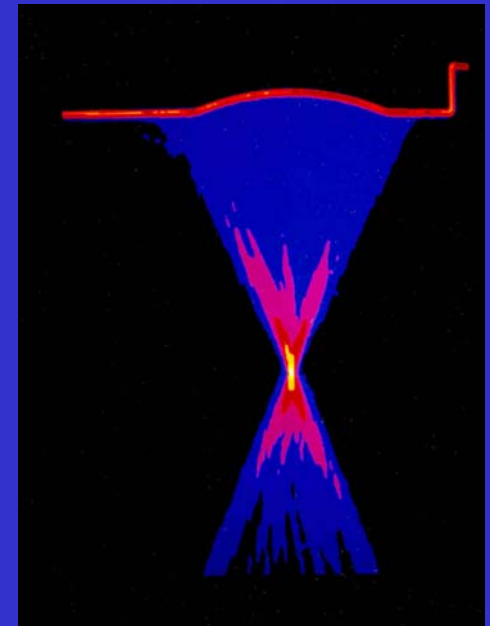
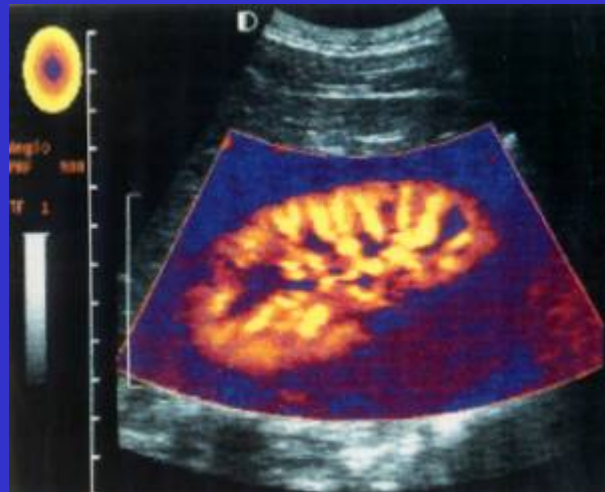
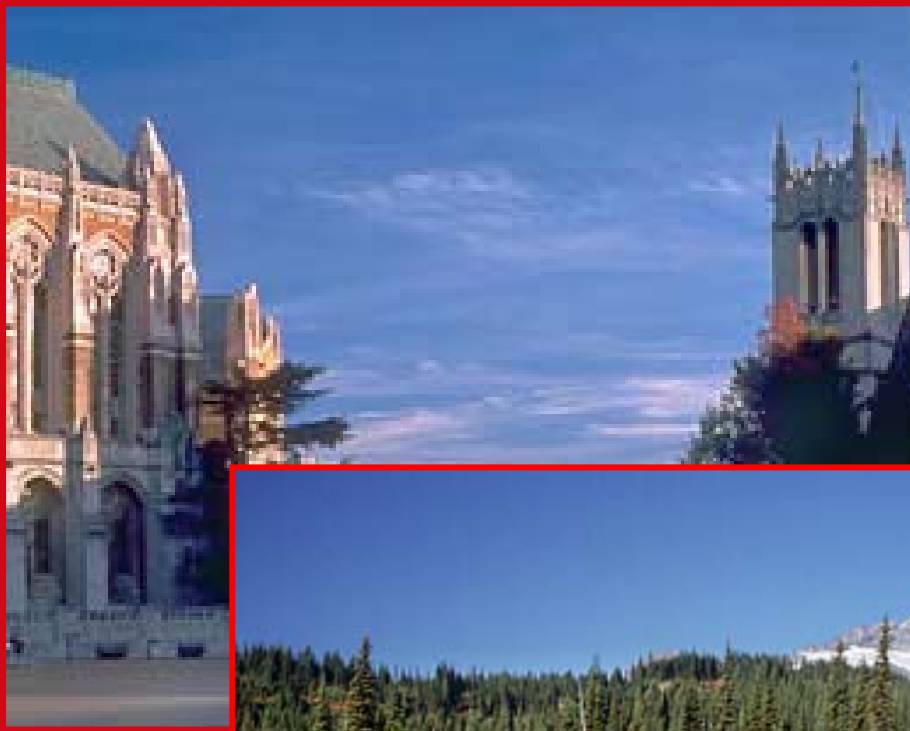


**Center for Industrial and Medical Ultrasound**  
**Applied Physics Laboratory/University of Washington**

**Lawrence A. Crum, et al.**

**Acoustic Hemostasis**





TH

Mt Rainier



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## Second International Symposium on Therapeutic Ultrasound

*Applied Physics Laboratory, University of Washington*  
29 July — 1 August 2002 Seattle, Washington USA



Washington Athletic Club  
6th & Madison, Seattle, WA

**Deadline for receipt of Abstracts is 1 May 2002.**  
**Review the preliminary list of accepted abstracts.**

**Go directly to online submission, or visit the Technical Program page to learn more.**

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**Vesna already  
showed this slide**

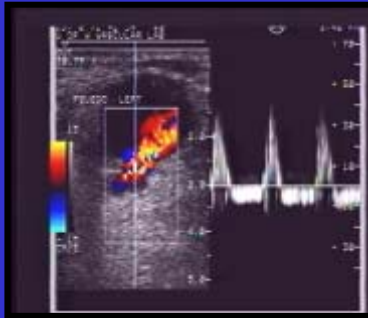


**And this one too....**

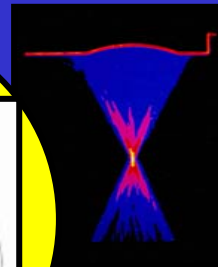
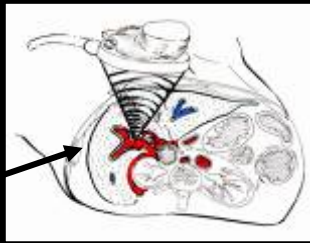
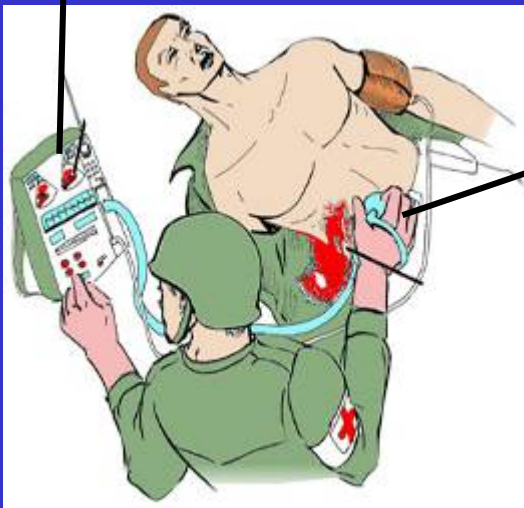




**The KIA problem (posed by Col. Satava at DARPA in 1994): 50% of combat casualty mortality results from exsanguination**



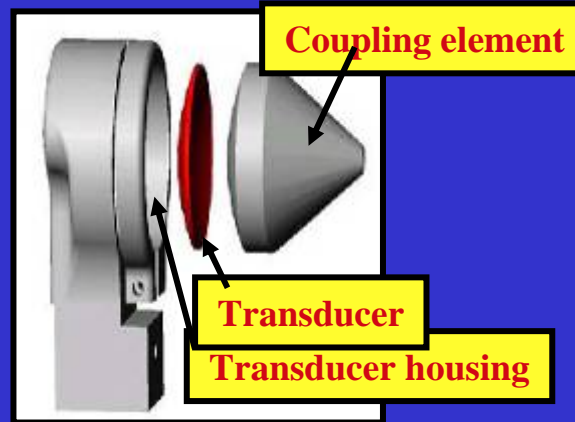
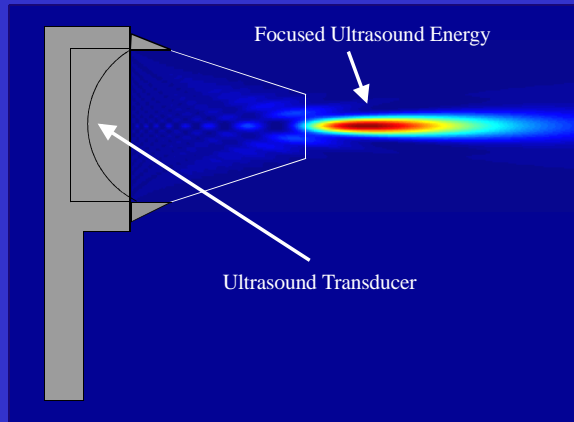
**Ultrasound scanners can detect and locate internal bleeding**



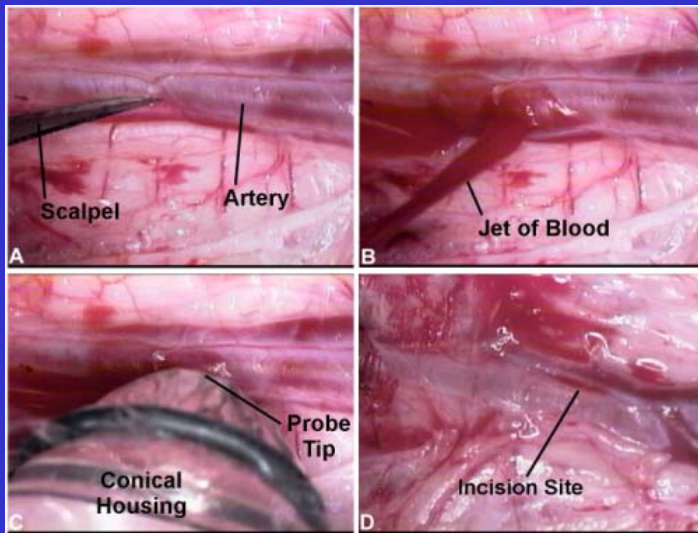
**HIFU can stop bleeding**

**OBJECTIVE: Construct a portable, ultrasound-guided acoustic hemostasis device that could be used near the battlefield to reduce mortality from severe blood loss.**

# The application of hand-held-HIFU to punctured and lacerated vessels can induce hemostasis without occlusion



**Metal cone;  
water cooled**



QuickTime™ and a  
Cinepak decompressor  
are needed to see this picture.

# Cinematographic comparisons between Electrocautery and Acoustocautery

QuickTime™ and a  
Cinepak decompressor  
are needed to see this picture.

QuickTime™ and a  
Cinepak decompressor  
are needed to see this picture.





# Cinephotographic illustrations of acoustocautery

QuickTime™ and a  
DV/DVCPRO - NTSC decompressor  
are needed to see this picture.

QuickTime™ and a  
Cinepak decompressor  
are needed to see this picture.

