Innovation of Acoustic Research on Biomedical Applications

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SIU CARBONDALE Southern Illinois University

Acoustic Research Projects in Our Lab

1. Applications on Therapeutic Ultrasound

--- Innovation of Shock Wave lithotripsy (SWL) on Treatment of Kidney Stone Diseases

--- Cavitation Bubbles – Cell Interaction for Ultrasound Enhanced Gene Activation

2. Applications on Audible Sound

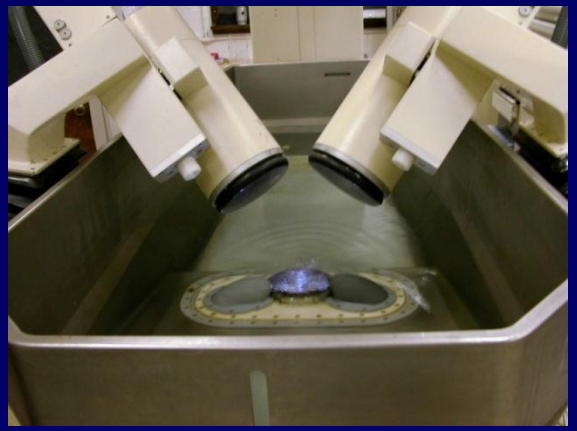
--- Research on Noise-Induced Human Hearing Loss

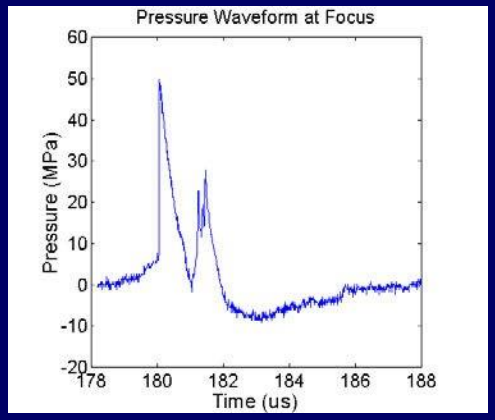
--- Diagnosis and Treatment of Human Tinnitus

PART I:

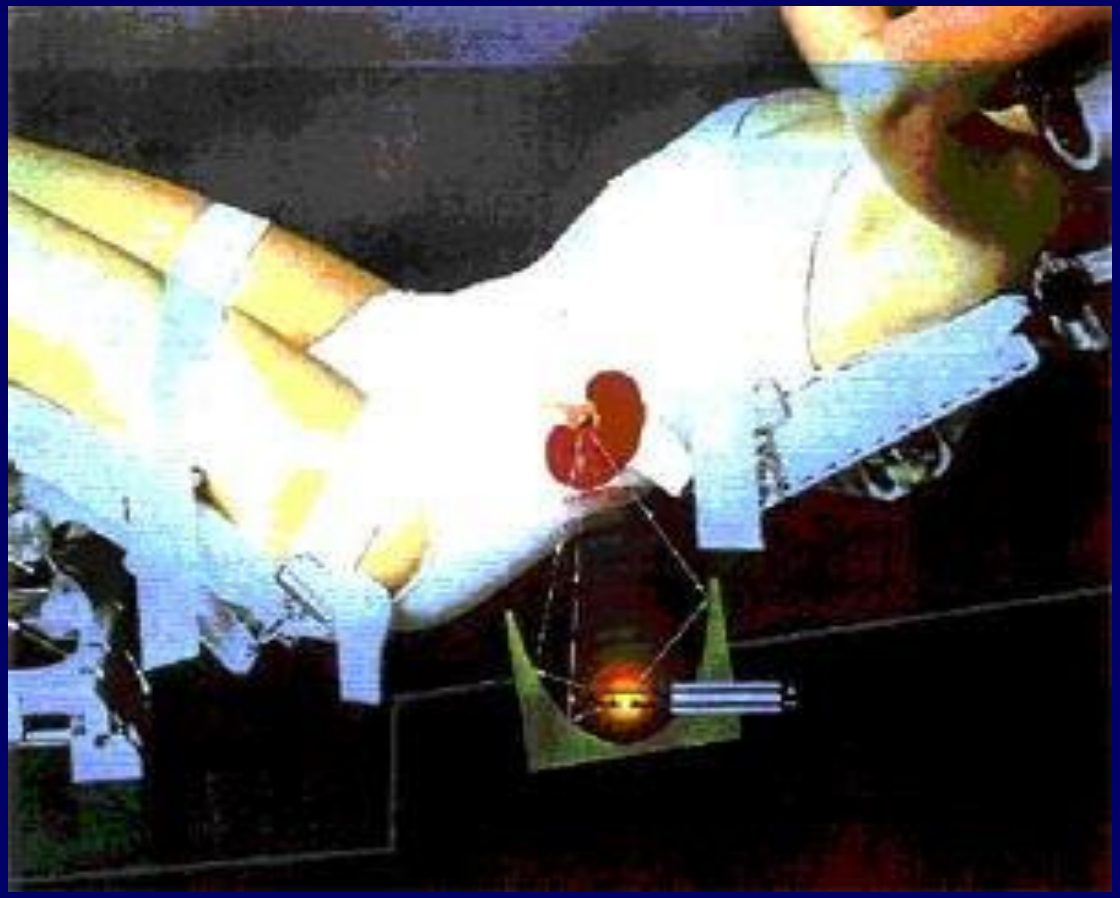
Comparison of Electrohydraulic (EH) and Electromagnetic (EM) SWLs

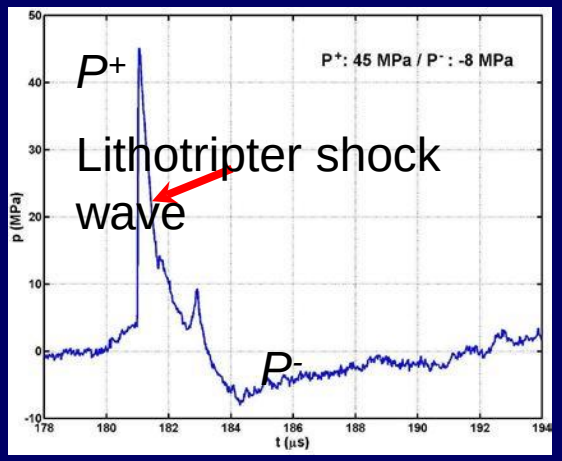
- Introduction to SWLs.
- Characterization of acoustic fields
- Stone fragmentation *in vitro* and *in vivo*

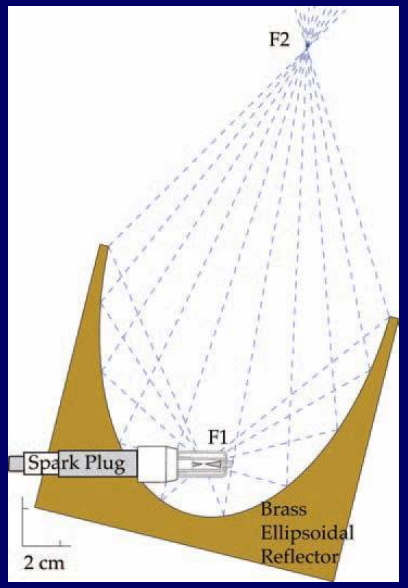




Shock Wave lithotripsy







Electromagnetic (EM) Shock Wave Generator

- Widely use in the newer generation lithotripters
- Stable and highly reproducible shock waves, long life time
- High peak pressure and narrow focal beam size

Newer generation machines:

- **Less effective in stone comminution**
- **Higher propensity for tissue injury**

1st generation--- Dornier HM-3:

"Gold standard"

Newer is not better! Why?

Comparison of EH and EM Lithotripters

- **Electrohydraulic:**

Unmodified HM-3 at 20 kV

- **Electromagnetic**

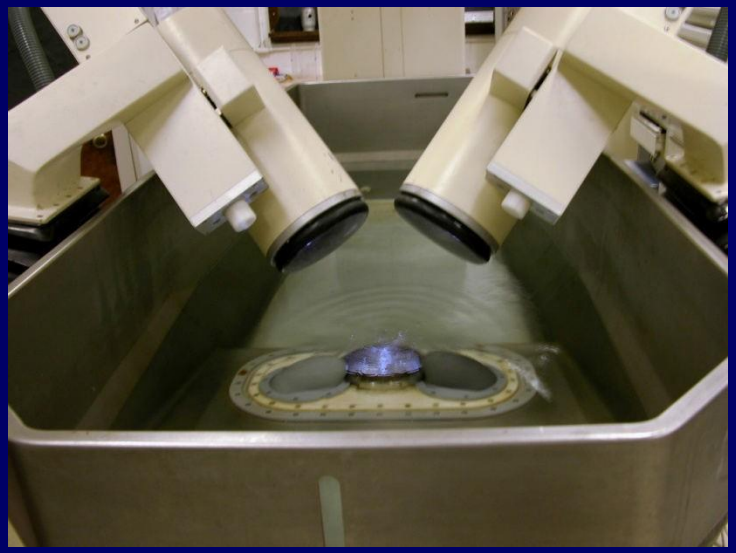
Siemens Modularis at E4.0

- ***In vitro* comparison**

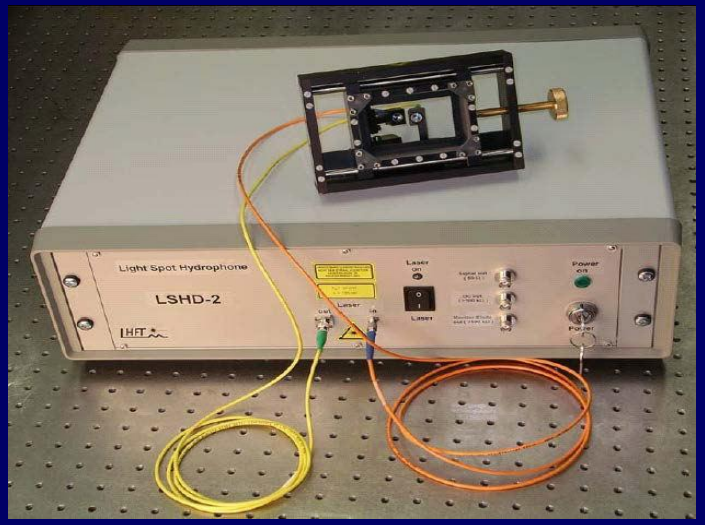
Acoustic fields Stone fragmentation

- ***In vivo* comparison**

Stone fragmentation



Acoustic Field Measurement



Light Spot Hydrophone (LSHD-2)

