

# **Diagnostic Ultrasound Physics and QC Workshop**

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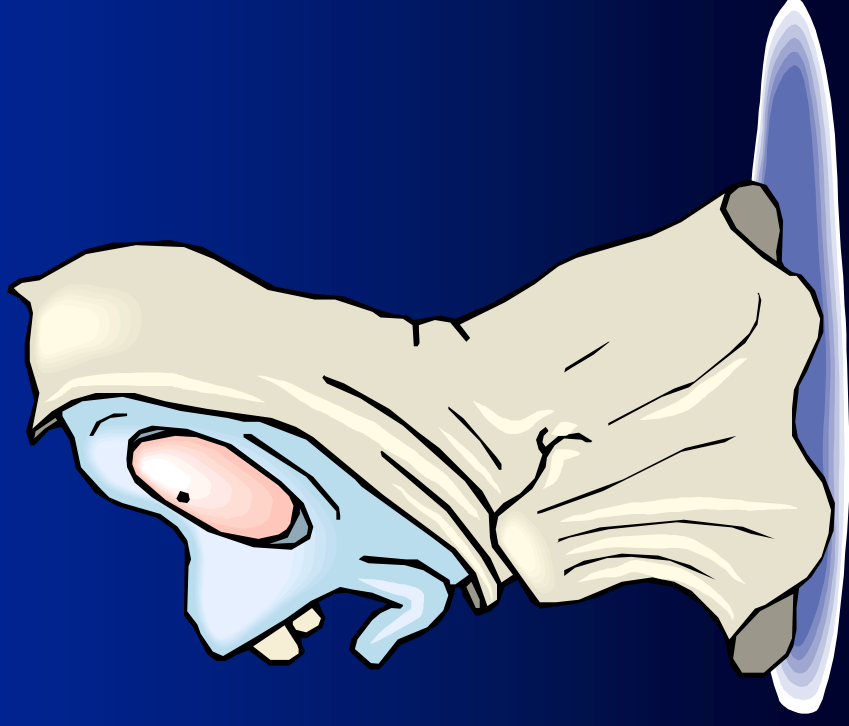
# Workshop Outline

- Introduction
- Overview of ultrasound phantoms
- QA/QC introduction and background
  - QA/QC requirements
  - Ultrasound accreditation
  - Resources
- QC Test / physics demonstrations
  - Eight tests reviewed
  - Review test procedures
  - Review physics principles

# **Diagnostic Ultrasound Physics and QC Workshop : An Overview of Ultrasound Phantoms**

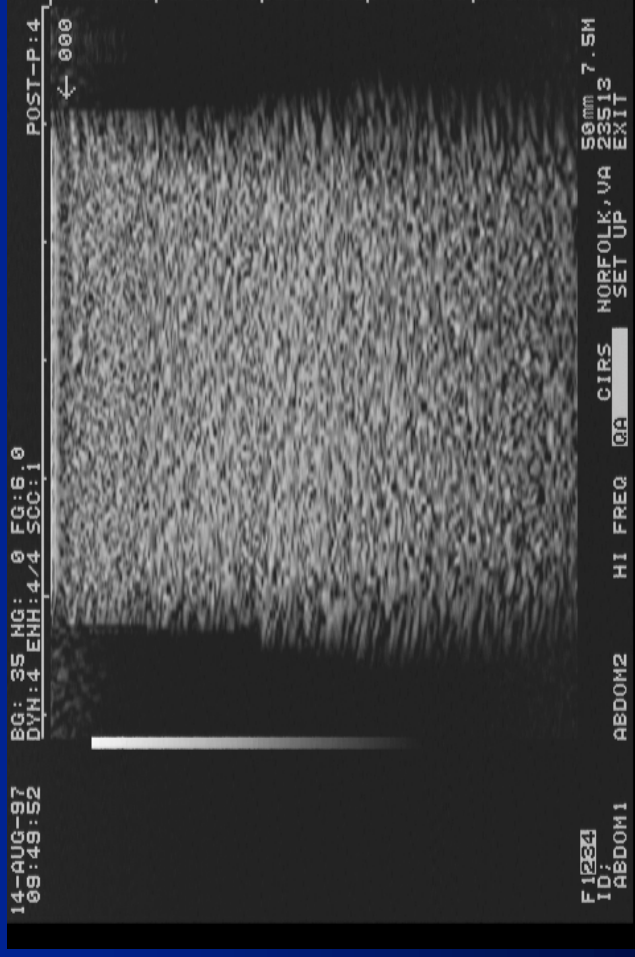
# What is an ultrasound phantom?