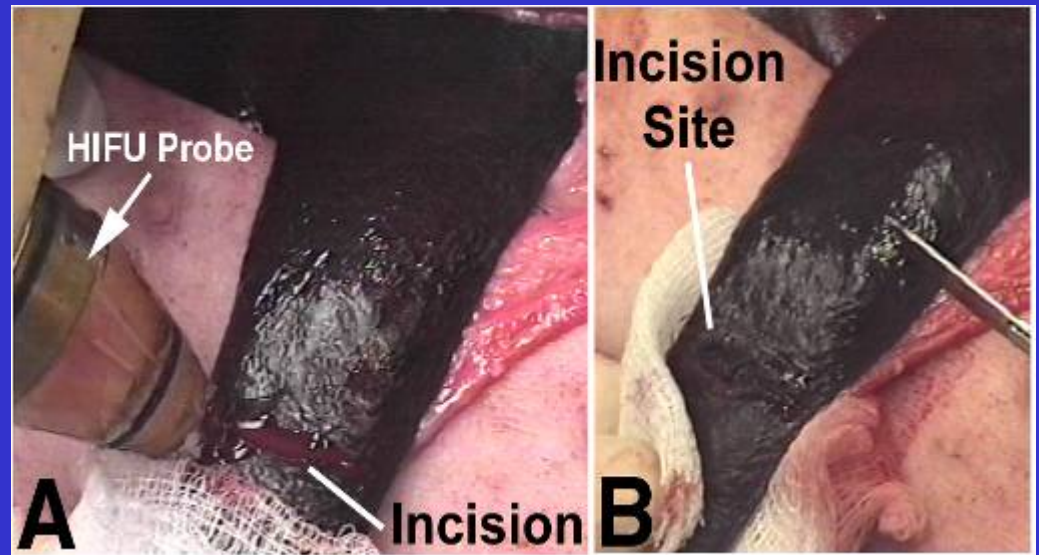
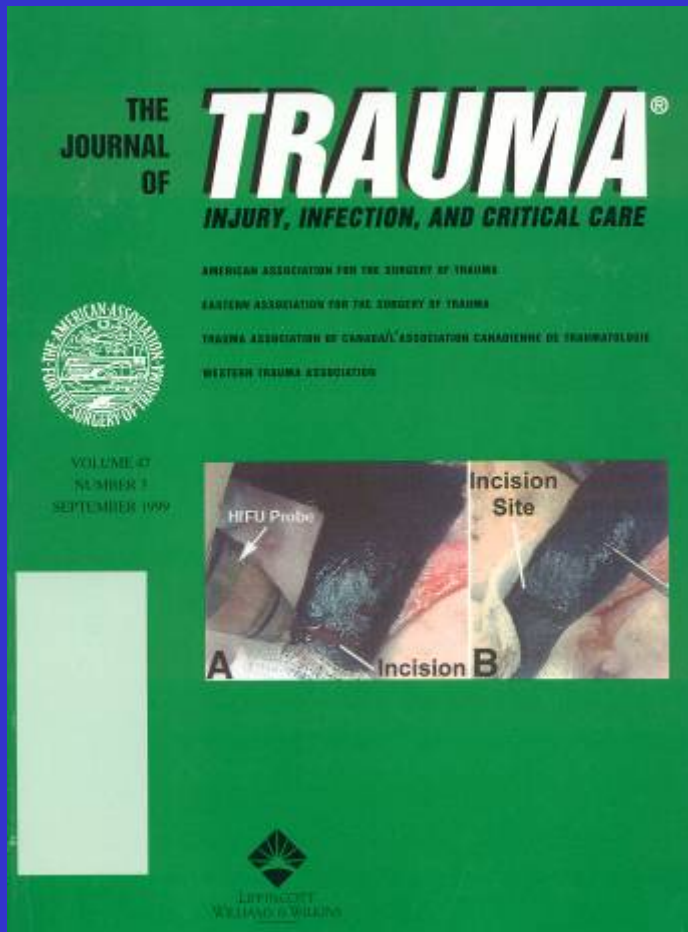
**Lung**

**Spleen**

QuickTime™ and a  
Video decompressor  
are needed to see this picture.

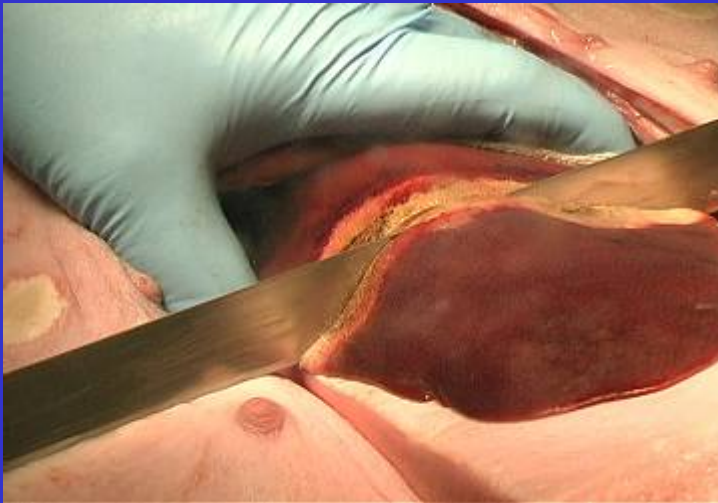
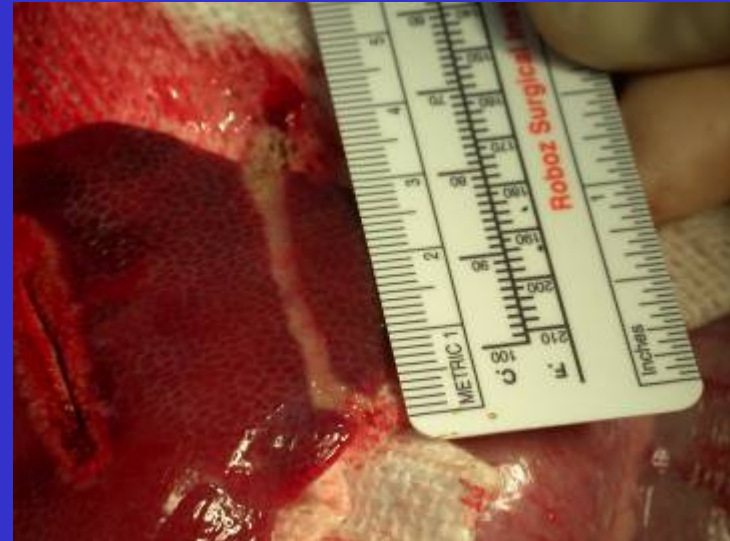


Acoustic Hemostasis is a **unique technology** that has been shown to be an effective means of hemorrhage control



# HIFU can be used for tissue ablation and bloodless resection

QuickTime™ and a  
Cinepak decompressor  
are needed to see this picture.



## UST: The SonoStat 400

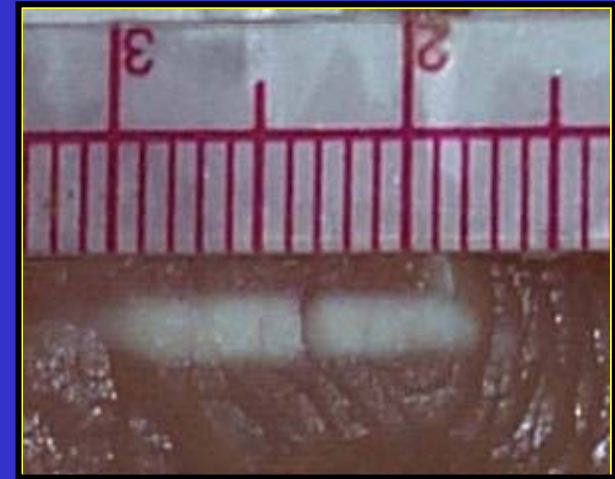


# Modeling: Acoustic field and lesion generation

QuickTime™ and a  
decompressor  
are needed to see this picture.

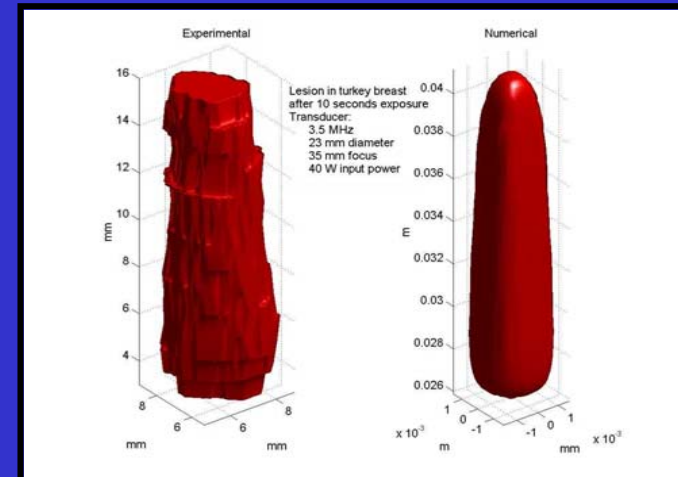
QuickTime™ and a  
Cinepak decompressor  
are needed to see this picture.

## Acoustic field generation



## Lesion in turkey tissue

## Computed lesions

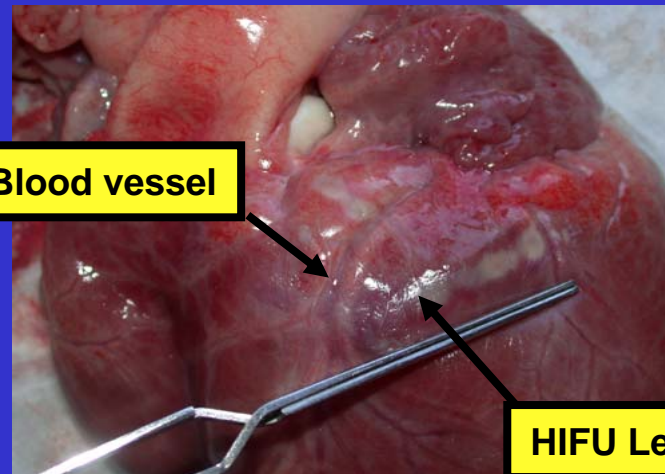




**HIFU generates high temperatures only on  
surface of blood vessels and not in interior**

QuickTime™ and a  
Cinepak decompressor  
are needed to see this picture.

QuickTime™ and a  
H.263 decompressor  
are needed to see this picture.