(Siemens/University of Erlangen-Nuremberg)

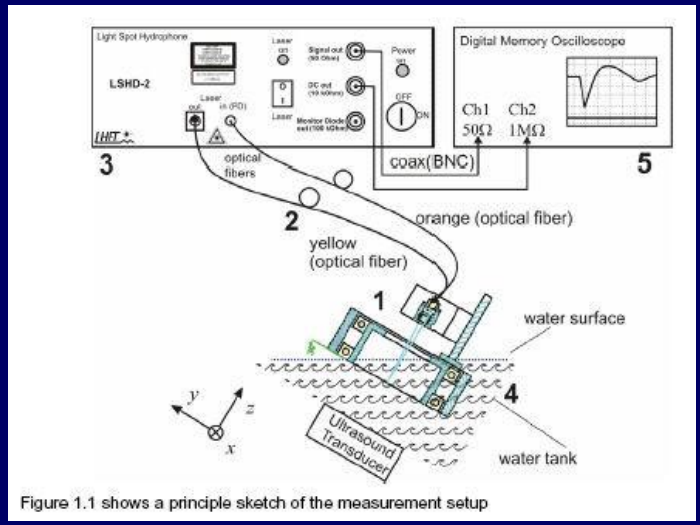
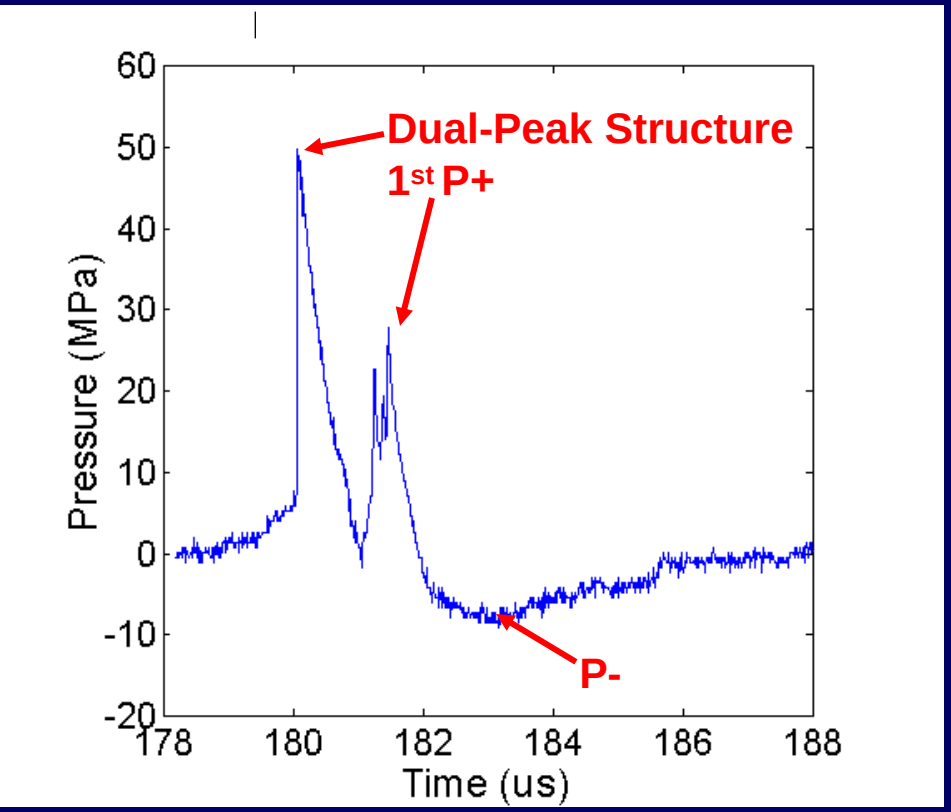
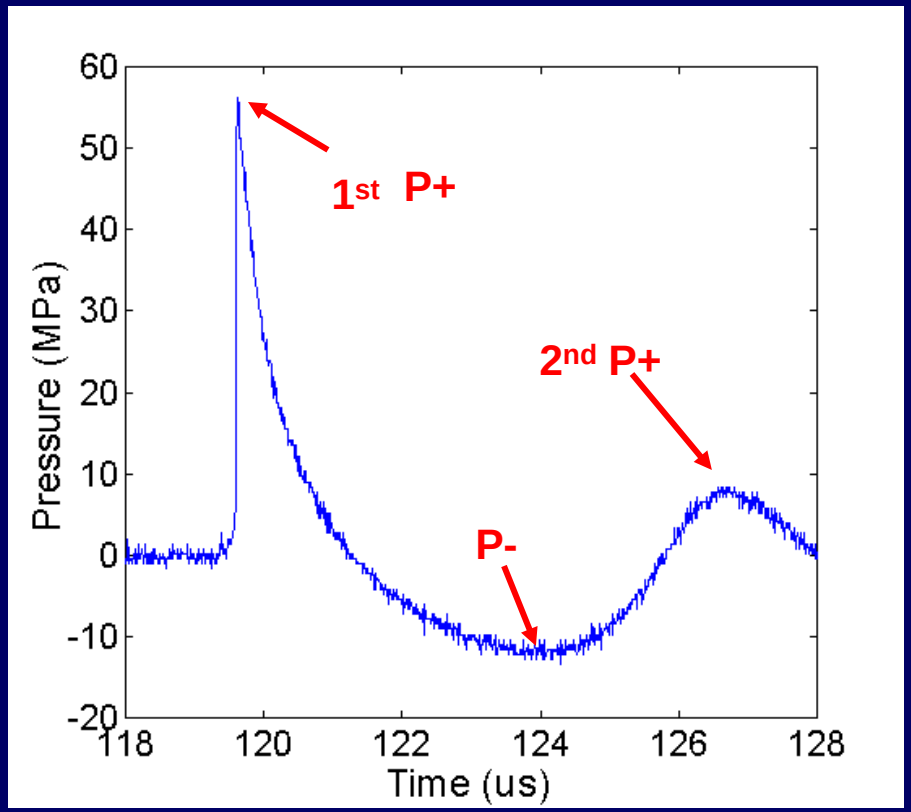


