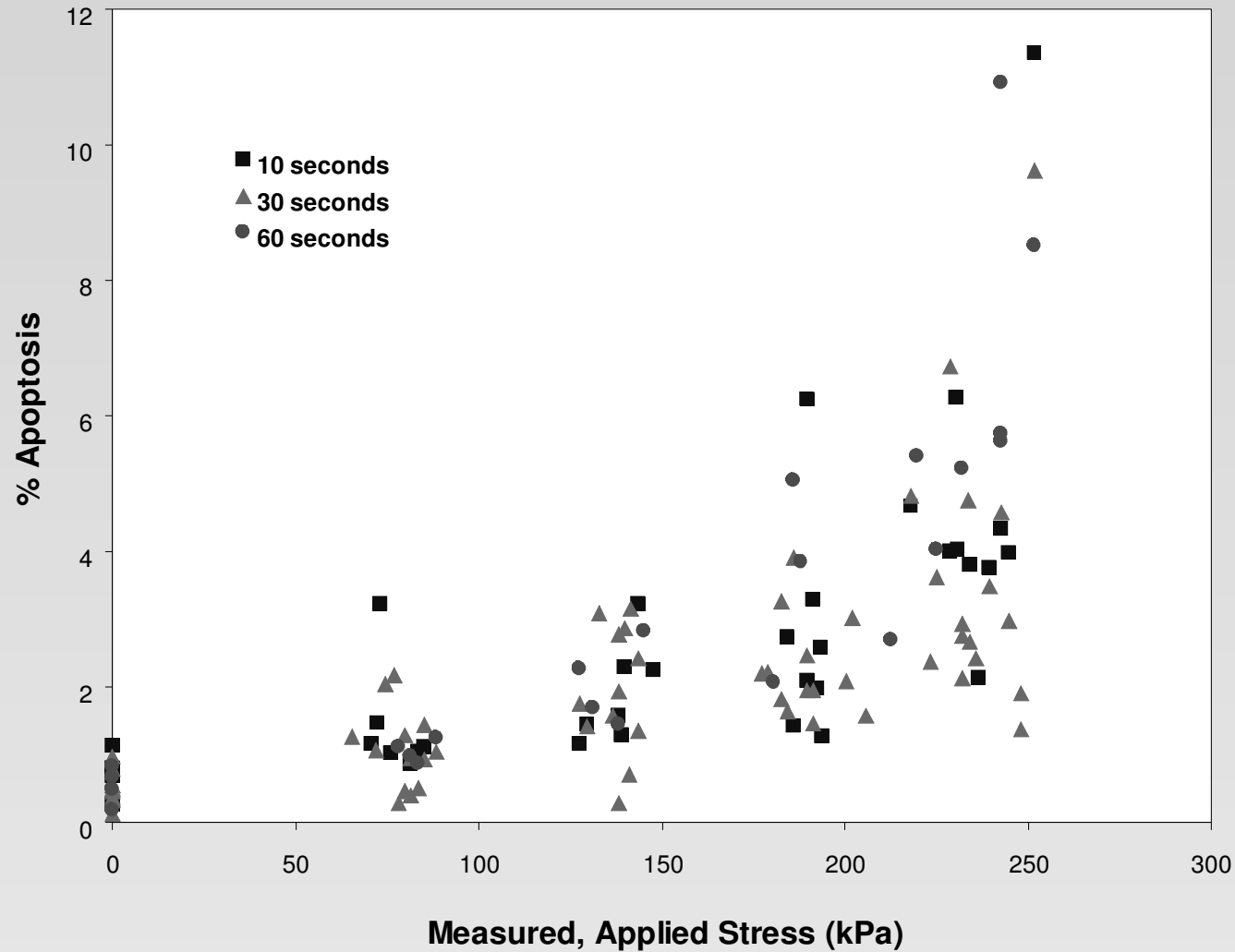
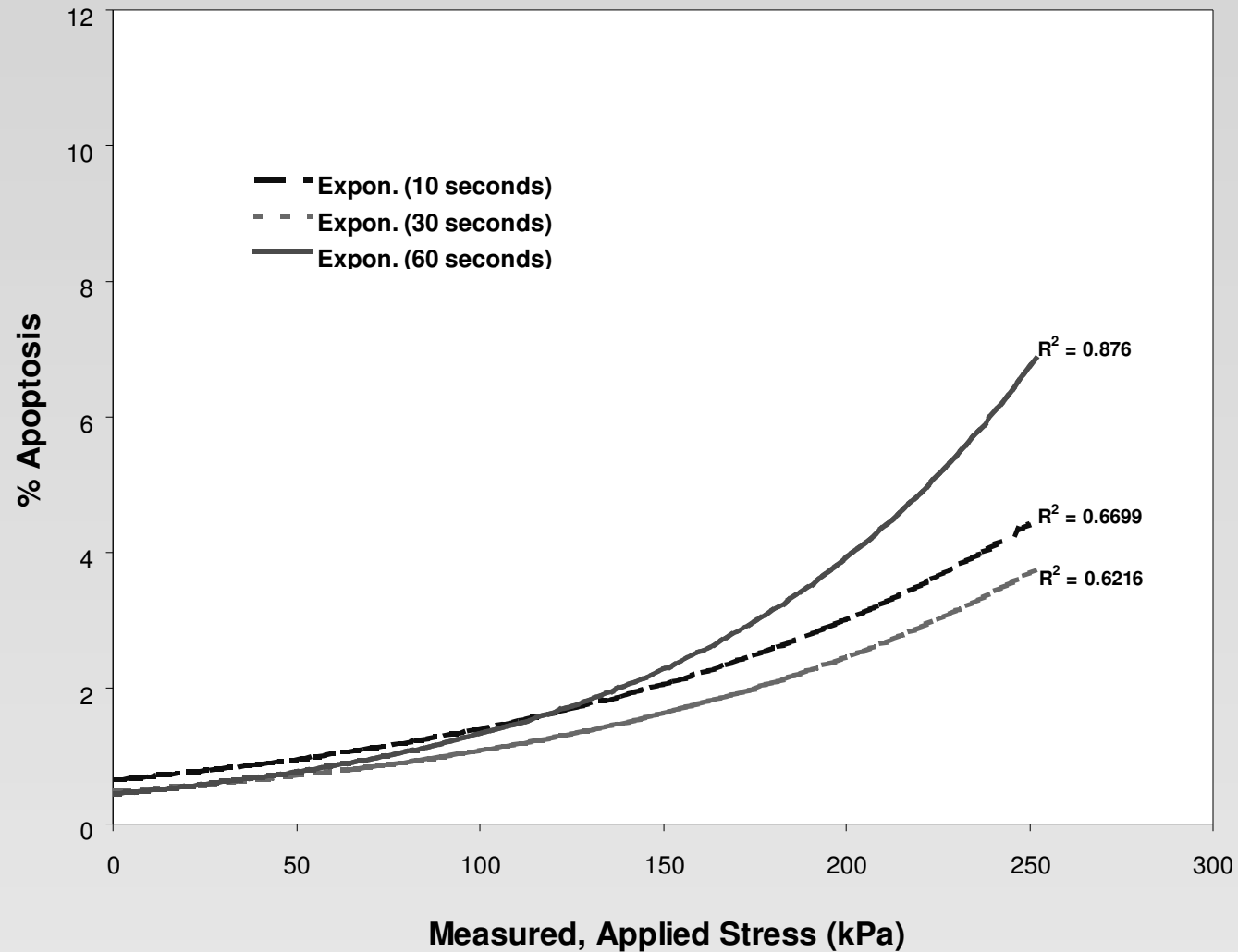# Necrosis