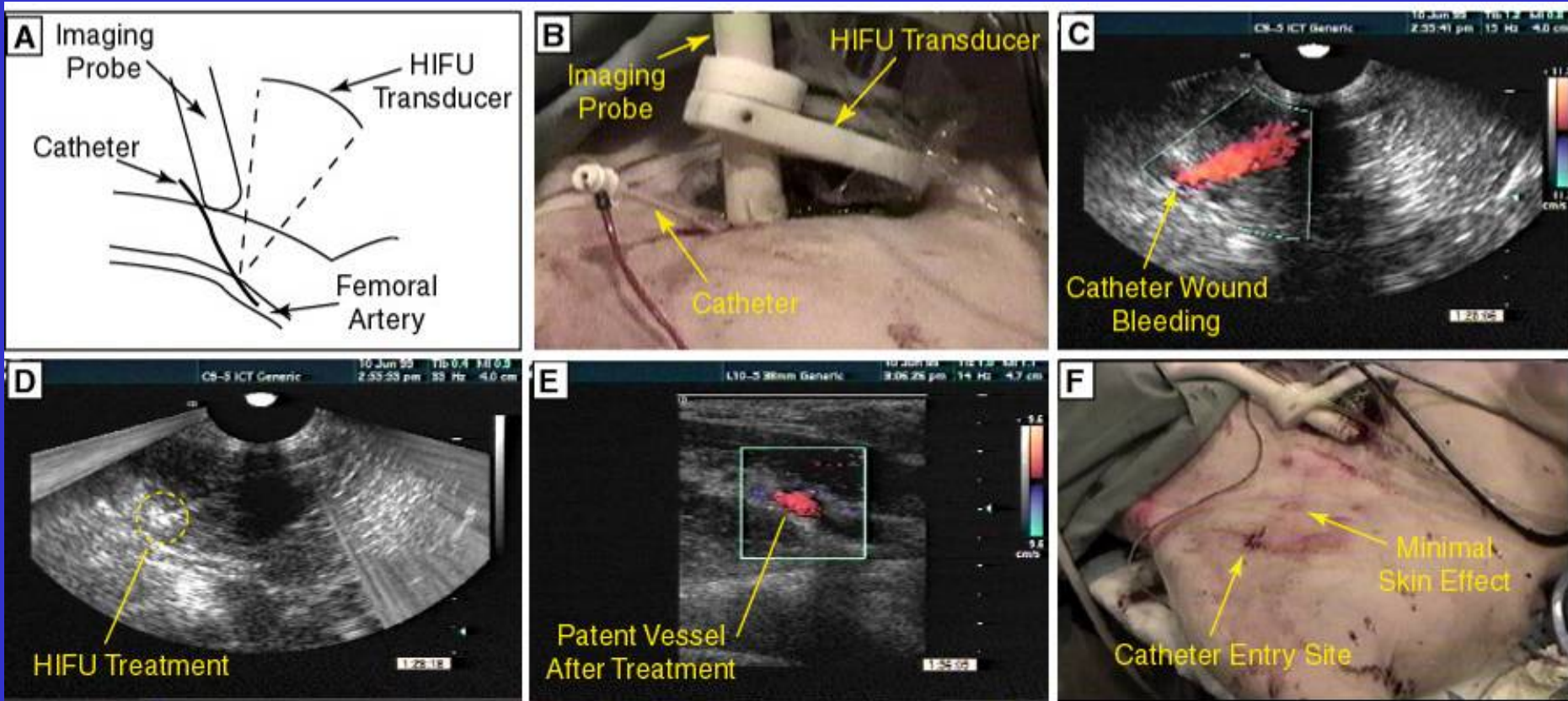
**Blood vessel**

**HIFU Lesion**





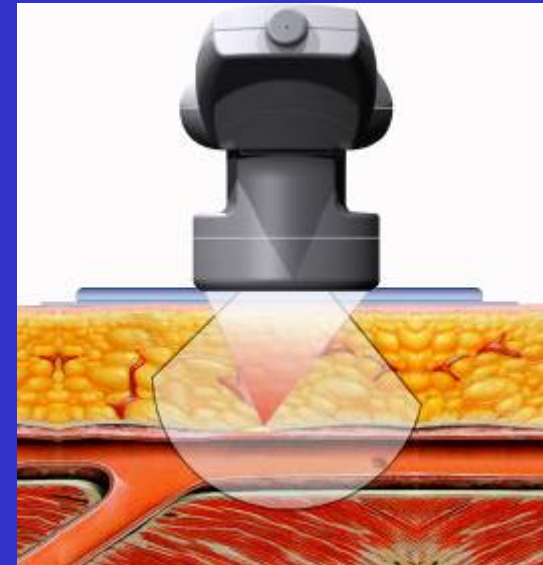
# Demonstration of Image-guided Transcutaneous Acoustic Hemostasis



## Successful technology spin-off: THERUS, INC.



QuickTime™ and a  
Cinepak decompressor  
are needed to see this picture.



1. Successful human trials in Germany (approximately 60 patients)
2. Clinical trials underway with patients in US
3. Boston Scientific has \$150 million option to purchase THERUS

# THERUS CORPORATION

## SoundSeal™ Noninvasive Hemostasis System

*Disposable Patient Interface (DPI)*



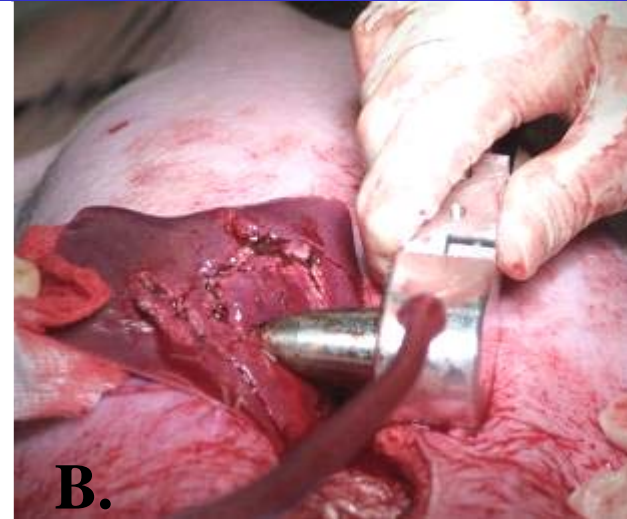
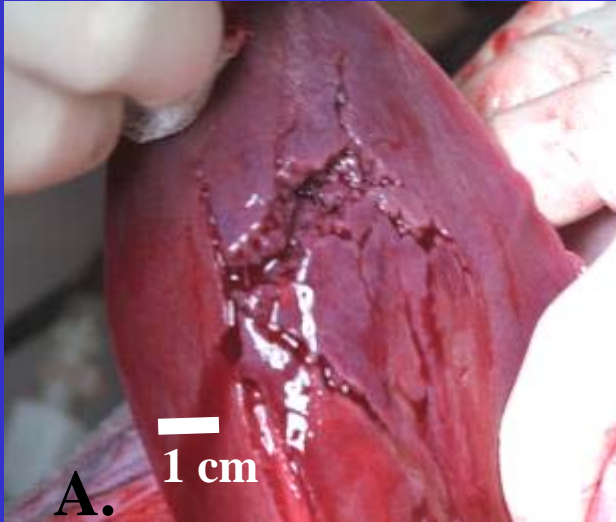
*Applicator*

*Mobile Generator*



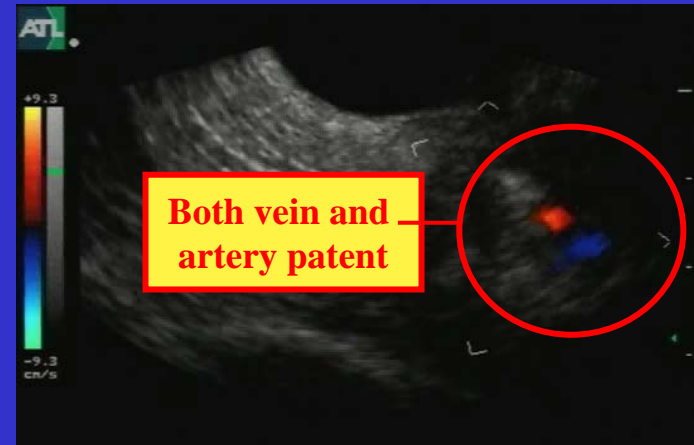


## Grades II and III liver injuries

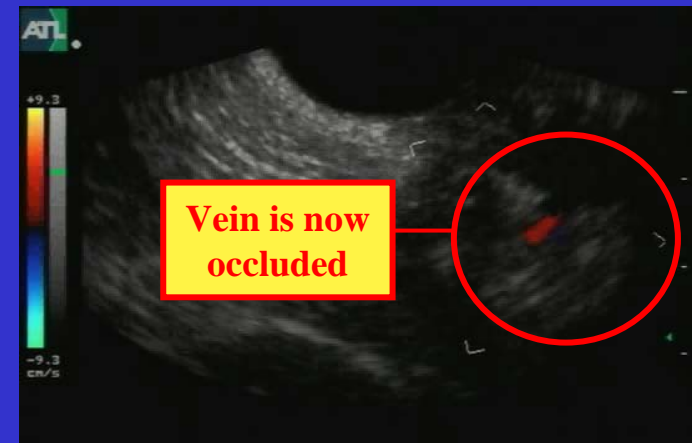


# Demonstration of image-guided transcutaneous venous occlusion

QuickTime™ and a  
Microsoft Video 1 decompressor  
are needed to see this picture.

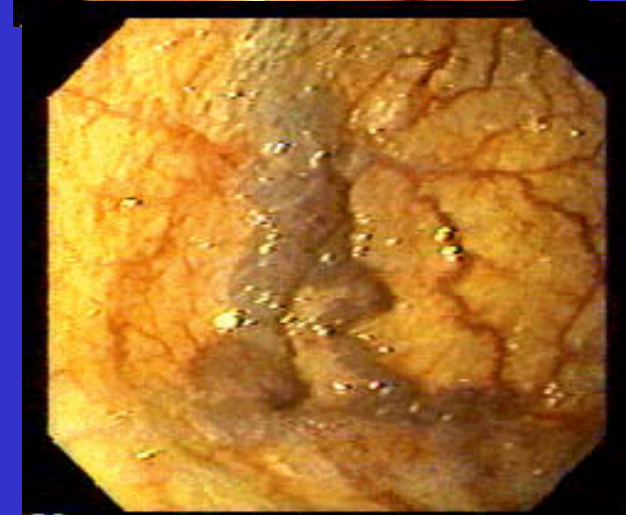


QuickTime™ and a  
Cinepak decompressor  
are needed to see this picture.



# Esophageal and Gastric Varices

- Dilated veins on the mucosal surface of the esophagus and stomach
- Bleeding from varices is a major cause of morbidity and mortality in patients with cirrhosis
- Varices develop due to portal hypertension





# Current Methods of Endoscopic Therapy for Varices

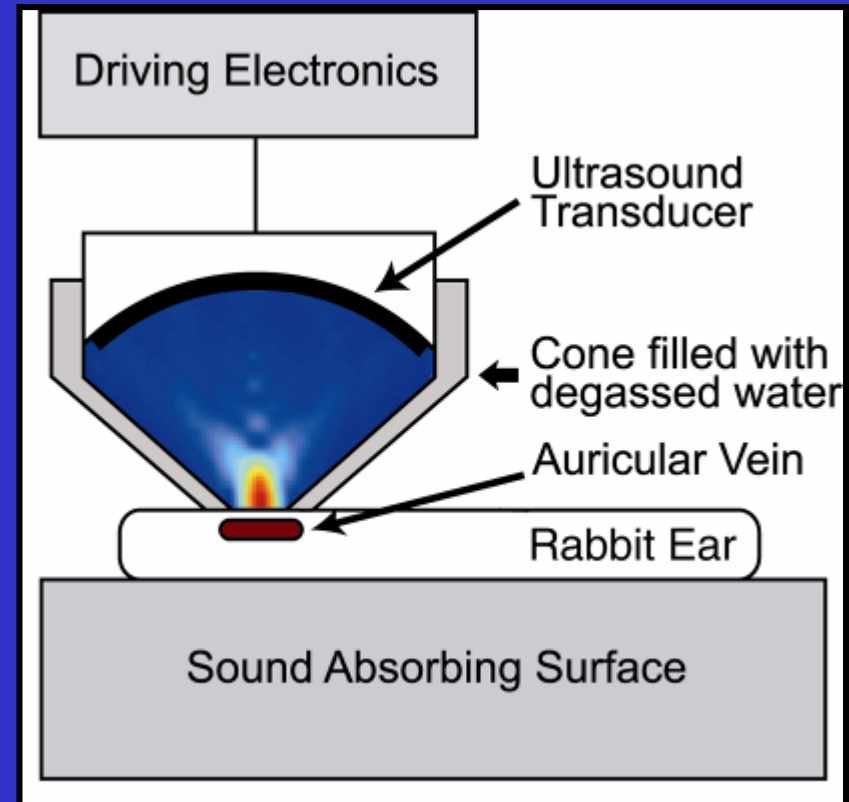
- **Band ligation**

- Highly effective in arresting active bleeding esophageal varices
- Minimal complications
  - Mucosal ulceration
  - Pain
  - Risk of re-bleeding
- Limitations:
  - High rate of recurrence (50%)
  - Requires multiple sessions