Figure 1.1 shows a principle sketch of the measurement setup

Pressure Waveforms at Focus

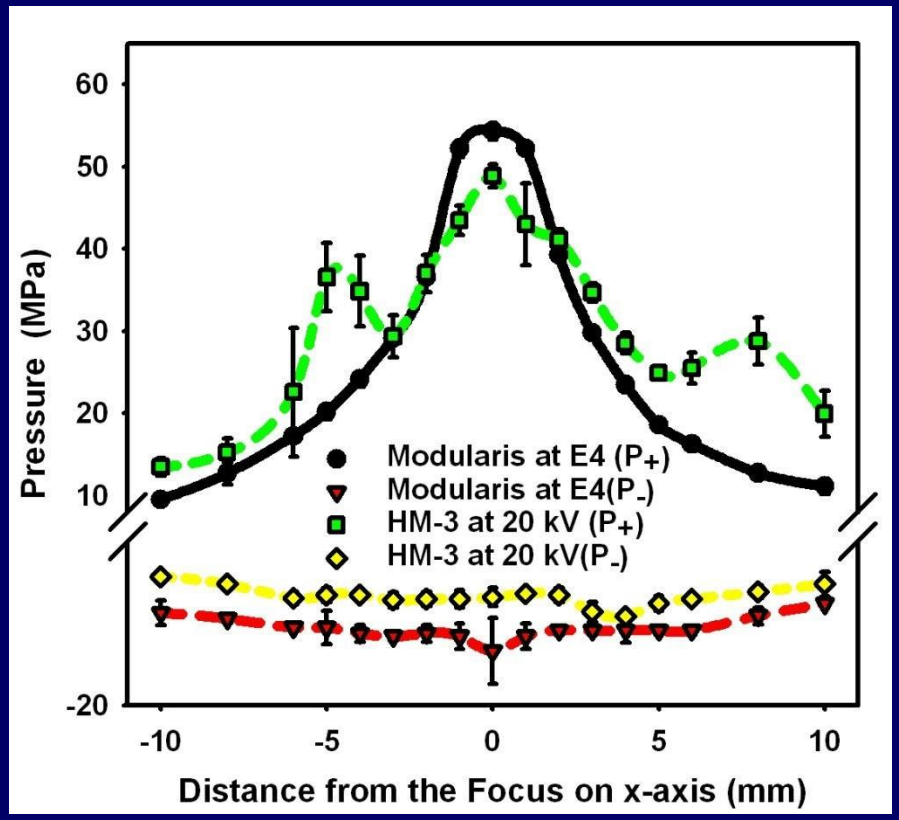


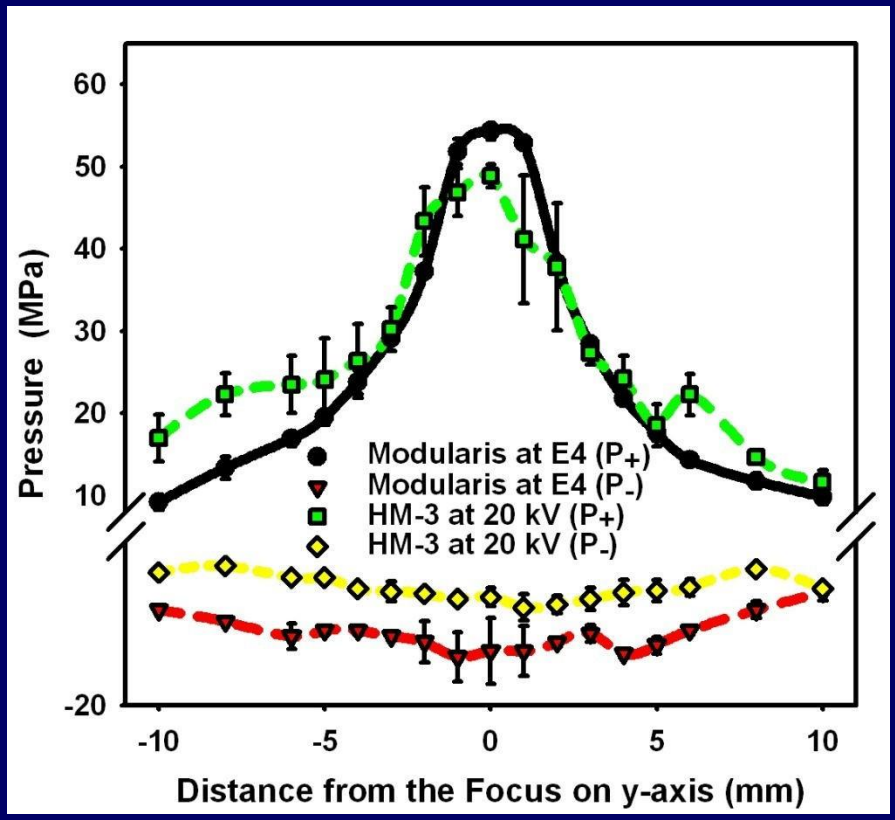
HM3 at 20 kV



Modularis at E4.0

Pressure Distribution and Characteristics of Acoustic Fields

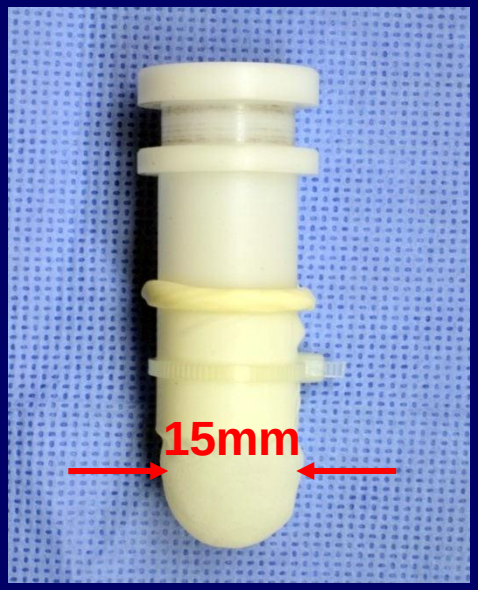




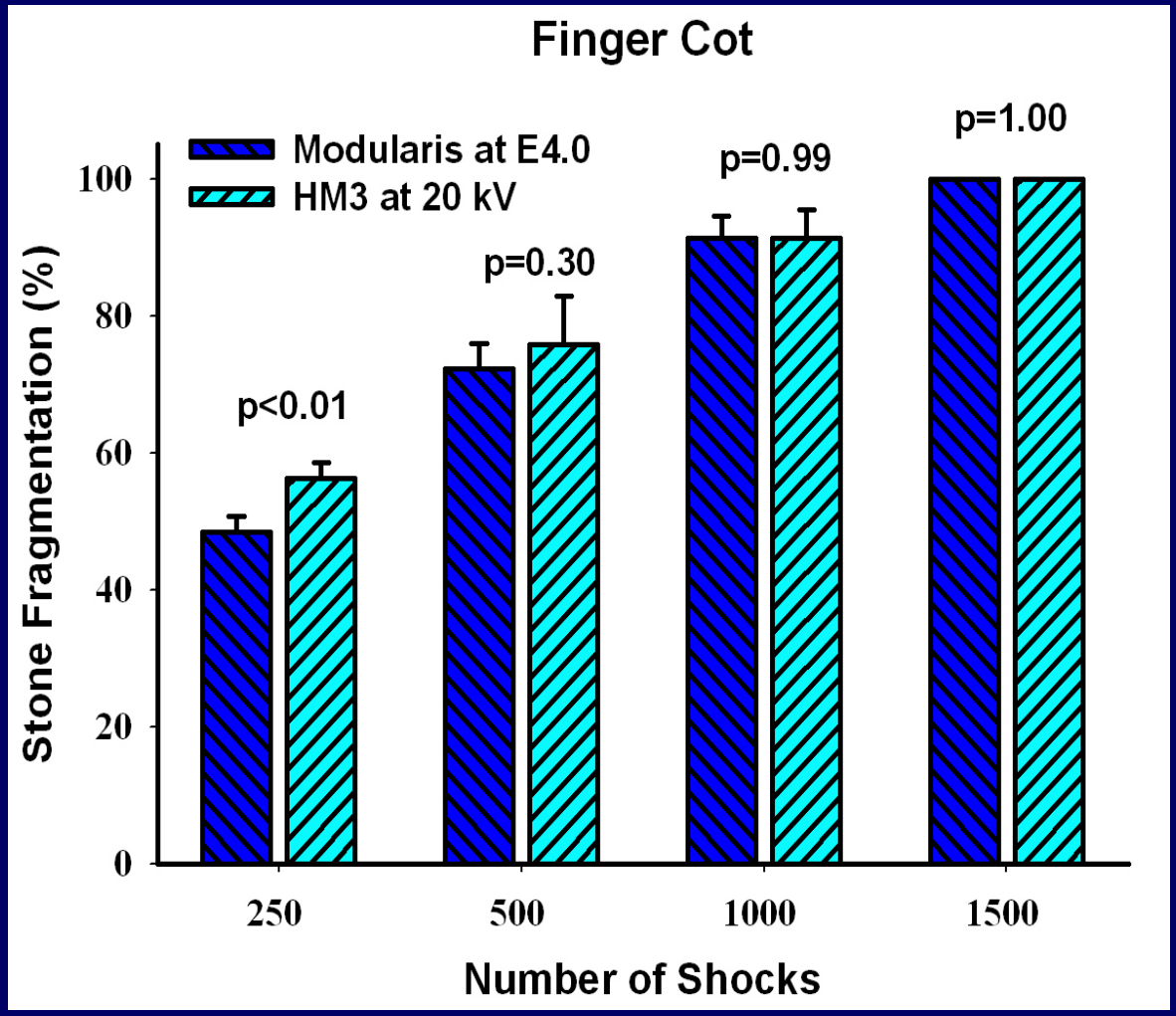
	Peak P+ (MPa)	Peak P- (MPa)	-6 dB Beam Size, Head-Foot (mm)	-6dB Beam Size, Left-Right (mm)	Effective Energy (mJ)
HM3 at 20 kV	48.9 ± 1.3	-10.7 ± 0.6	12.5	9.3	42.9
Modularis at E4.0	54.3 ± 1.0	-14.4 ± 3.4	6.8	6.6	62.1

Stone Fragmentation in a Finger Cot Holder

Finger Cot Holder

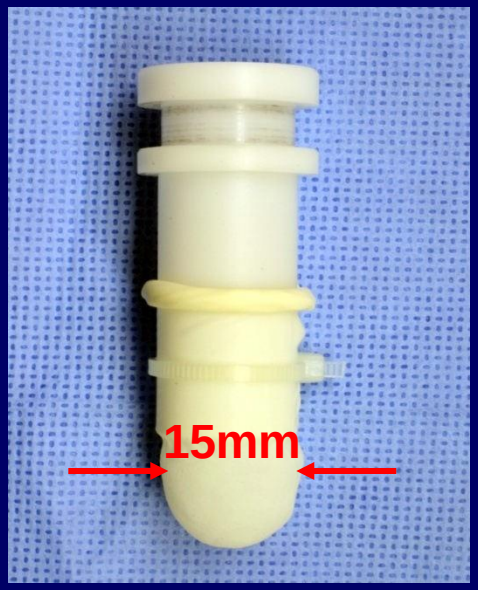


- Stone fragments are always kept in a 15 mm diameter area during SWL
- Do not represent stone fragmentation *in vivo*