Control

120 kPa

240 kPa

- Necrosis- disordered cell death: no specific stain
- Use H&E stain to look at tissue architecture and cell morphology
  - Pyknotic nuclei
  - Blanching or eosinophillia of cytoplasm
  - Congested sinuses (bleeding in sinusoids)
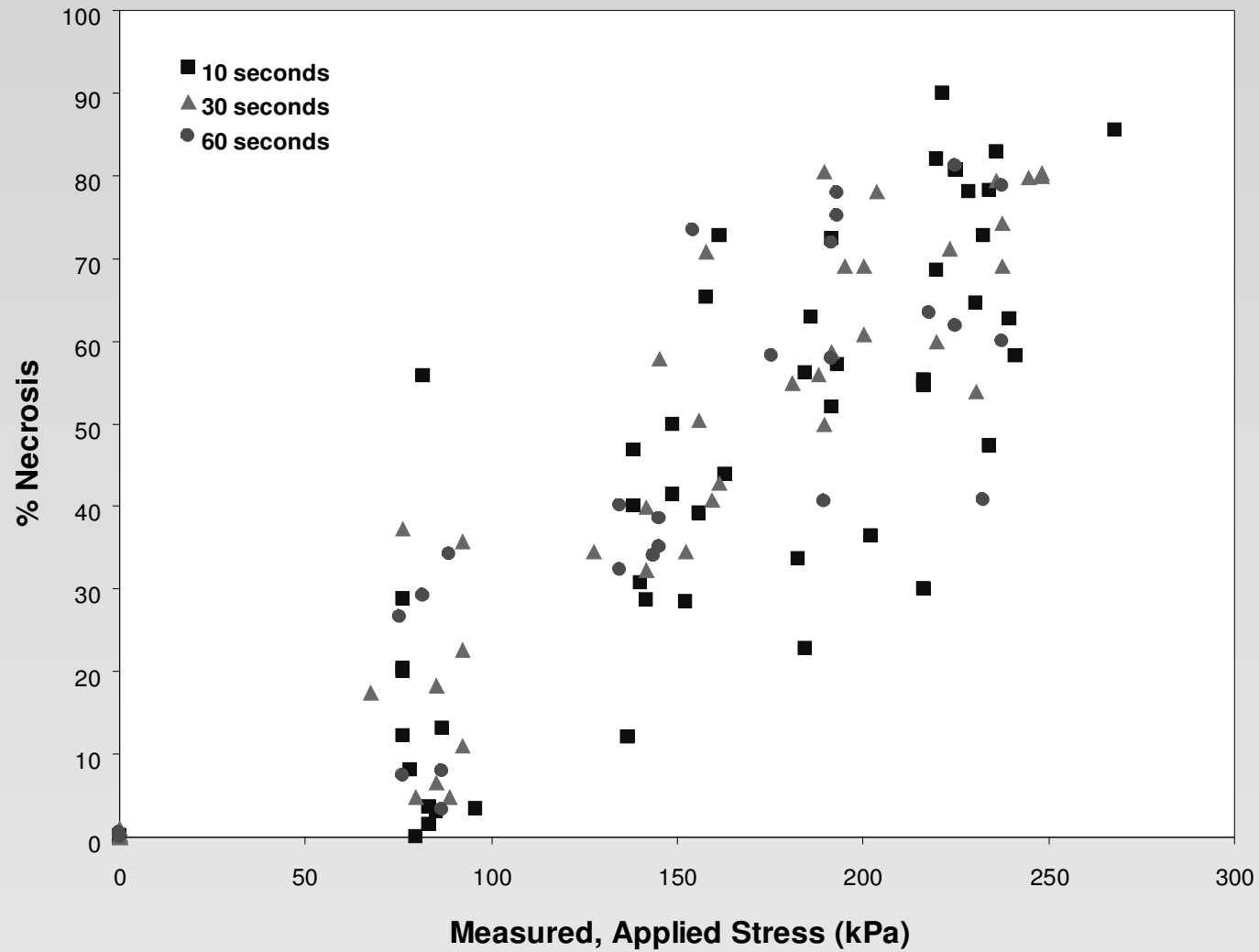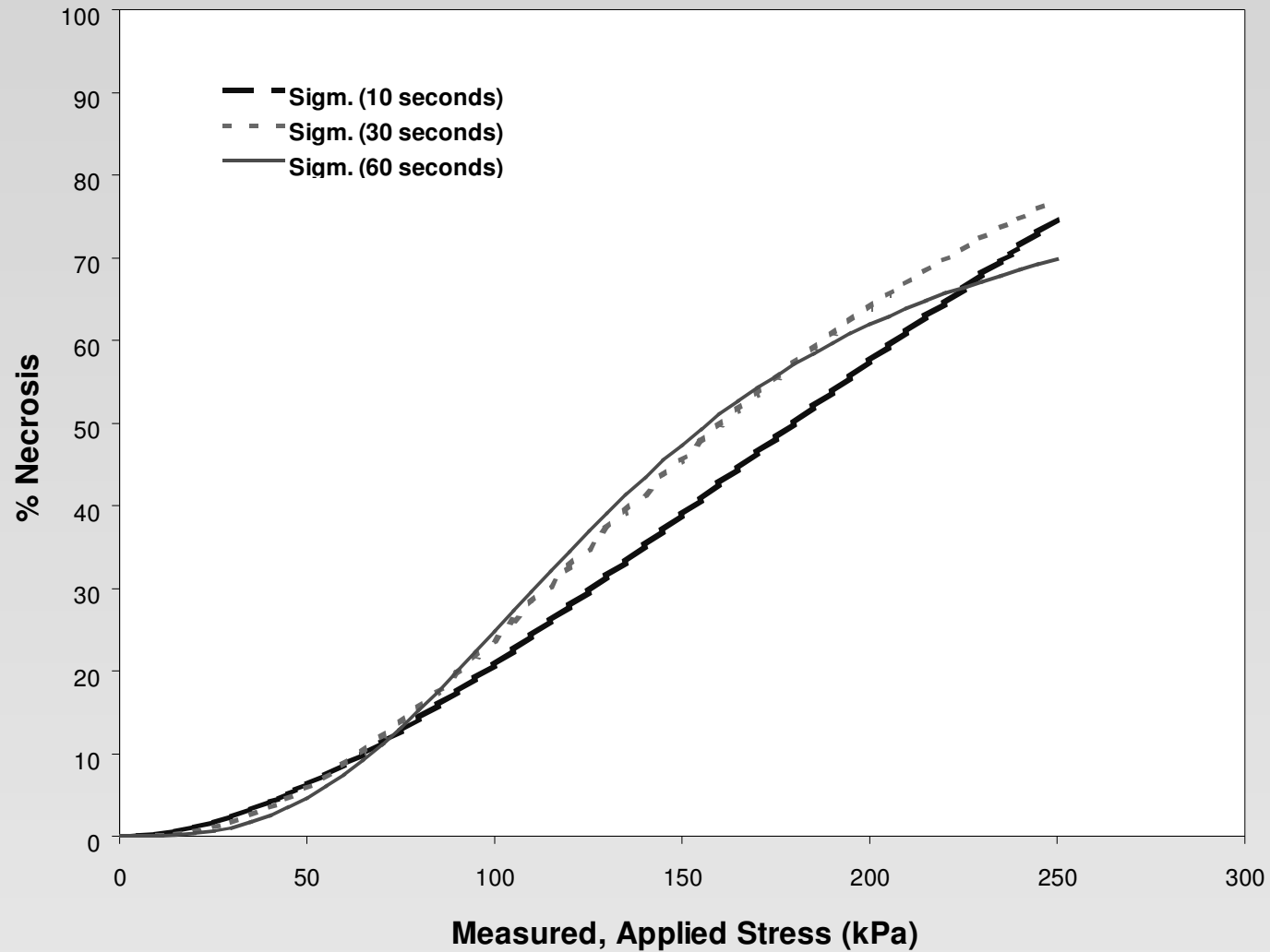 - Loss of hepatic chord structure.