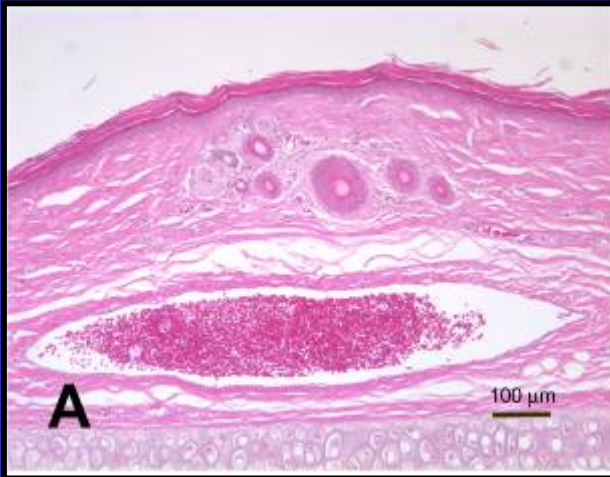


# Treatment/Evaluation

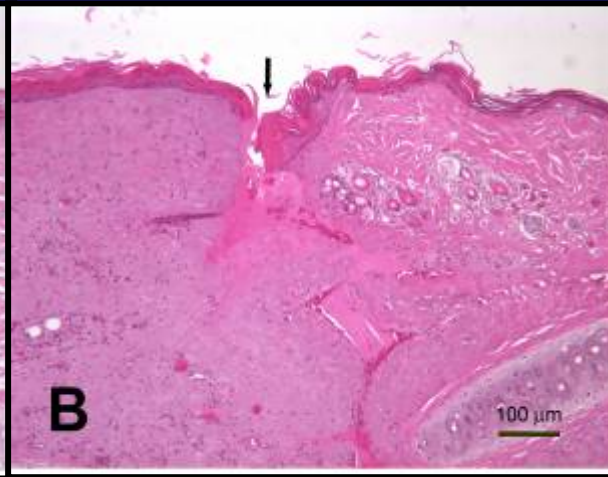
- 18 vessels lacerated
- Treated in 5 second intervals until bleeding stopped
- 3 vessels were given a sham treatment (ultrasound off)
- 3 animals in the treatment group were sacrificed at each time point (0, 2, 7, 14, 28 days)



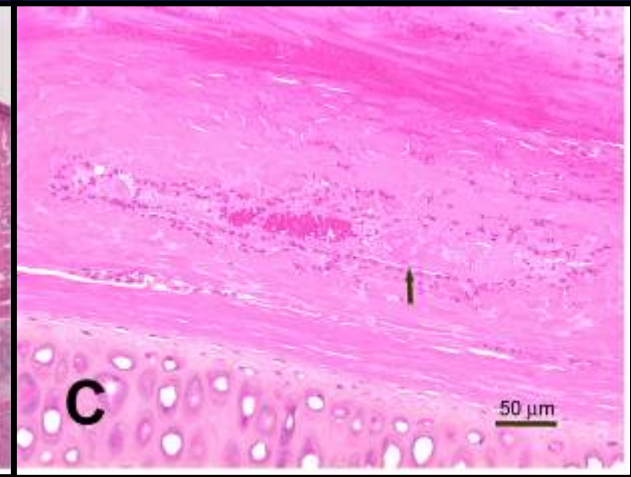
# Histology



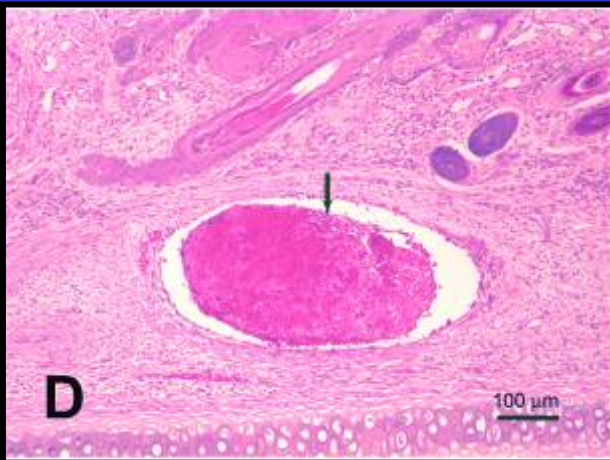
Normal



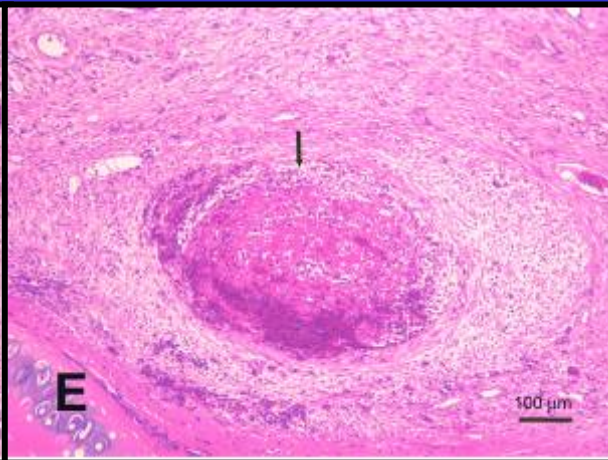
Day 0



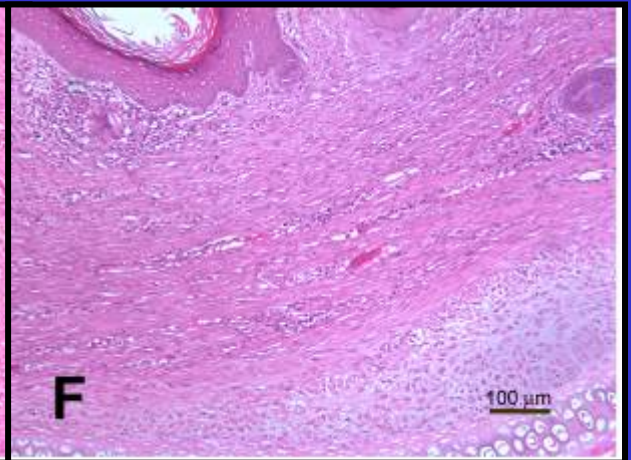
Day 2



Day 7



Day 14



Day 28

## Adverse Effects

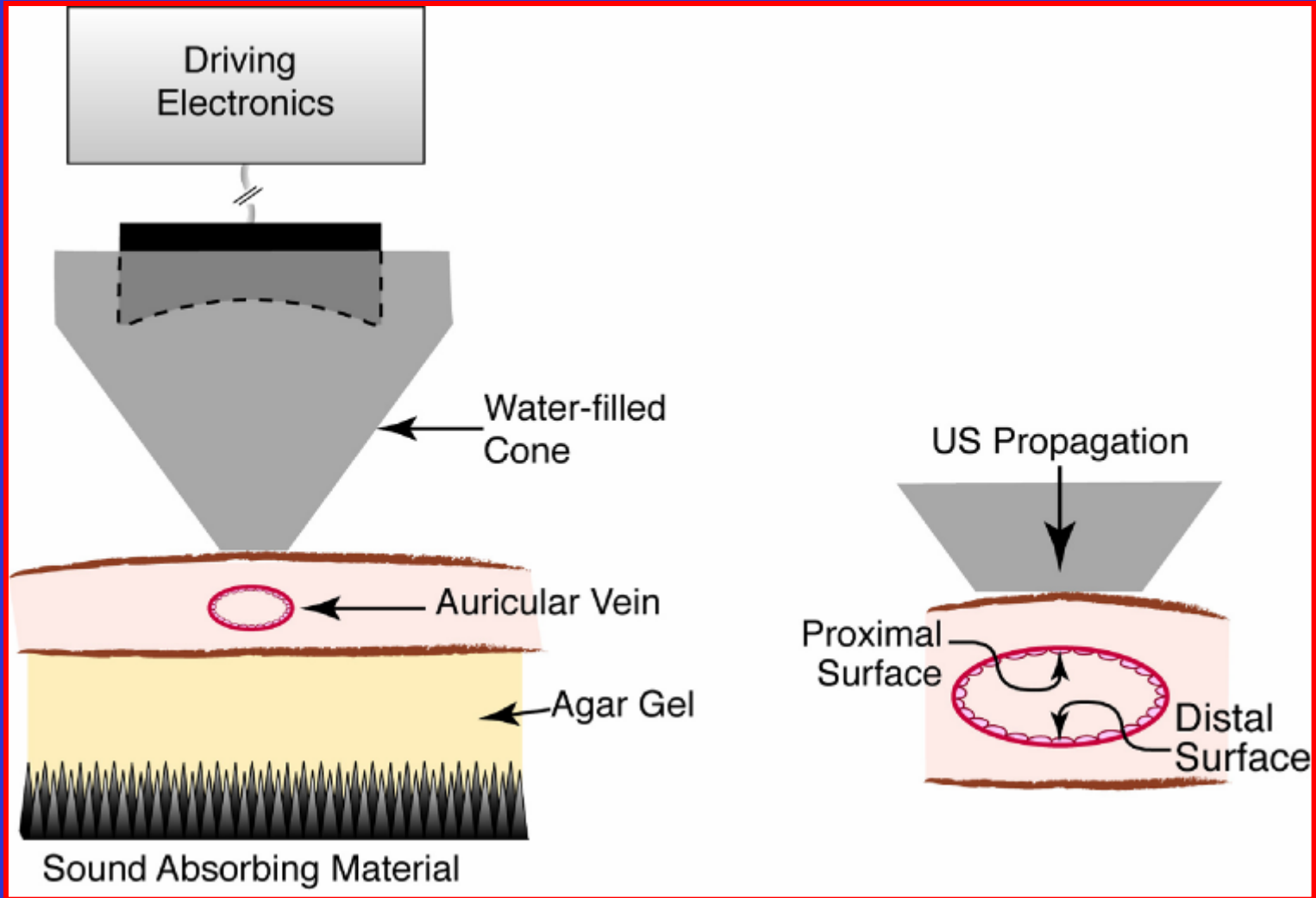


7 days after treatment



28 days after treatment

## Experimental Setup





## Conditions for Cavitation-Occlusion

| Variable                         | Range            |
|----------------------------------|------------------|
| Frequency                        | 1.17 MHz         |
| Peak negative pressure           | 1, 3, 6.5, 9 MPa |
| Pulse length                     | 500 cycles       |
| Pulse repetition frequency (PRF) | 1 Hz             |
| Duty factor                      | 0.042%           |
| Exposure duration                | 120 seconds      |

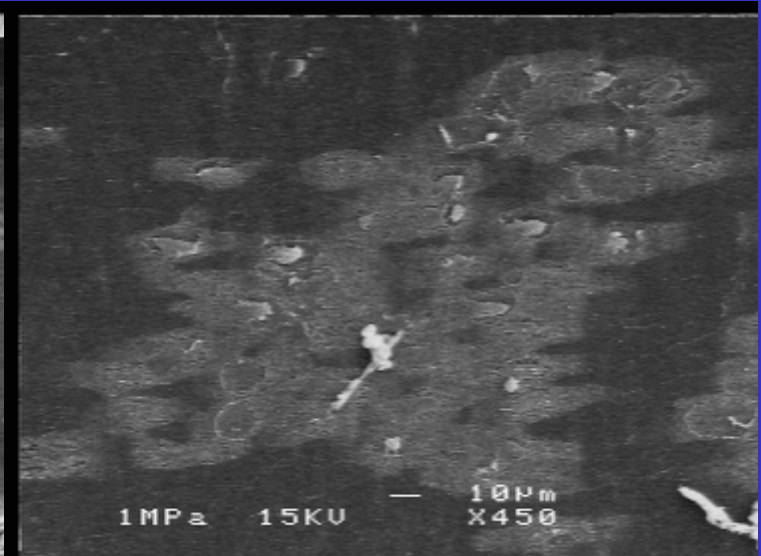
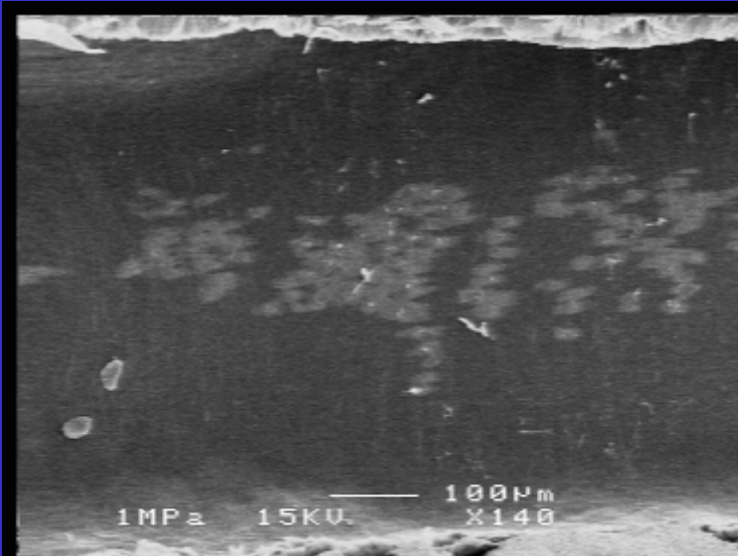