New Stone Holder: Membrane Holder

Finger Cot Holder



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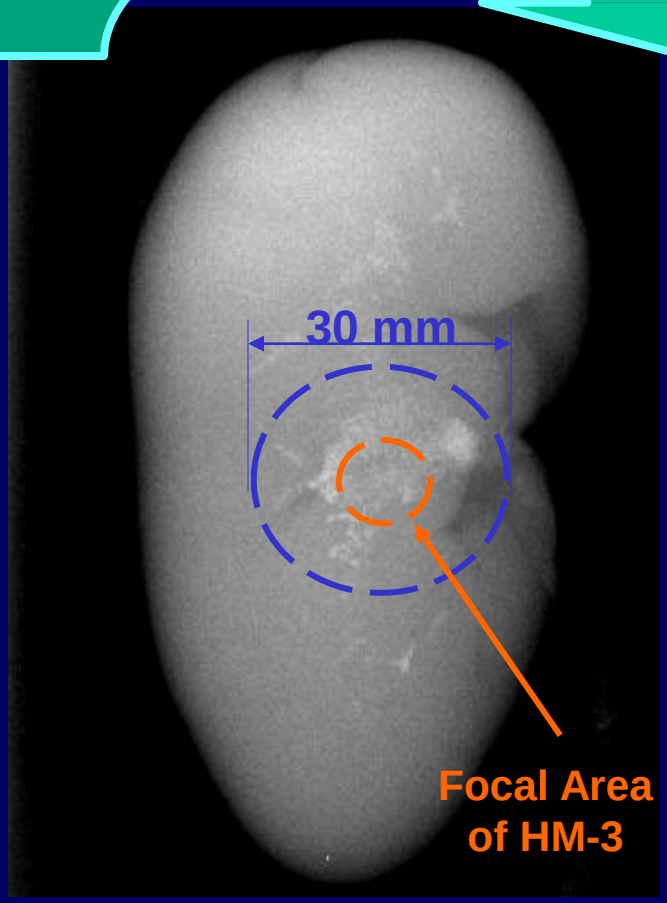
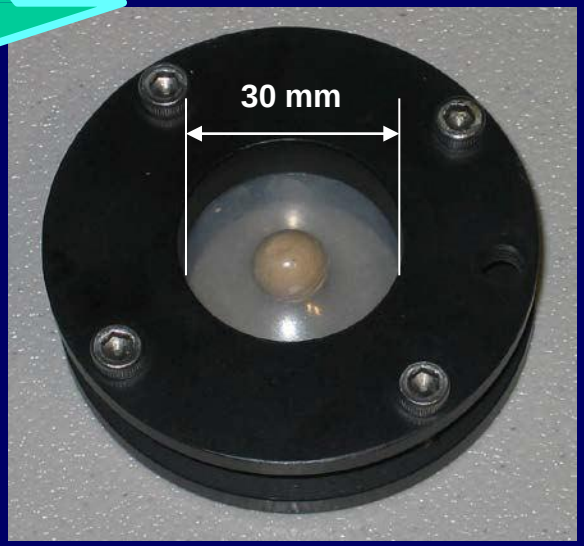


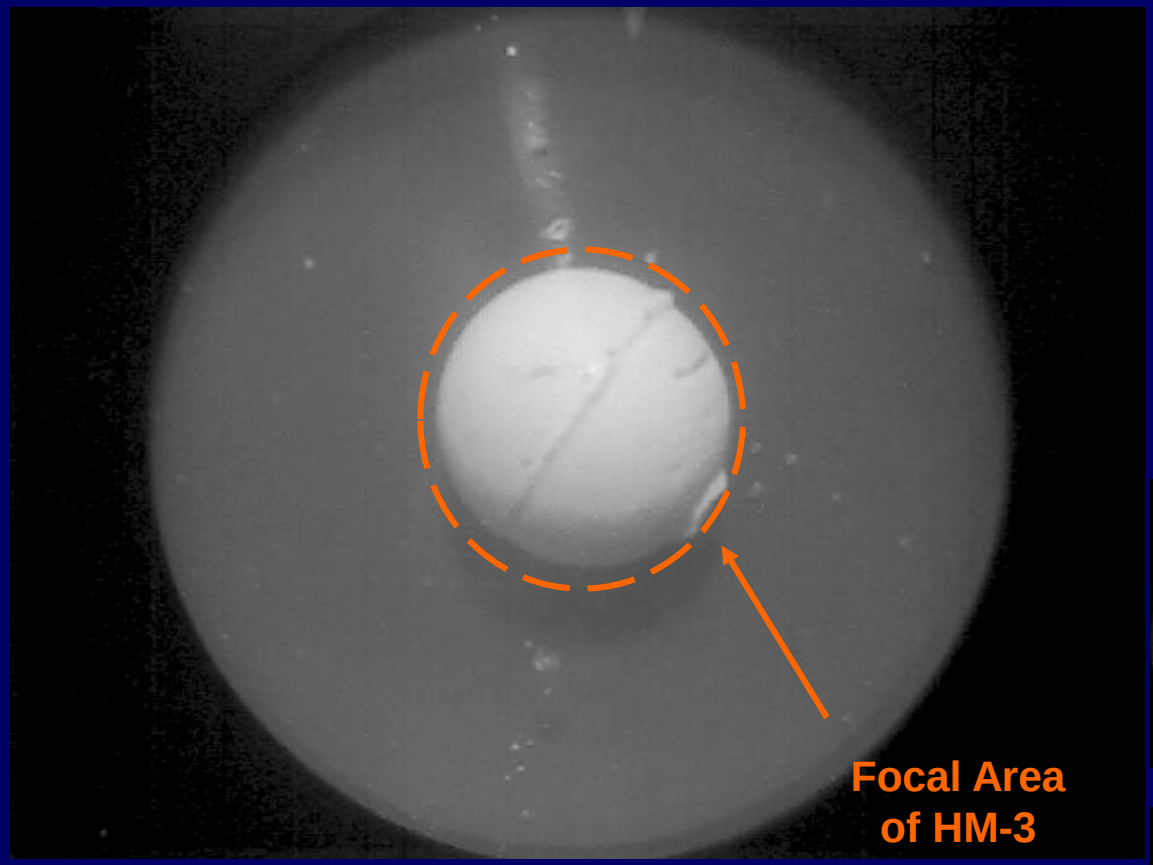
2000 shocks *in vivo*

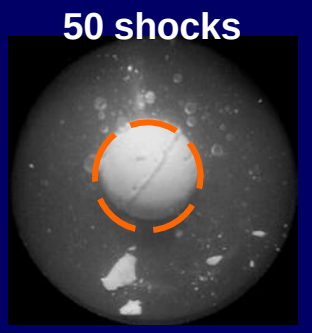
Membrane Holder

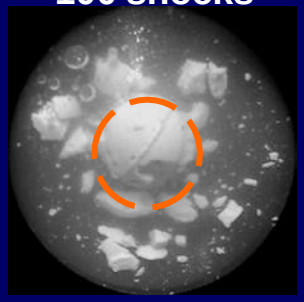


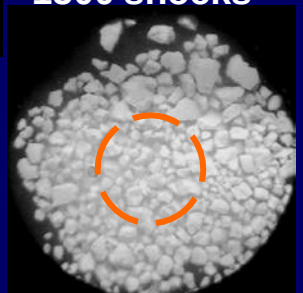
- Allow fragments to accumulate & spread out laterally
- Mimic more closely stone fragmentation *in vivo*

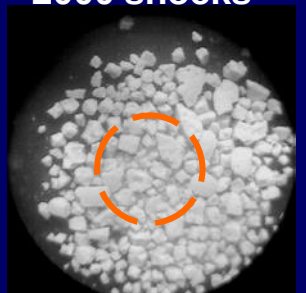
Spreading of Fragments in a Membrane Holder