Results

Small Bowel Apoptosis

Small Bowel Apoptosis

Hepatic Necrosis

# Hepatic Necrosis

Conclusions

- Grasper stress within the range seen in MIS causes tissue damage at the cellular level

- Tissue damage increases with the level of stress applied

  – Potential thresholds:

    - Bowel~150-200 kPa
    - Liver~100-150 kPa

- Impact of duration of force on tissue damage not statistically significant

Significance

- Potentially improve surgical instrument design to reduce inadvertent excessive stresses

- Aid in 'Smart Grasper' design that could alert surgeons to high stresses

- Provide feedback to students regarding tissue handling skills in surgical simulators
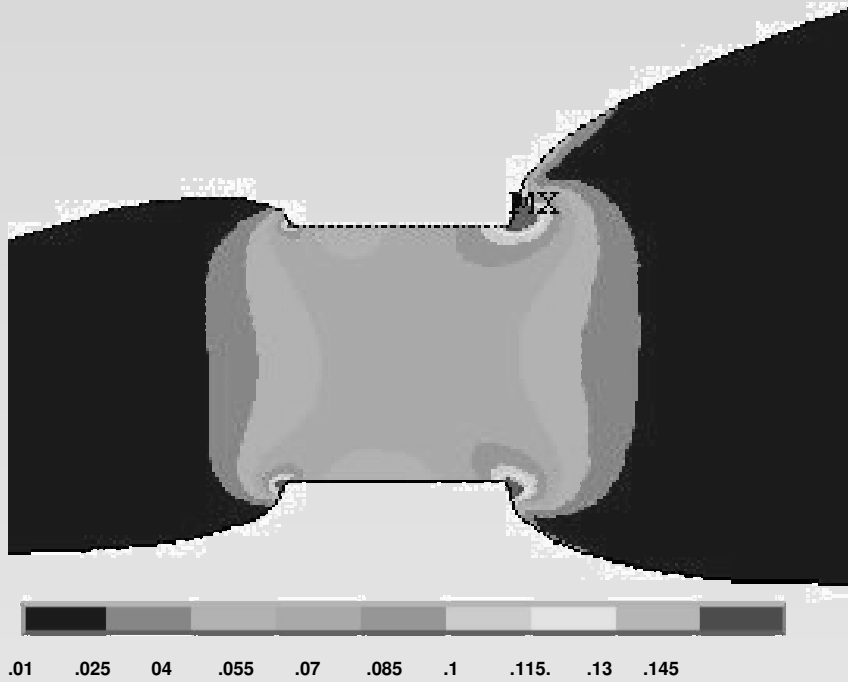
Instrument design