1 MPa, 120 s

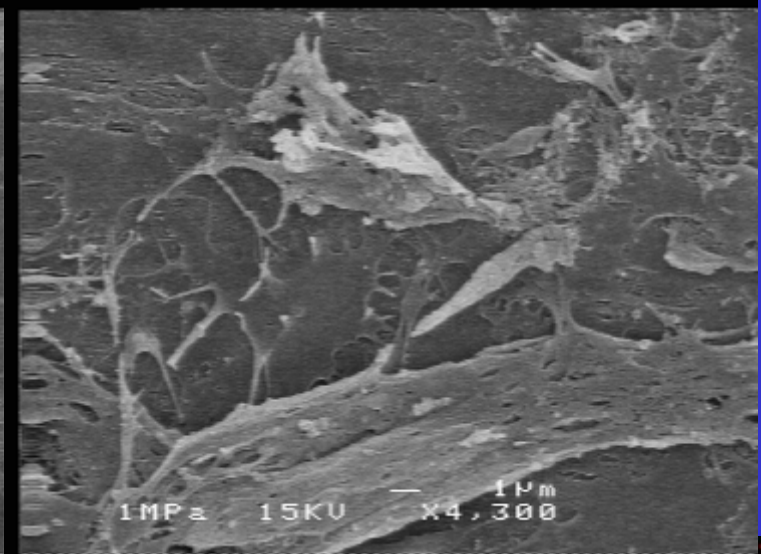
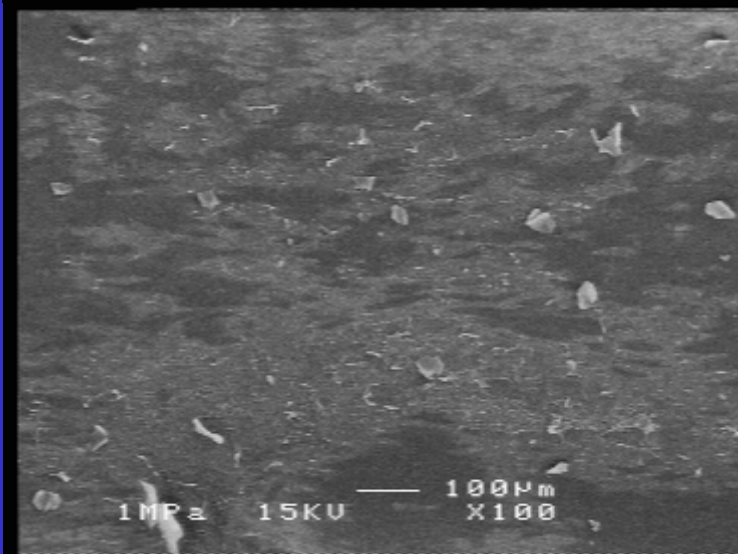
Low Mag

High Mag

-UCA



+UCA

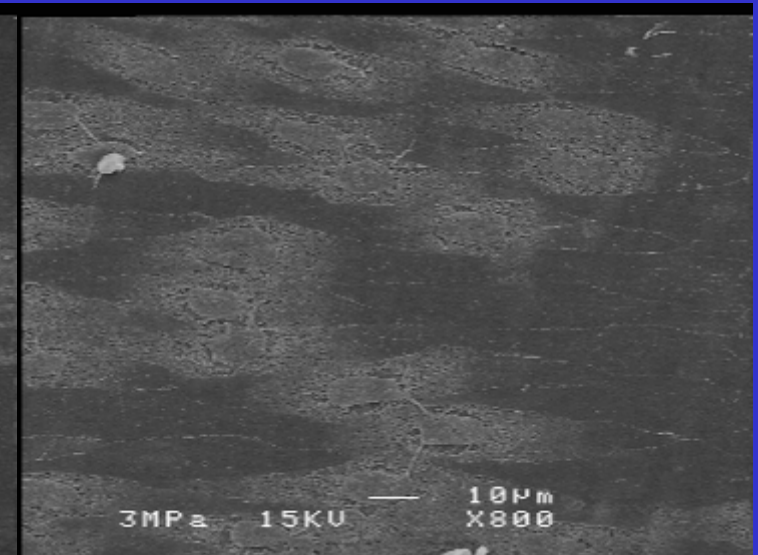
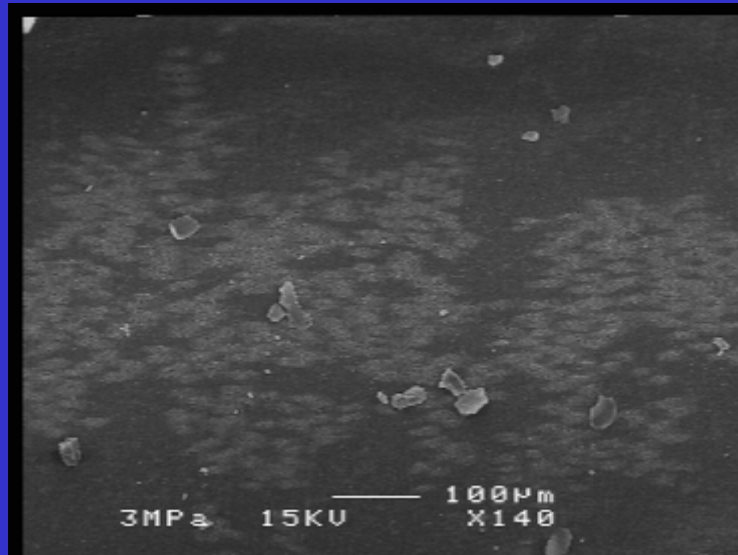


3 MPa, 120 s

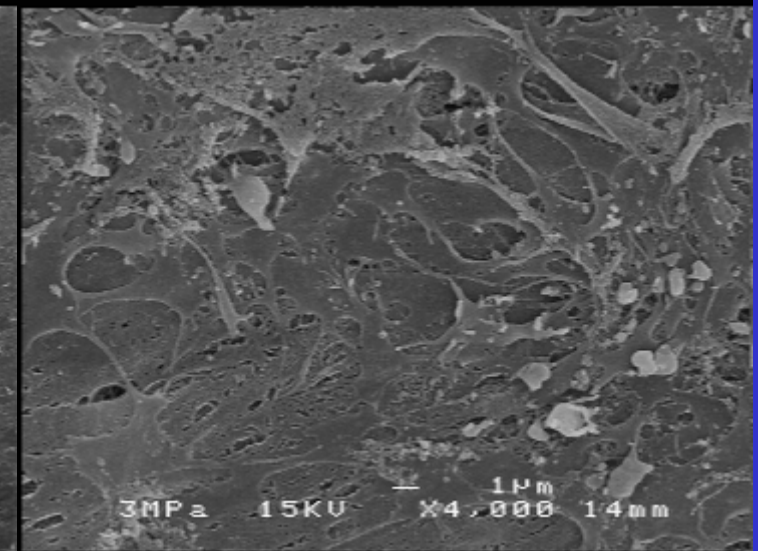
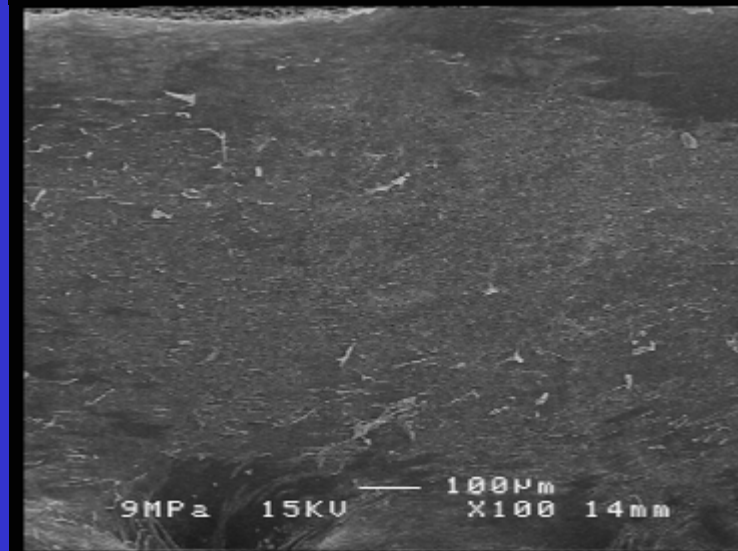
Low Mag