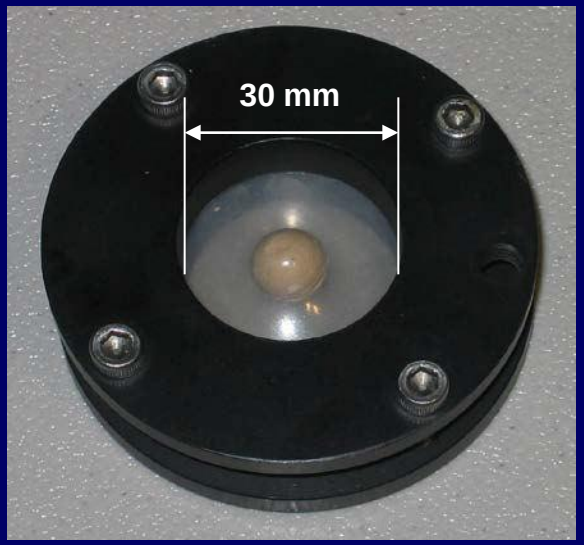




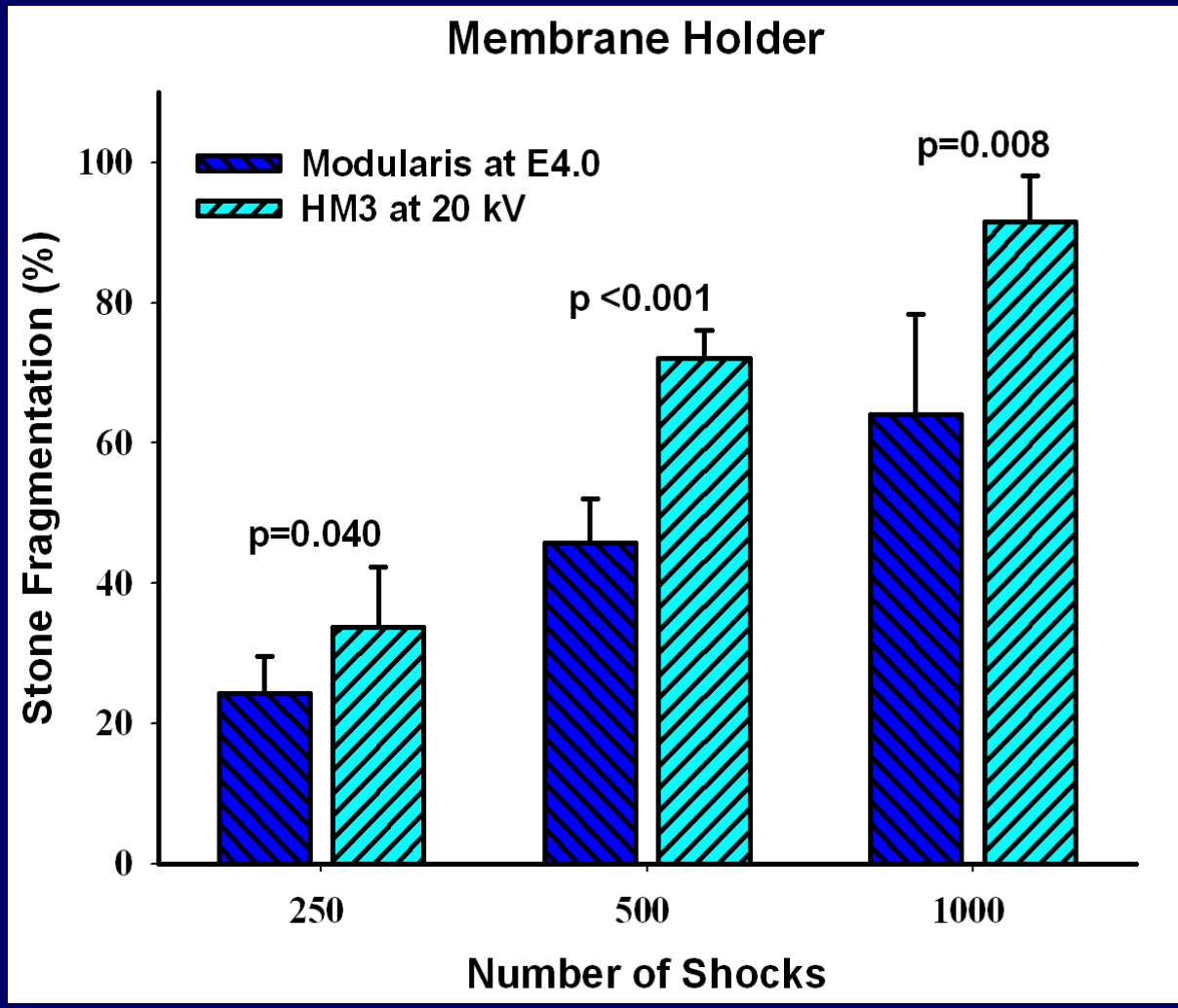


Stone Fragmentation in a Member Holder

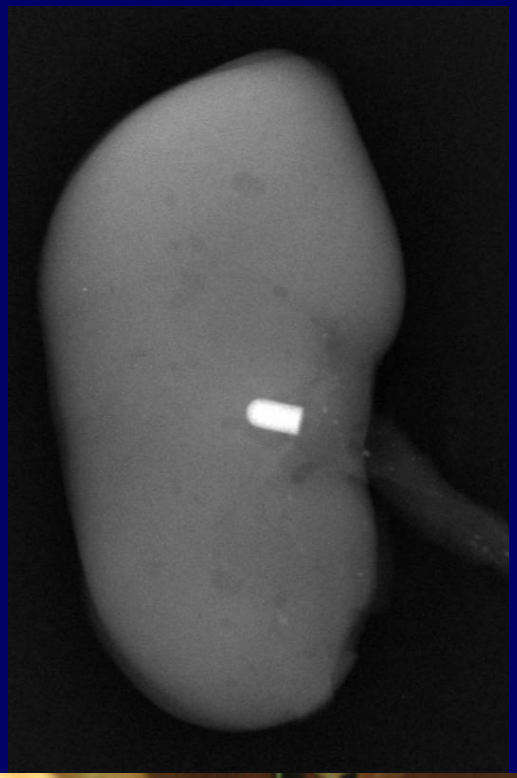
Membrane Holder

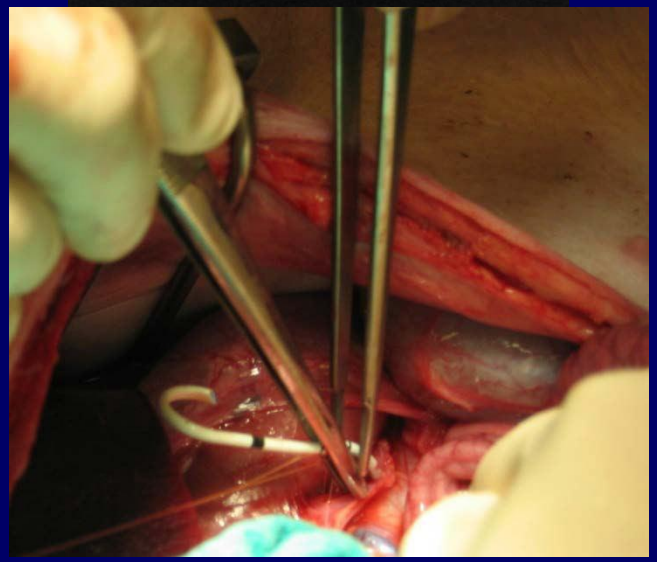


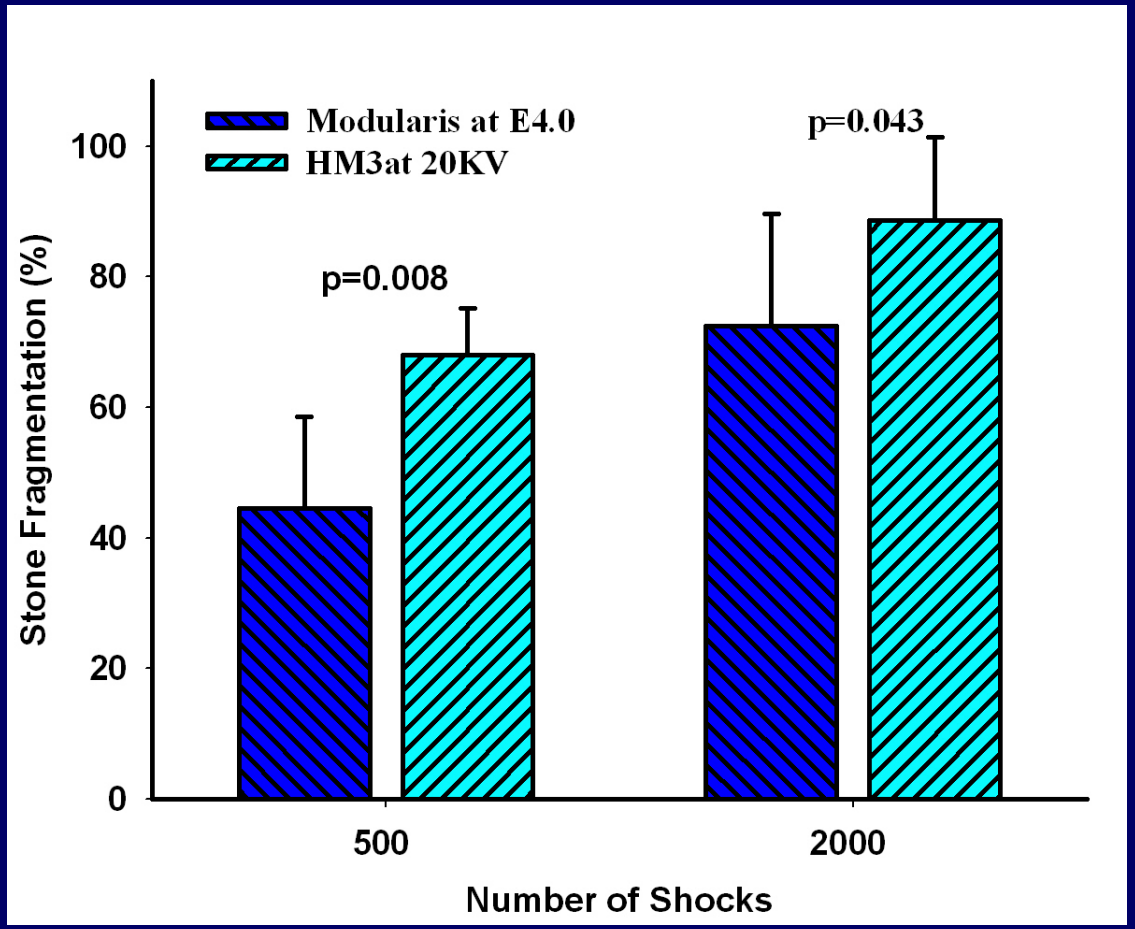
- Allow fragments to accumulate & spread out laterally
- Mimic more closely stone fragmentation *in vivo*