Any structure that contains one or more materials that simulate a body of tissue in its interaction with ultrasound and is used to mimic ultrasonic interactions in the human body.



# Tissue Mimicking Materials

- Agar
- Zerdine™
- Urethanes
- Other
  - epoxies
  - liquids
  - natural materials



# Acoustic Properties

- Speed of Sound
- Attenuation Coefficient
- Backscatter Coefficient/Relative Contrast

# Acoustic Properties

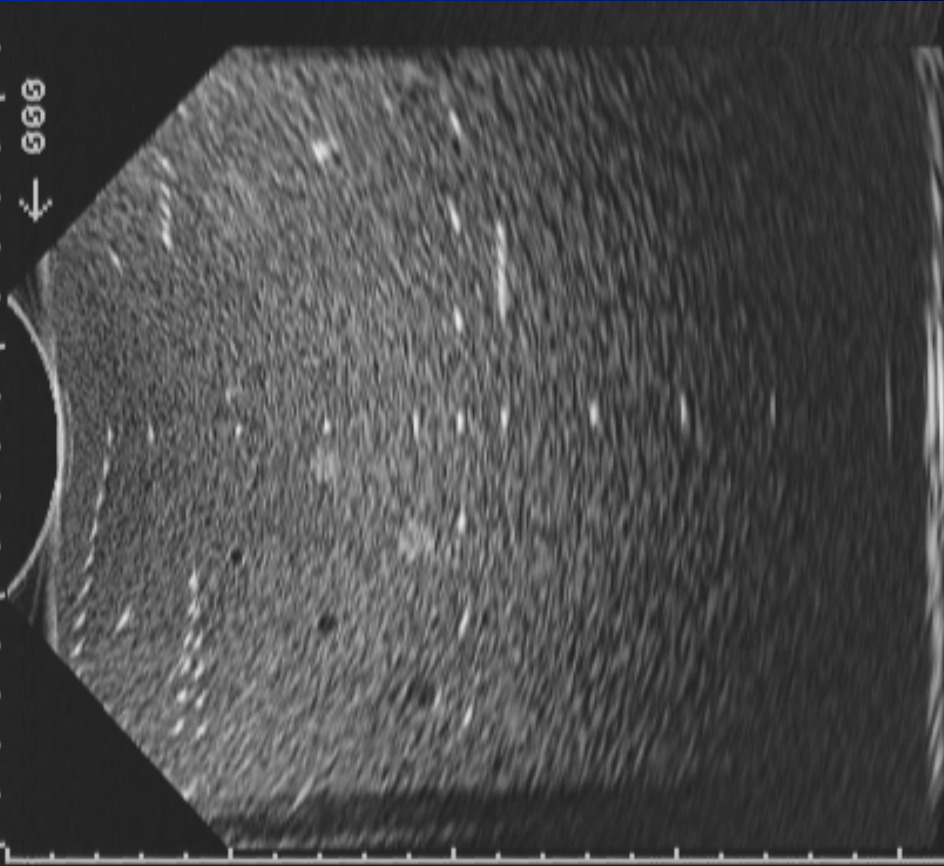
- Speed of Sound  $\longrightarrow$  1540 m/s
- Attenuation Coefficient
- Backscatter Coefficient/Relative Contrast

# Acoustic Properties

- Speed of Sound  $\longrightarrow$  1540 m/s
- Attenuation  $\longrightarrow$  0.5 dB/cm/MHz or 0.7 dB/cm/MHz
- Backscatter Coefficient