High Mag

-UCA



+UCA

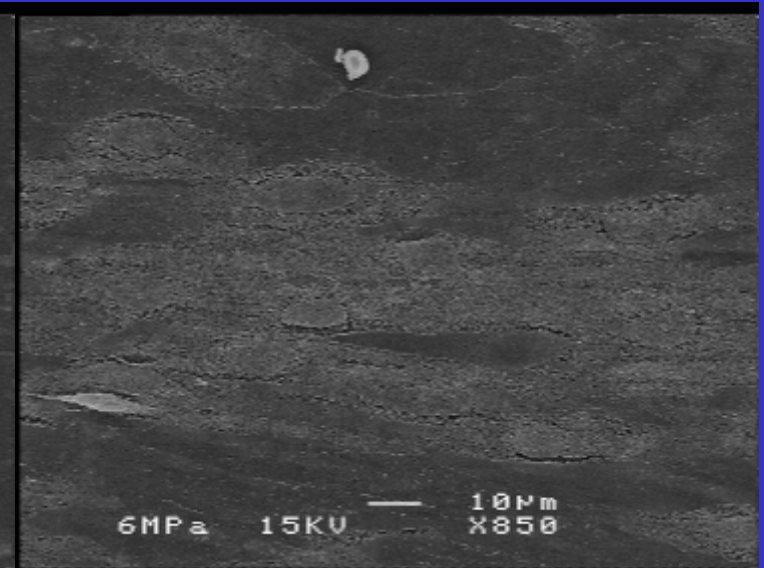


# 6.5 MPa, 120 s

## Low Mag

## High Mag

### -UCA



### +UCA



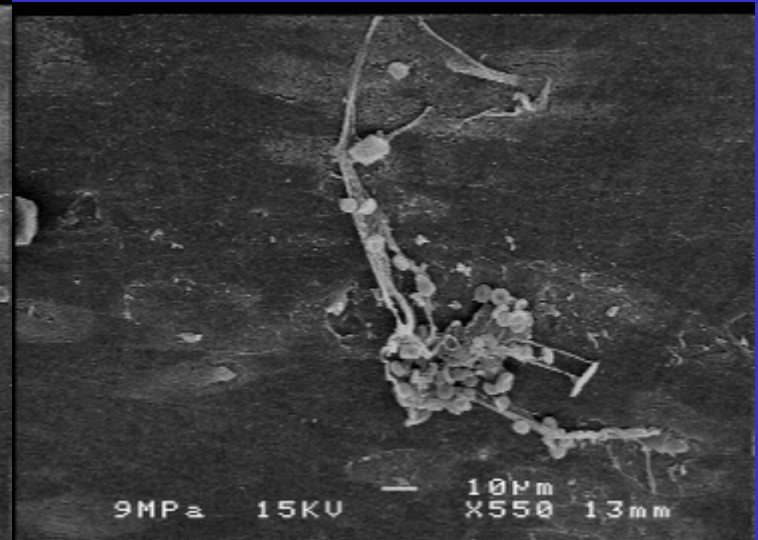


9 MPa, 120 s

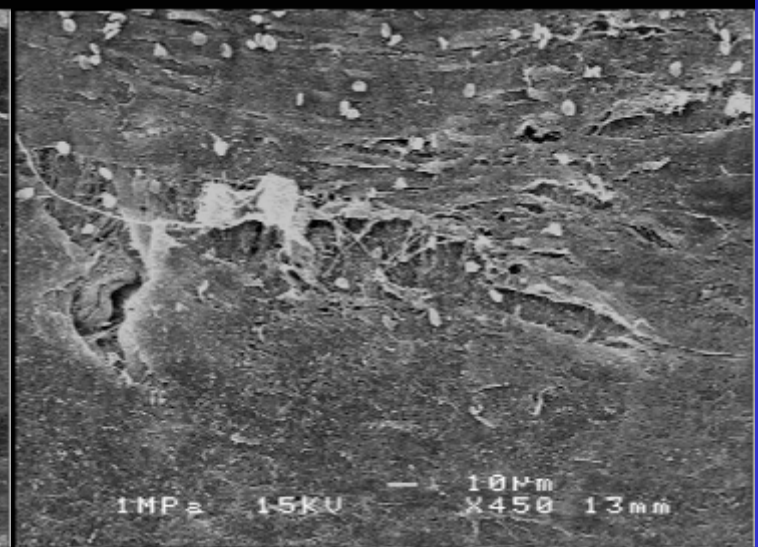
Low Mag

High Mag

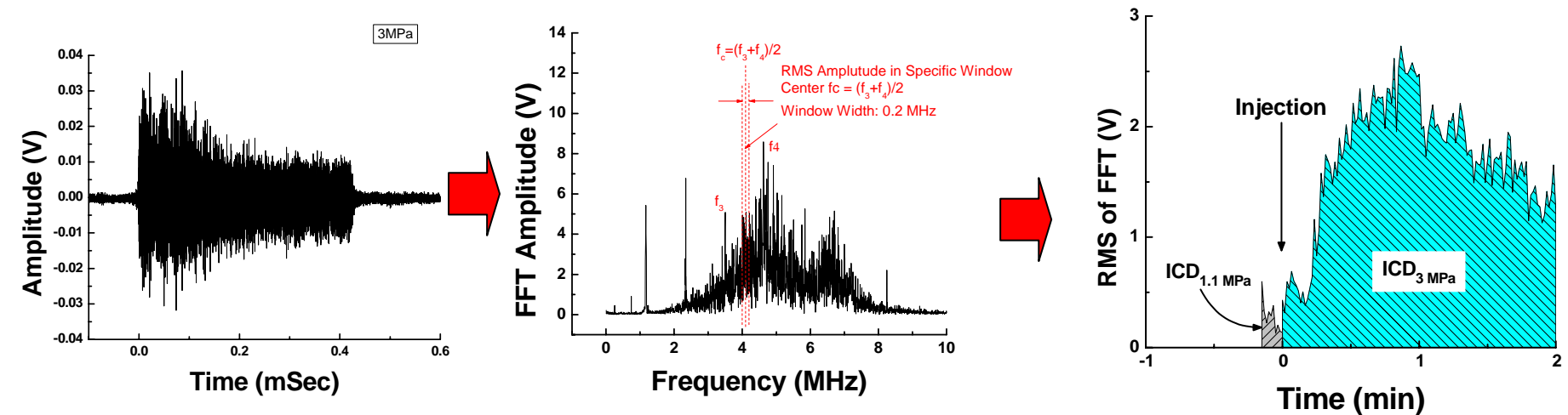
-UCA



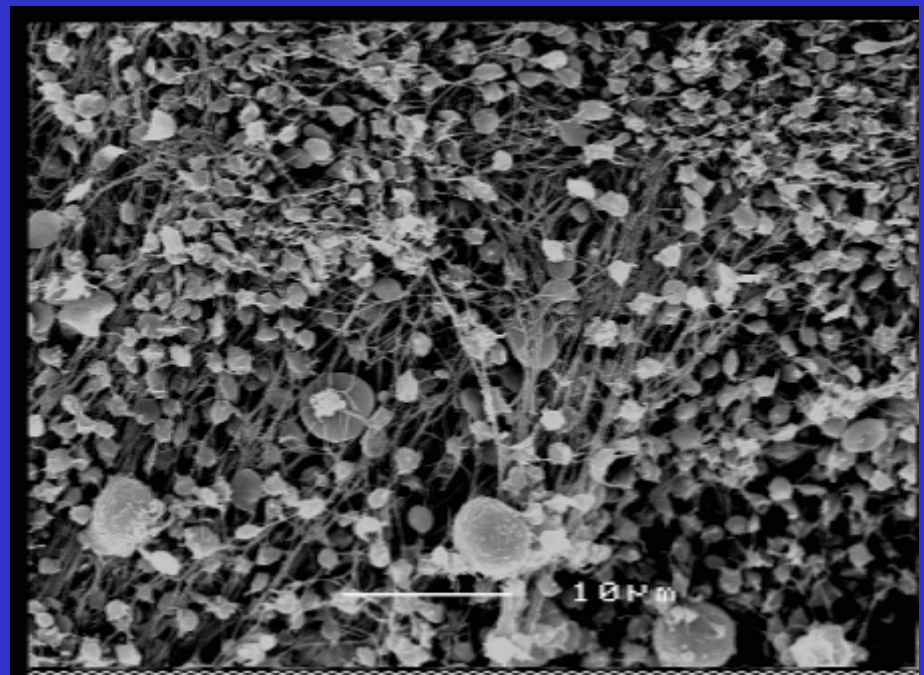
+UCA



# IC Dose Measurements/PCD



# SEM Intravascular Thrombus



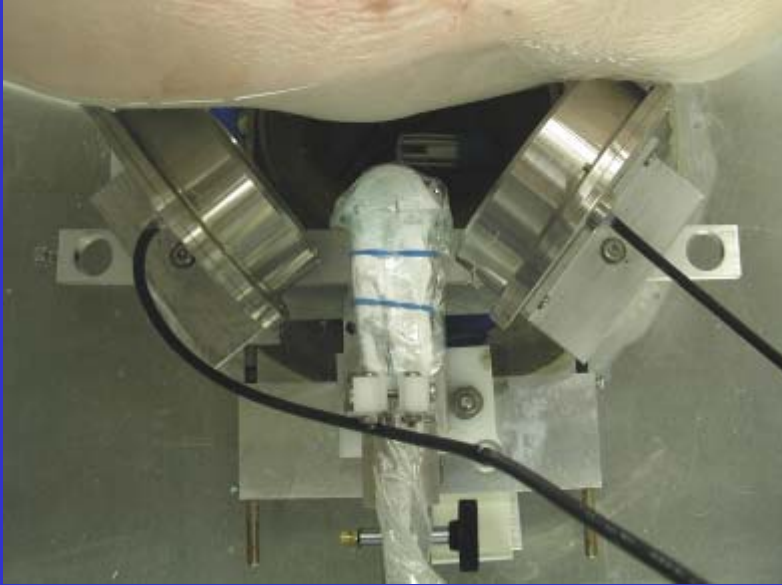


# Video of Cavitation Occlusion Results

QuickTime™ and a  
DV/DVCPRO - NTSC decompressor  
are needed to see this picture.

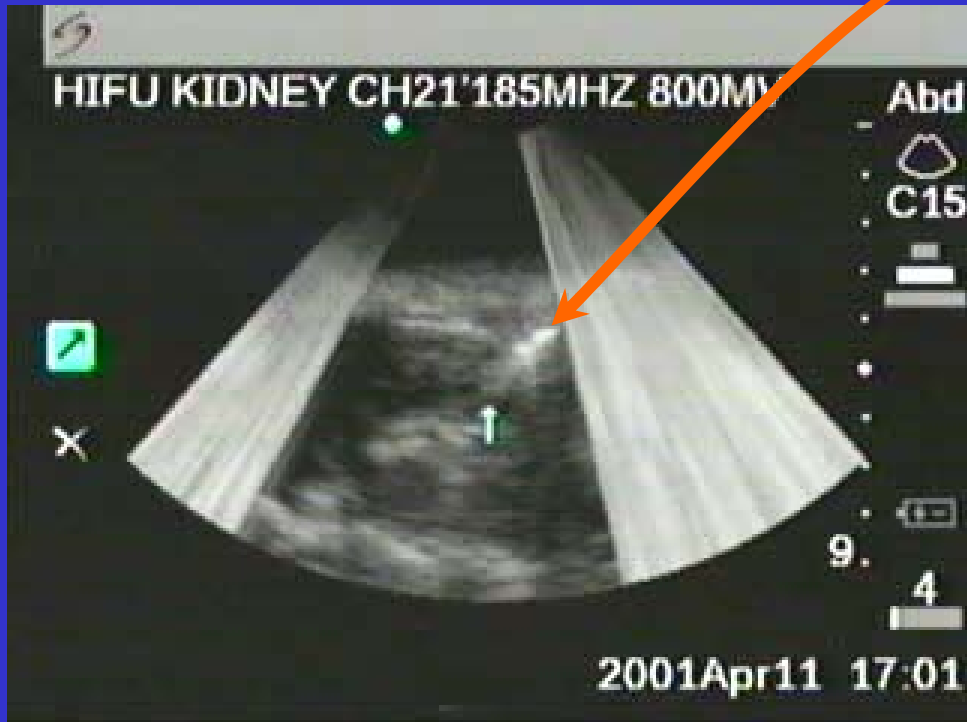


## Demonstration of image-guided transcutaneous HIFU surgery



QuickTime™ and a  
decompressor  
are needed to see this picture.

**LONG EXPOSURE HIFU: HYPERECHOIC SPOT  
CORRESPONDS TO A LESION**



# HIFU Lesion Development with and without overpressure

QuickTime™ and a  
Cinepak decompressor  
are needed to see this picture.

QuickTime™ and a  
Cinepak decompressor  
are needed to see this picture.