Stone Fragmentation *in vivo*







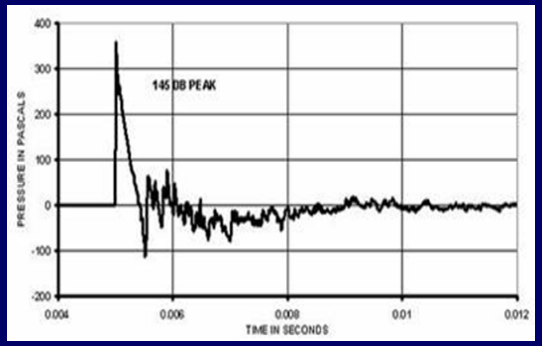
Summary of PART I

- Stone fragmentation produced by the EM lithotripter is lower than that of the EH lithotripter both *in vivo* and in the membrane holder.
- The acoustic field characterization demonstrates two distinct differences between EM and EH lithotripters
  - 2nd compressive component in EM pulse, which could reduce maximum bubble size by 50%
  - EM lithotripter has much narrower beam size than EH lithotripter

PART II:

Development of a Noise Exposure System for Research on Impulse Noise Induced Hearing Loss

- Anatomy of Human Ear
- Noise Induced Hearing Loss
- Development of the Impulse Noise Exposure System

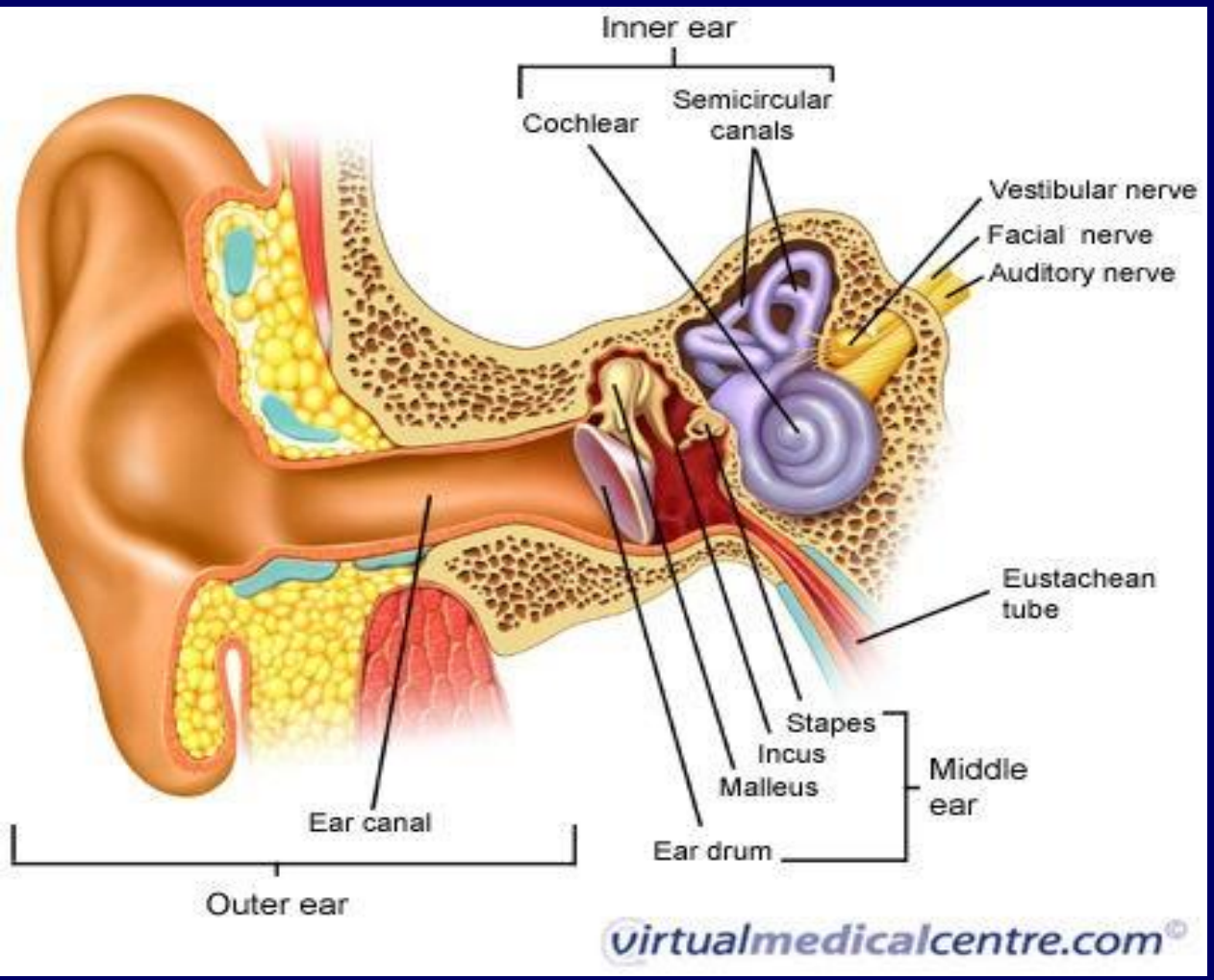


Noise-Induced Hearing Loss (NIHL)

- **When an individuals hearing is damaged or altered by noise**

- One of the most common occupationa in the United States
  - **More than 30,000,000 American work to unsafe noise levels at their job**
  - **Estimated 600 million people world hazardous noise levels**

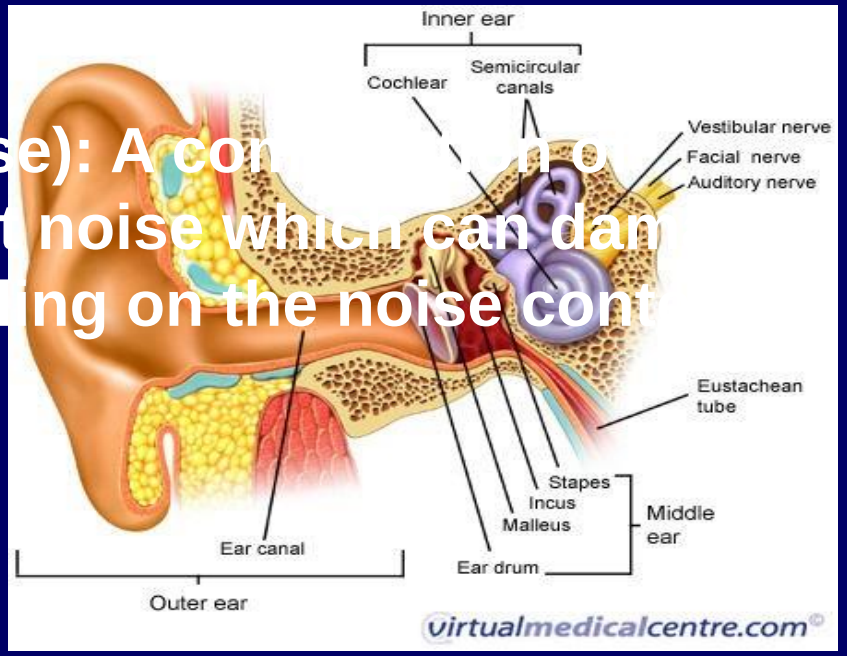
Anatomy of the Human Ear



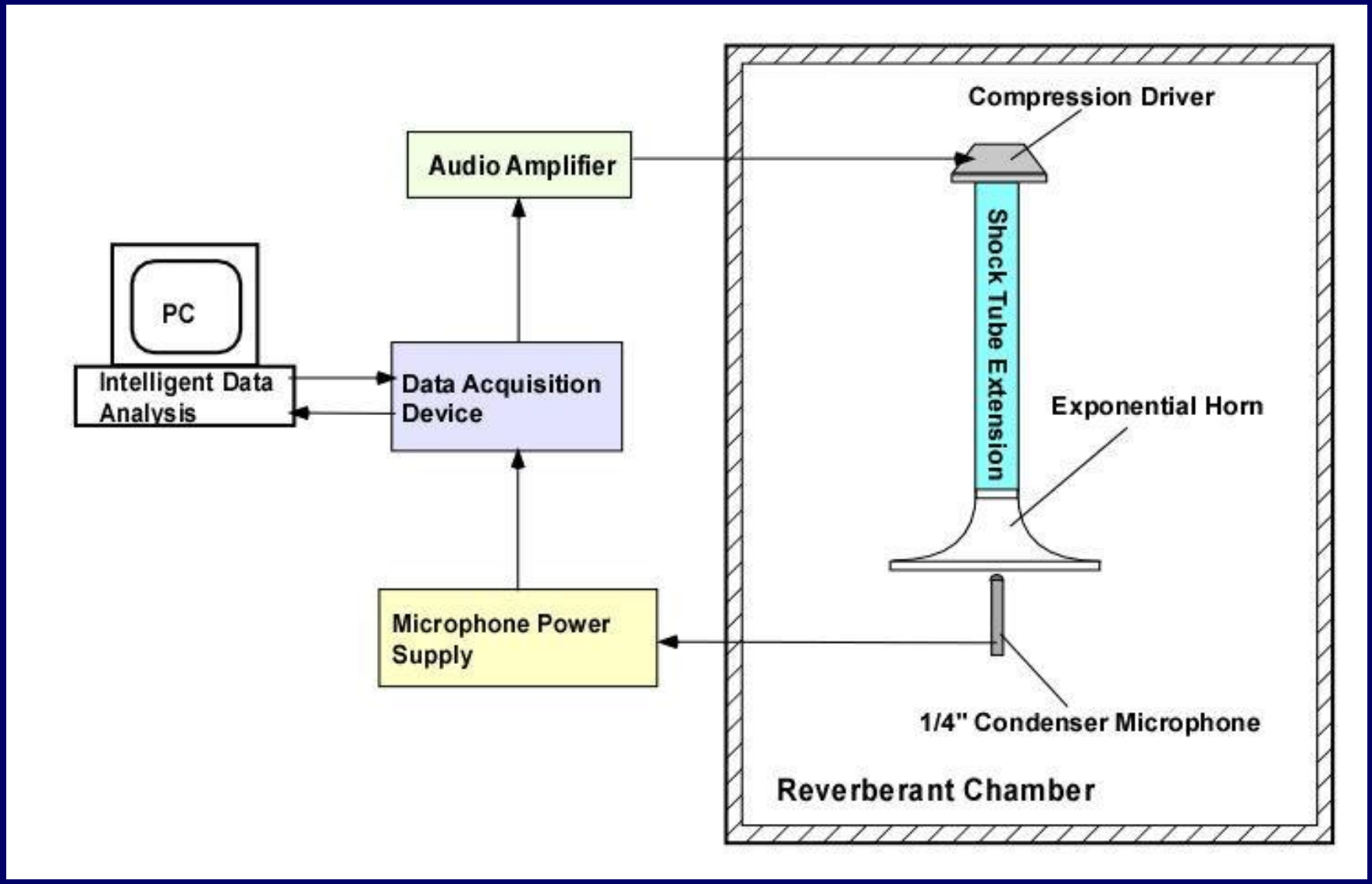
- Pinna
- Tragus
- Exterior Auditory Canal
- Tympanic Membrane
- Ossicles
- Scala Vestibuli
- Scala Tympani
- Cochlea