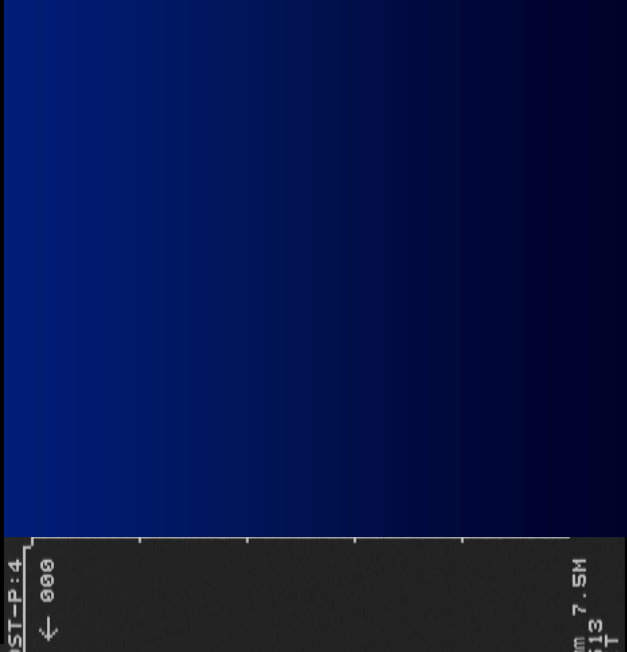
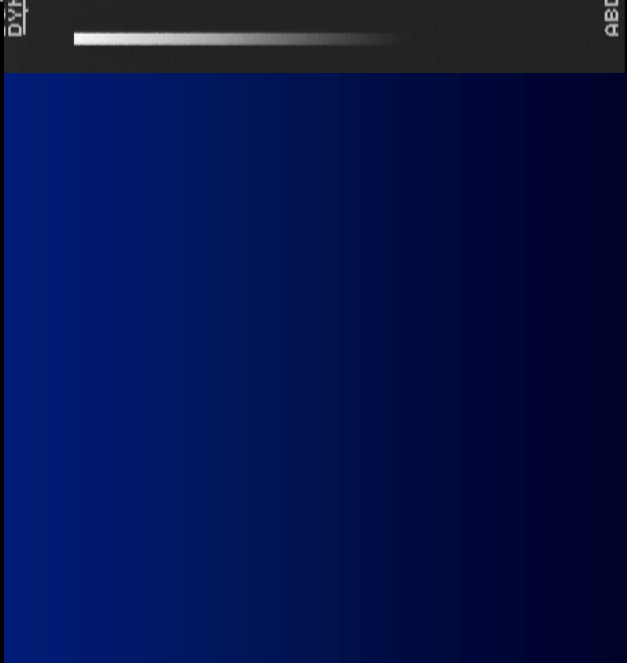
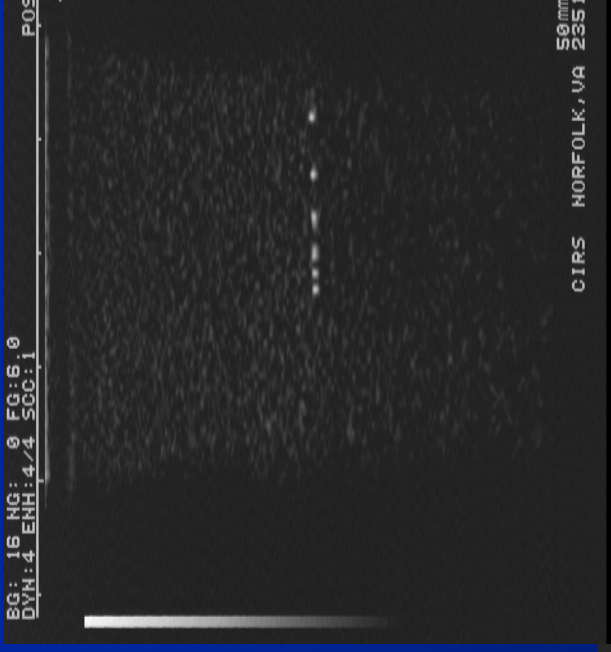
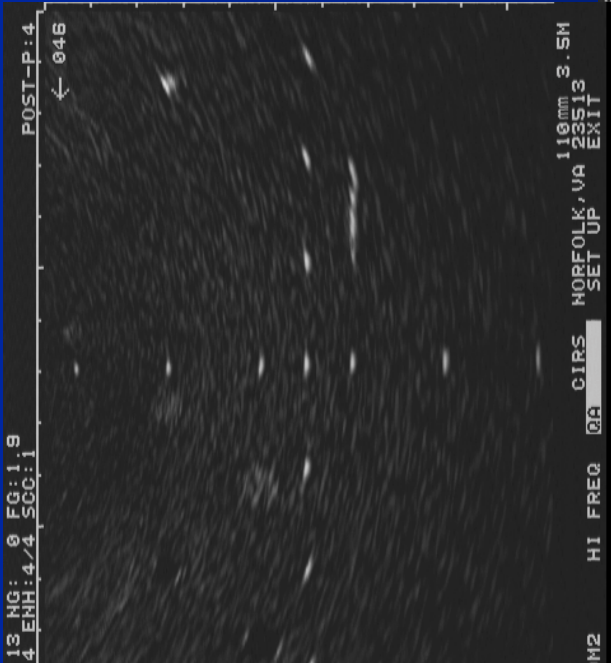