- Identify areas of increased stress
- Computer modeling of instrument-tissue interface
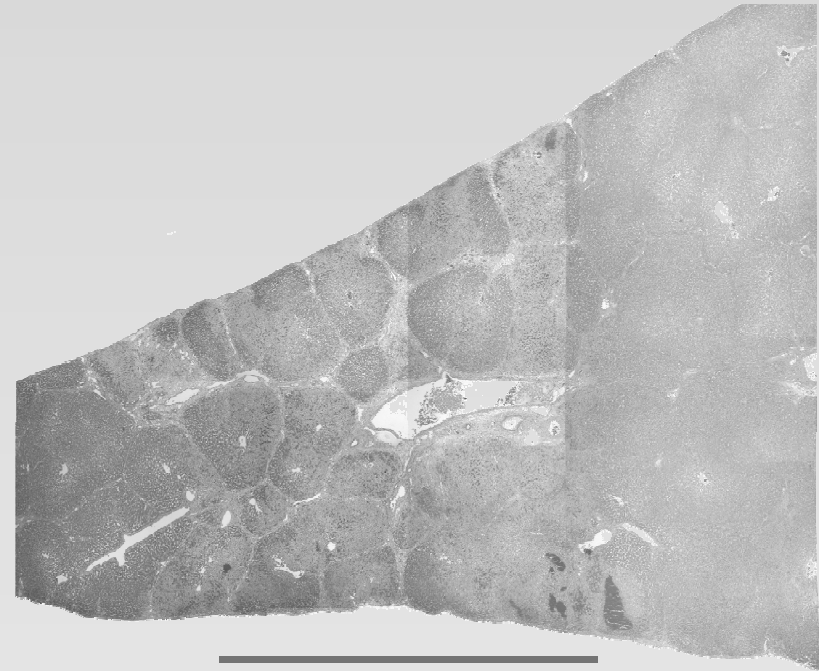- Estimated stress distributions to guide instrument modification

Jaws of Babcock grasper

Tissue
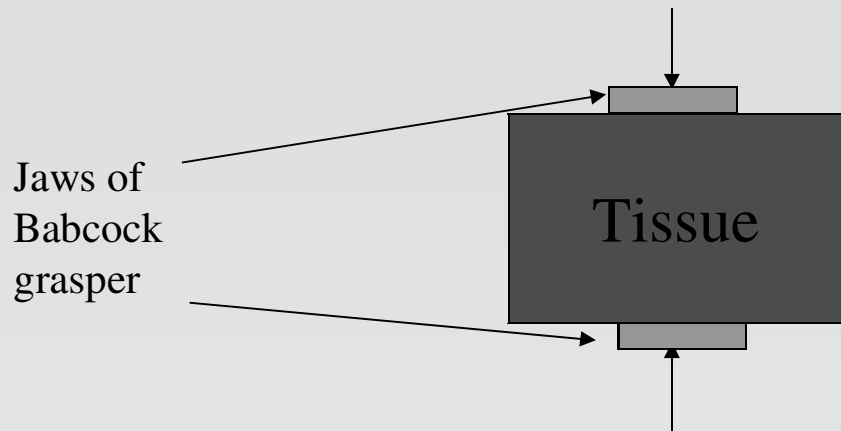
FEM and *in vivo* section

von Mises stress plot

H&E stained liver section from *in vivo* experiments

.01   .025   04   .055   .07   .085   .1   .115.   .13   .145

Scale in MPa

Width of grasper

Acknowledgments

- Collaborators
  - Dr. Paul Swanson
  - Veterinary Services/Center for Videoendoscopic Surgery
  - Prof. George Turkiyyah
- Students
  - Emi Tokuda
  - Roy Chan
  - Phil Roan
  - Gina Donlin
  - Diana Friedman
  - Other members of the Biorobotics Lab
- Funding
  - NIH (67-1450)
  - NSF (66-6531)
  - Army (62-8360)