**Ambient pressure only**

**Approximately 10 MPa overpressure**

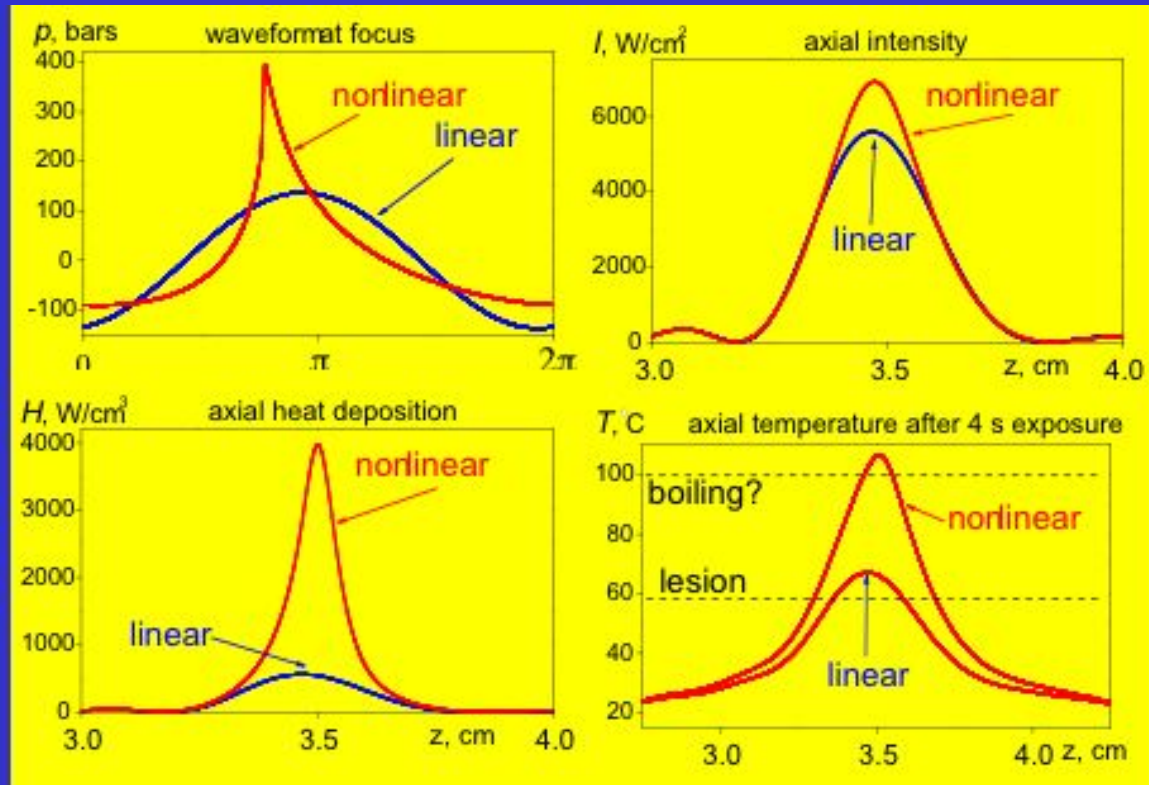
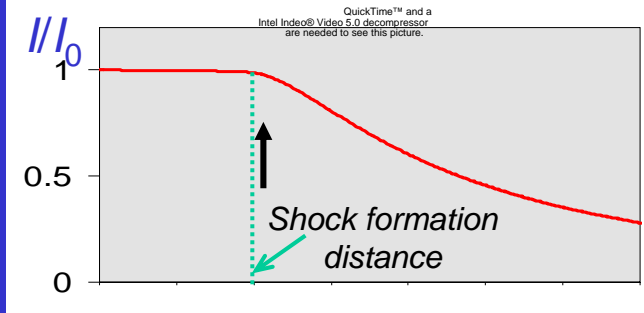


# Numerical modeling

## Waveform distortion

QuickTime™ and a  
Cinepak decompressor  
are needed to see this picture.

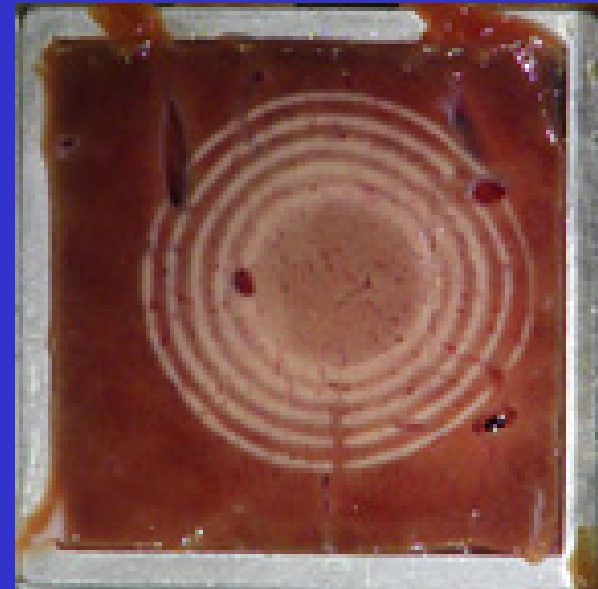
## Nonlinear enhanced absorption



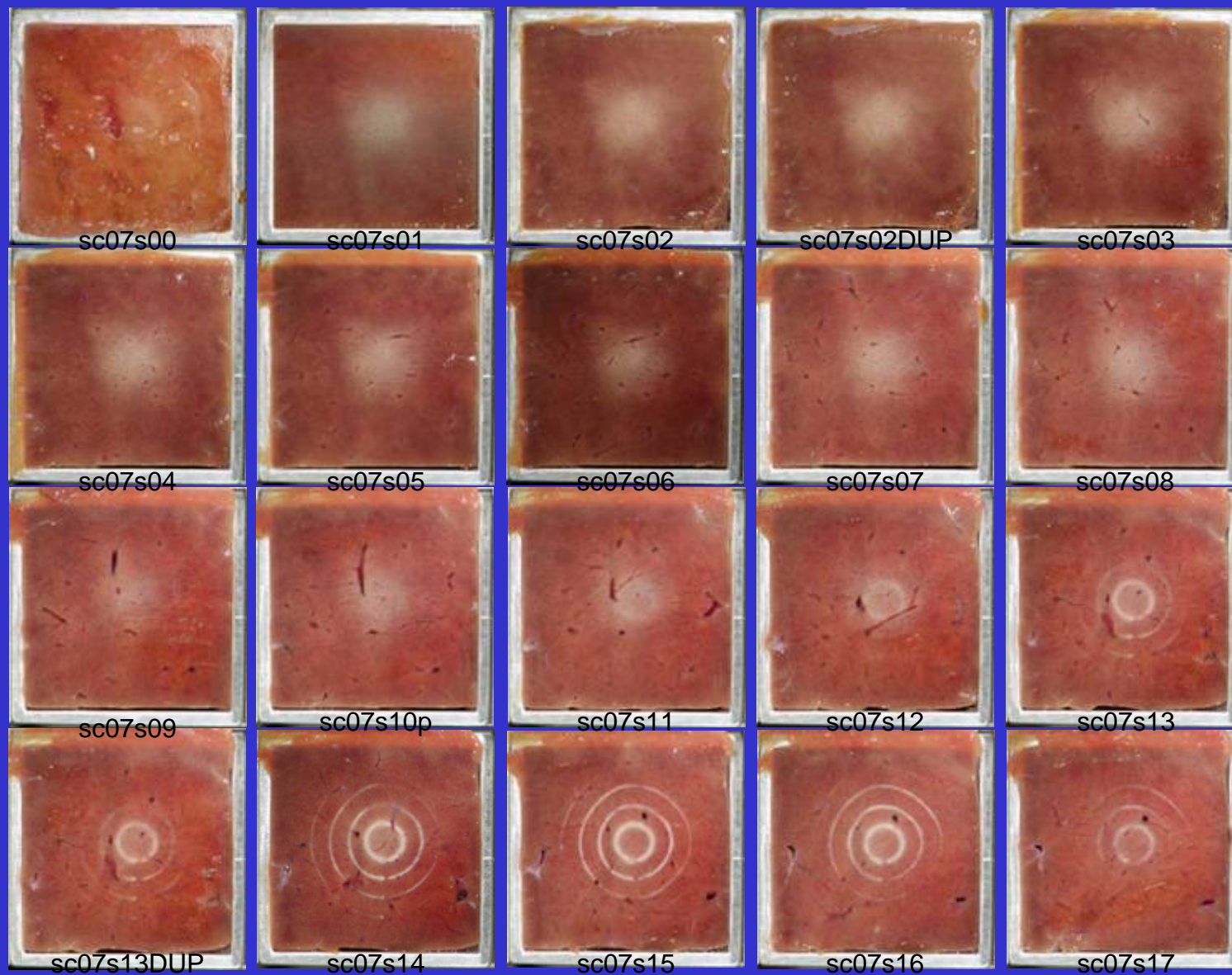


# Circular scans in liver (Simulation and *ex vivo* measurements )

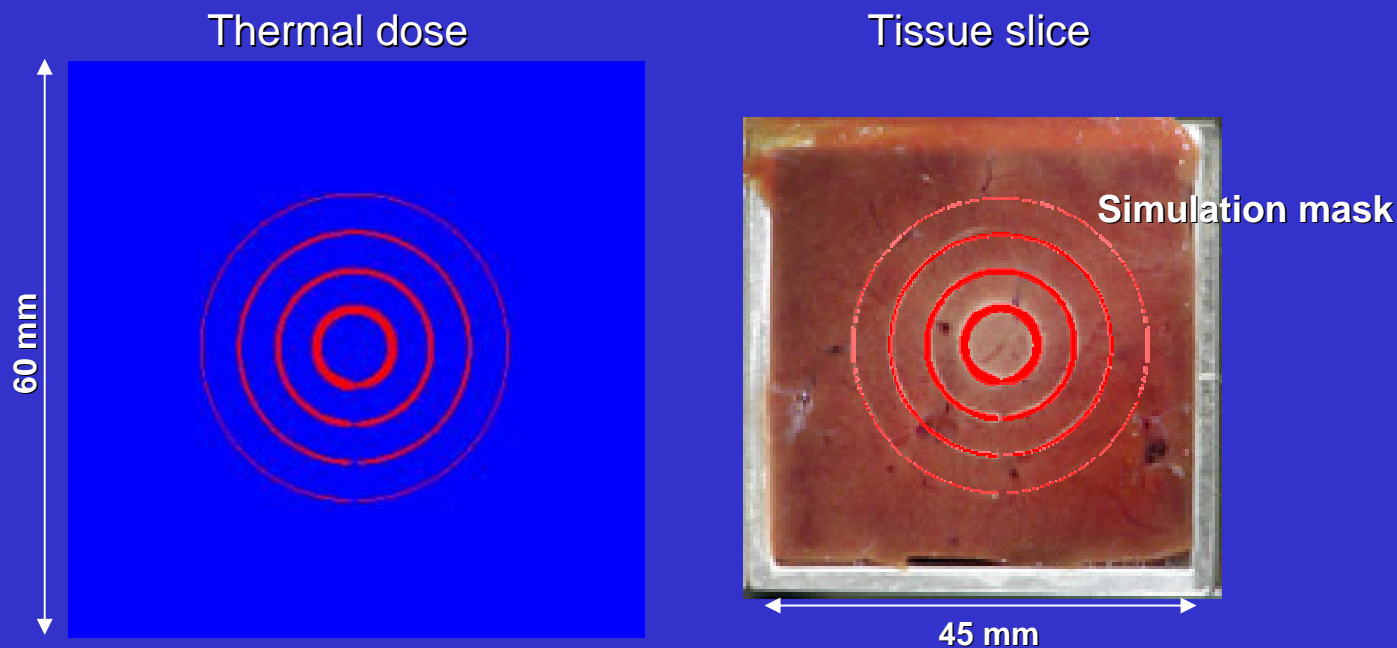
QuickTime™ and a  
YUV420 codec decompressor  
are needed to see this picture.