Anatomical Areas Affected by Different Noise Exposure

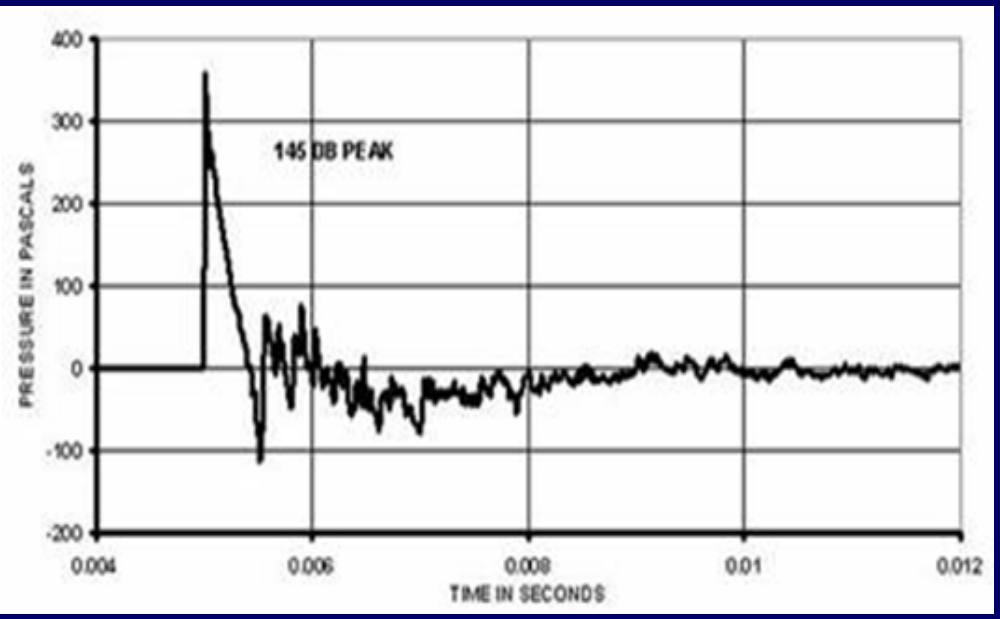
1) Gaussian Noise (Steady State Noise): Cochlea and Stria Vascularis
2) Impulse/Impact Noise: Cochlea and Stria Vascularis and possible tympanic membrane and ossicular damage depending on level
3) Kurtosis Noise (complex noise): A combination of Gaussian and impulse/impact noise which can damage all of the above areas depending on the noise content



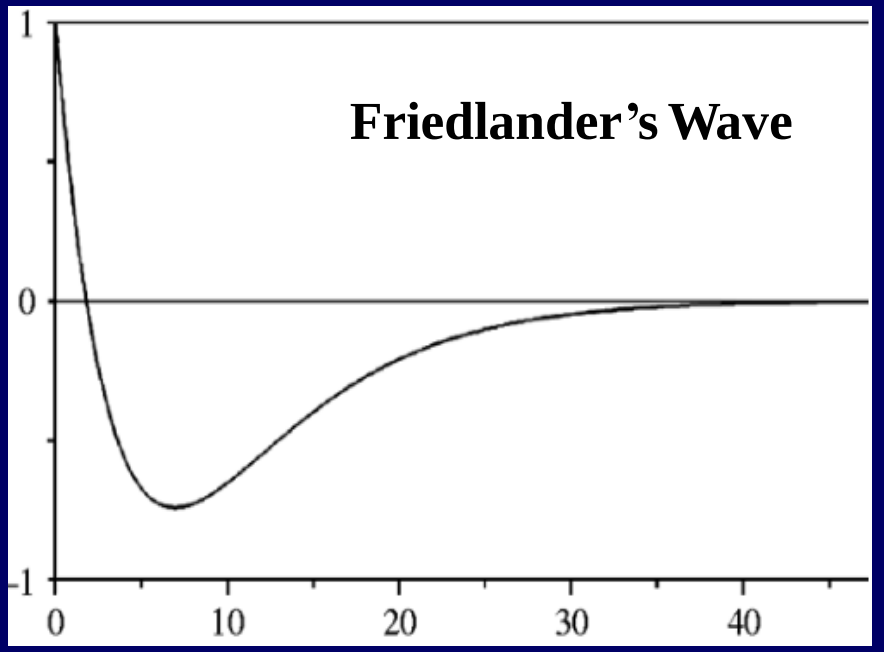
Noise Exposure System



Impulse Noise



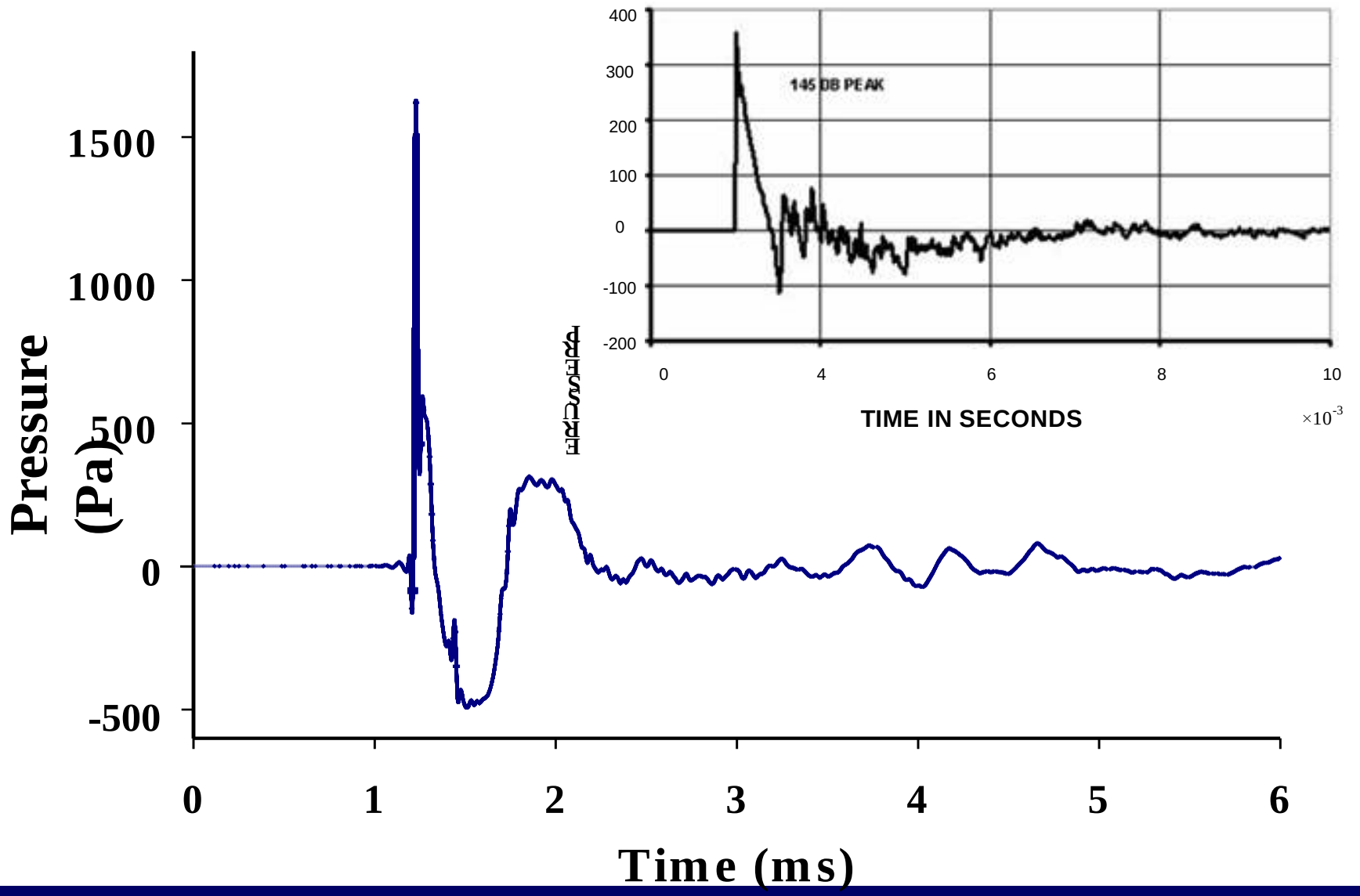
(http://www.arl.army.mil/www/default.cfm?page=352)