## Circular scans in liver (*ex vivo* measurements)

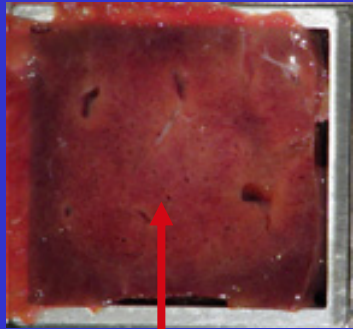


# Circular scans in liver (Simulation and *ex vivo* validation )

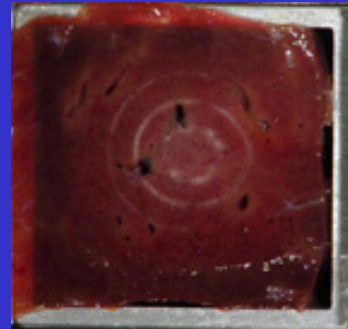
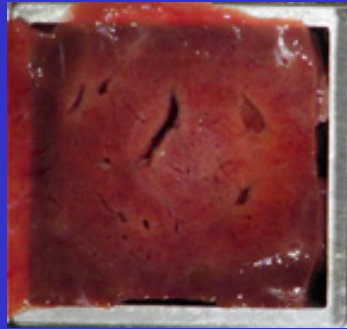
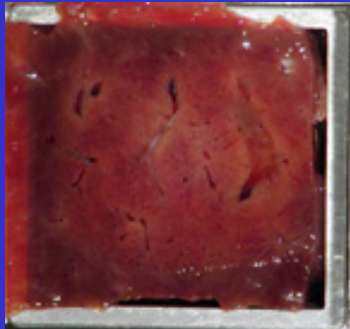


| Track | Lesion Width (mm) |                 |
|-------|-------------------|-----------------|
|       | Simulation        | Experiment      |
| 1     | 0.20              | $0.37 \pm 0.09$ |
| 2     | 0.40              | $0.48 \pm 0.11$ |
| 3     | 0.60              | $0.64 \pm 0.14$ |
| 4     | 1.00              | $1.22 \pm 0.19$ |

# Circular scans in liver (Simulation and *ex vivo* validation )



No pre-focal lesion



Well-defined circular lesions at focus

QuickTime™ and a  
Cinepak decompressor  
are needed to see this picture.

QuickTime™ and a  
decompressor  
are needed to see this picture.

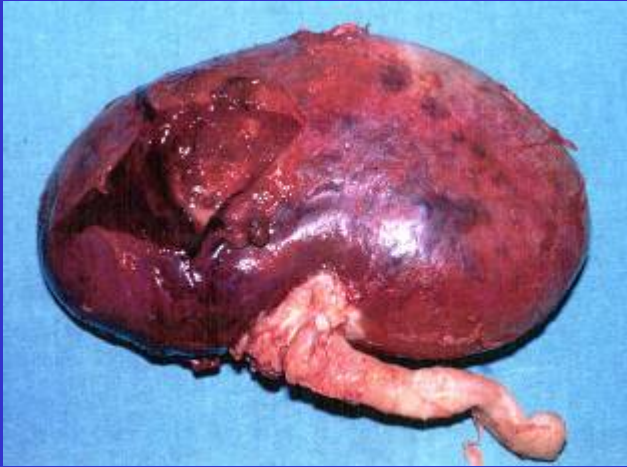
# Lesion imaging in tissue gel phantom

QuickTime™ and a  
Cinepak decompressor  
are needed to see this picture.





# Cavitation *in vivo*--ESWL



QuickTime™ and a  
Video decompressor  
are needed to see this picture.

QuickTime™ and a  
Video decompressor  
are needed to see this picture.



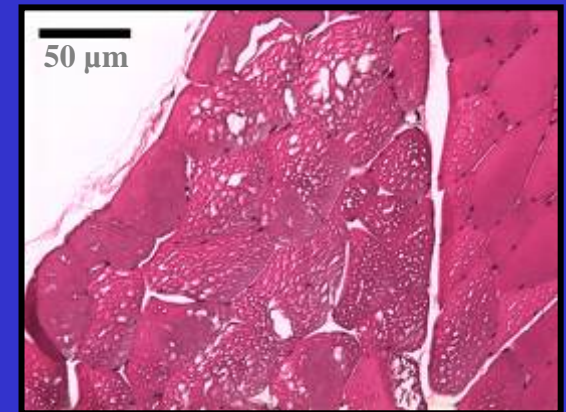
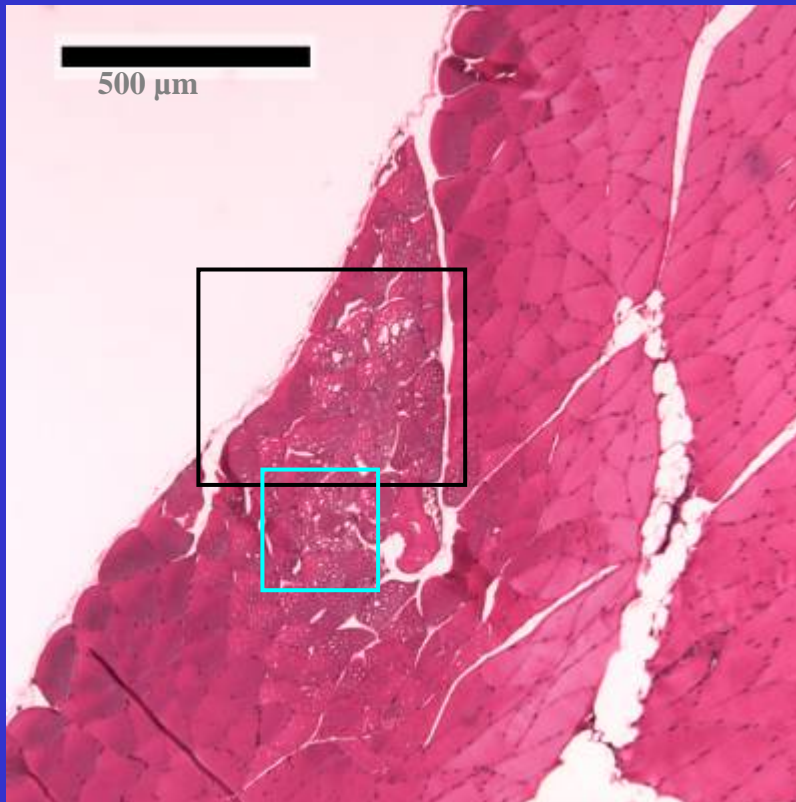
# Hyperechoic region histology: Results

0 hour

- Intra/extra-cellular cavities
- Ruptured cells

$$I_{\text{SATP}} = 4390 \text{ W/cm}^2$$

$$t = 31.25 \text{ ms}$$

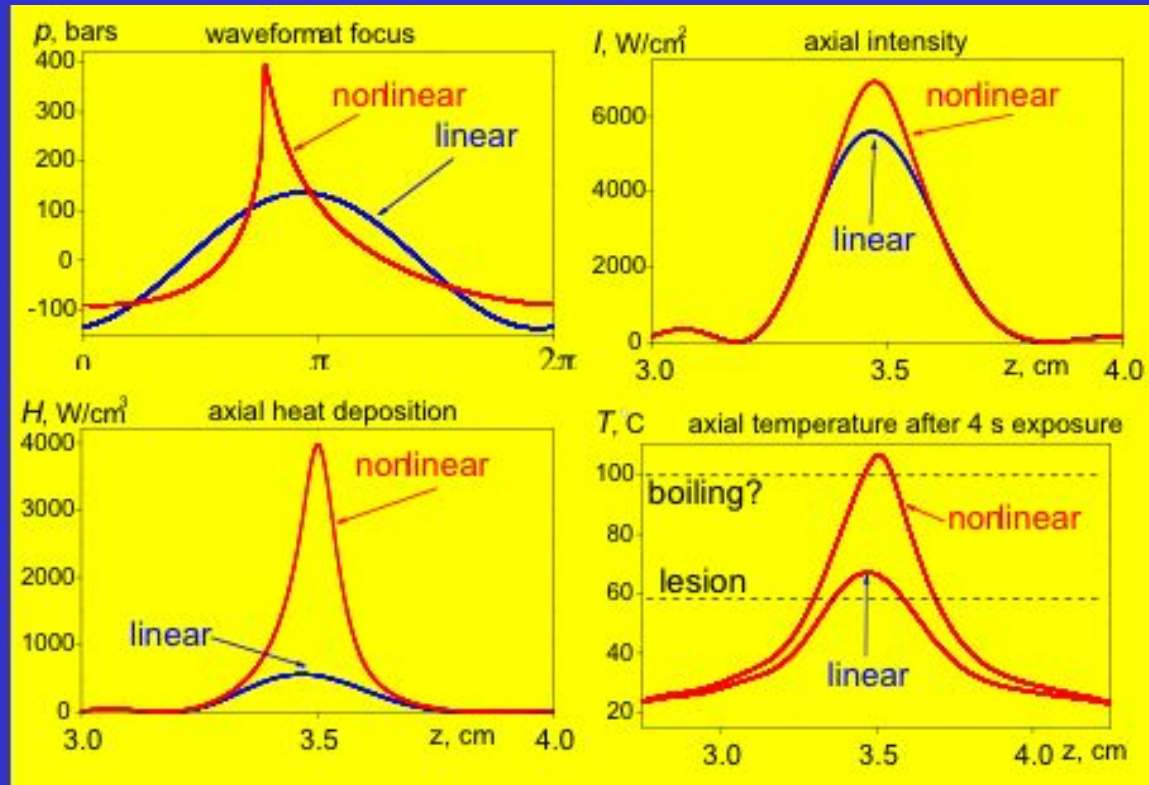
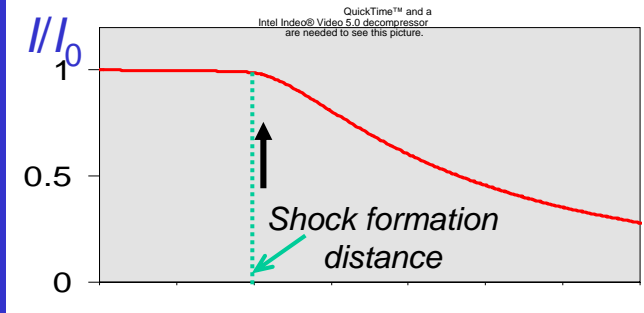


# Numerical modeling

## Waveform distortion

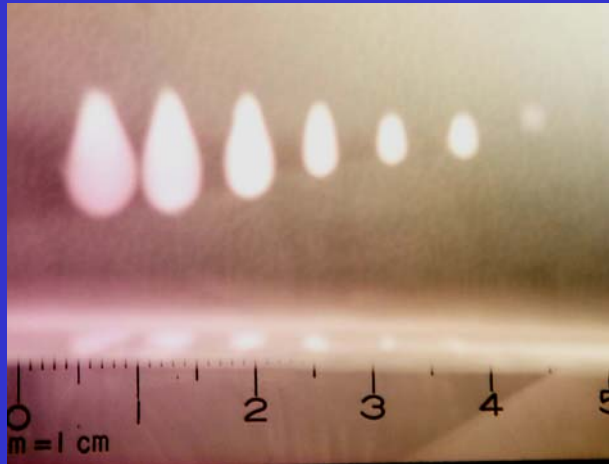
QuickTime™ and a  
Cinepak decompressor  
are needed to see this picture.

## Nonlinear enhanced absorption



## Lesion stripes--different velocity

Same acoustic energy



QuickTime™ and a  
Cinepak decompressor  
are needed to see this picture.



QuickTime™ and a  
Cinepak decompressor  
are needed to see this picture.

**212 mV, 2 mm/s**

**519 mV, 6 mm/s**

# Temperature at the HIFU focus can be monitored in real time

QuickTime™ and a Video decompressor are needed to see this picture.

QuickTime™ and a  
Video decompressor  
are needed to see this picture.

QuickTime™ and a  
Video decompressor  
are needed to see this picture.





# Transducer Array