$$P(t) = P_s e^{-t/t^*}\left(1 - \frac{t}{t^*}\right)$$

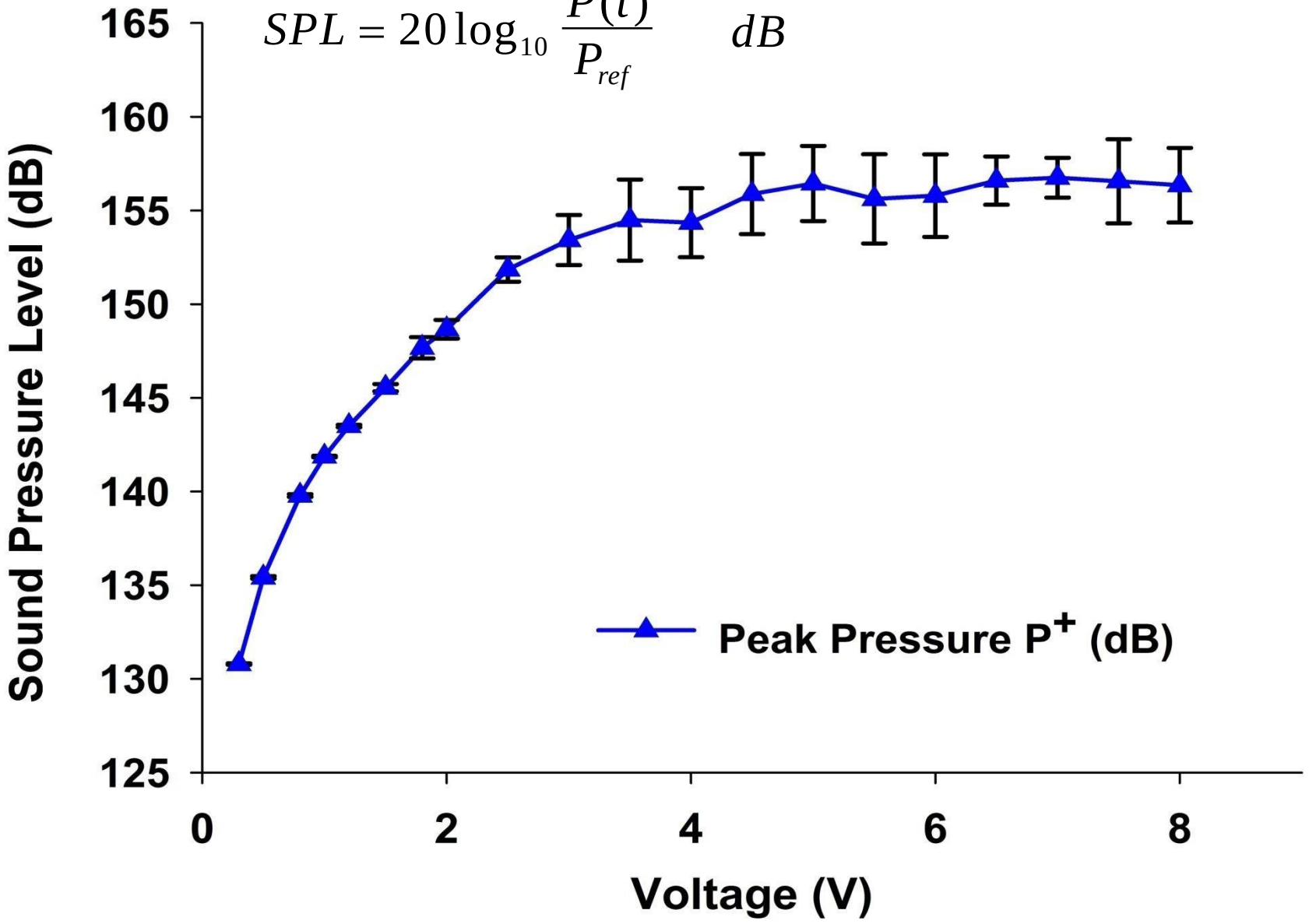
- P_s = peak sound pressure
- t^* = the time at which the pressure crosses the x-axis

Simulated Wave vs. Field-Measured Wave



Peak Pressure vs. Output Voltage

$$SPL = 20\log_{10}\frac{P(t)}{P_{ref}} \quad dB$$



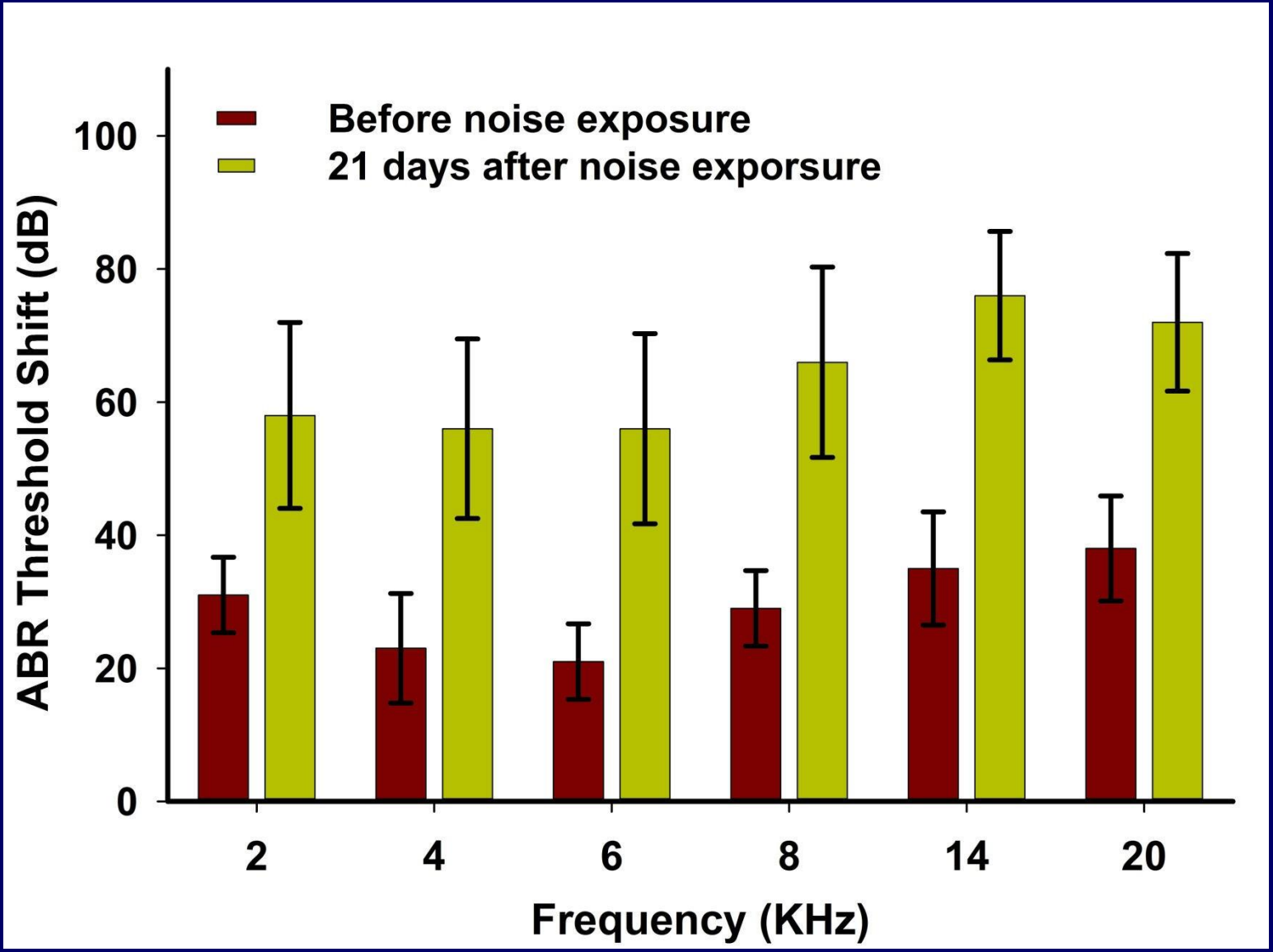
Animal Study Verifying the Impulse Noise Induced Hearing Loss

- Animal Model: Chinchilla
- 10 animals were tested

- Noise Exposure: impulse noise with peak SPL=155 dB at 2 Hz pulse repartition rate for 75 seconds (150 pulses).

- Auditory brainstem response (ABR) were measured before and 21 days after noise exposure

Animal Study Results



Summary of PART II

- A digital noise exposure system has been developed to generate the impulse noise.
- The waveforms of impulse noise are comparable to the field measurement test performed by the U.S. Army
- Impulse noise produces significant hearing loss in animal study.
- Future work includes Kurtosis noise simulate and high level impulse noise generation.

Upcoming Conference

- **For upcoming conferences please follow the below mentioned link**

http://www.conferenceseries.com/