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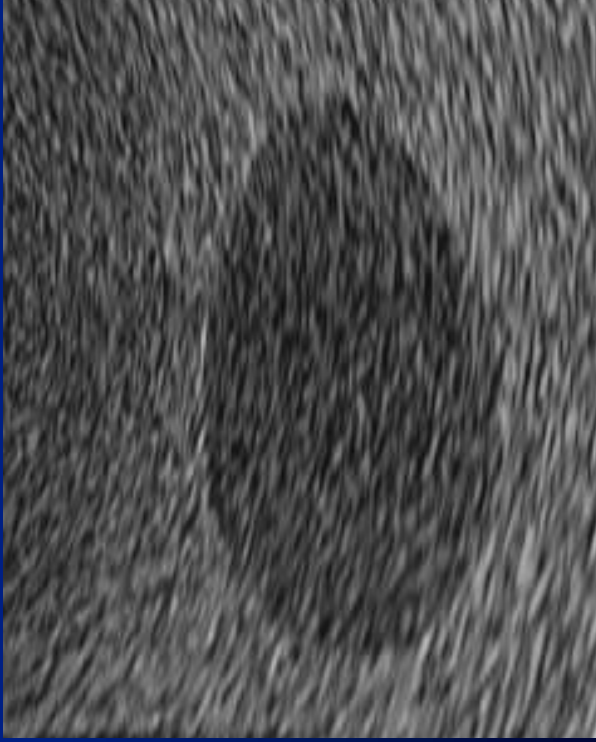
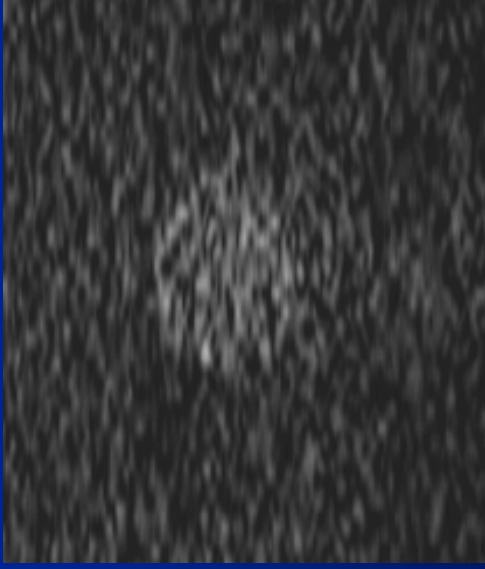


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# Wires



# Various Masses

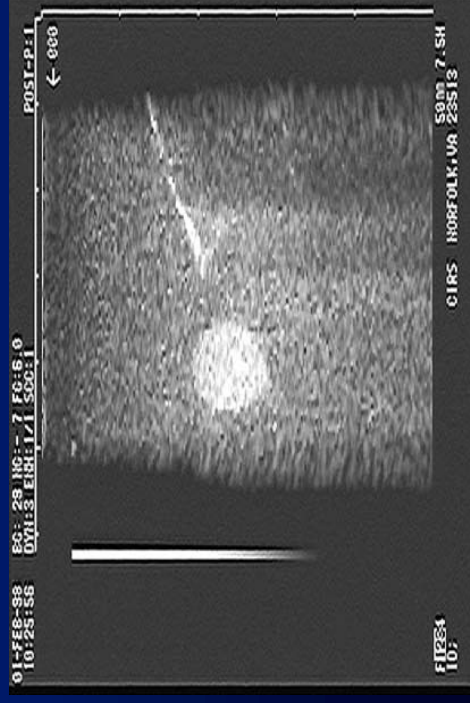
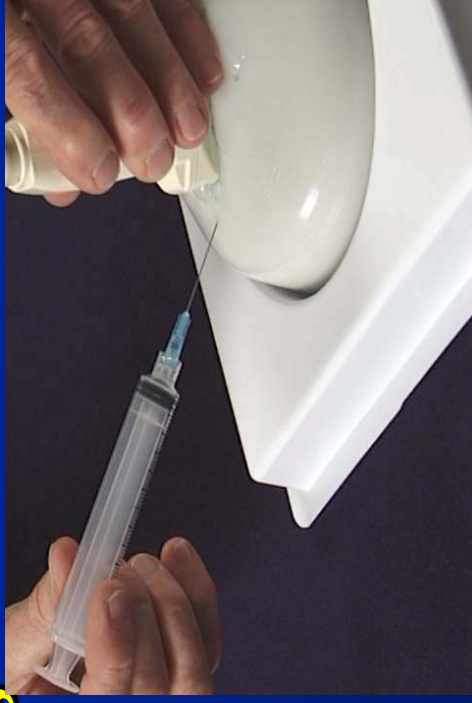


# Applications

- Training
- Demonstration
- Quality Assurance
- Research & Development

# Training Phantoms

- Biopsy
- Cryosurgery
- Brachytherapy
- HIFU
- IVUS
- 3D

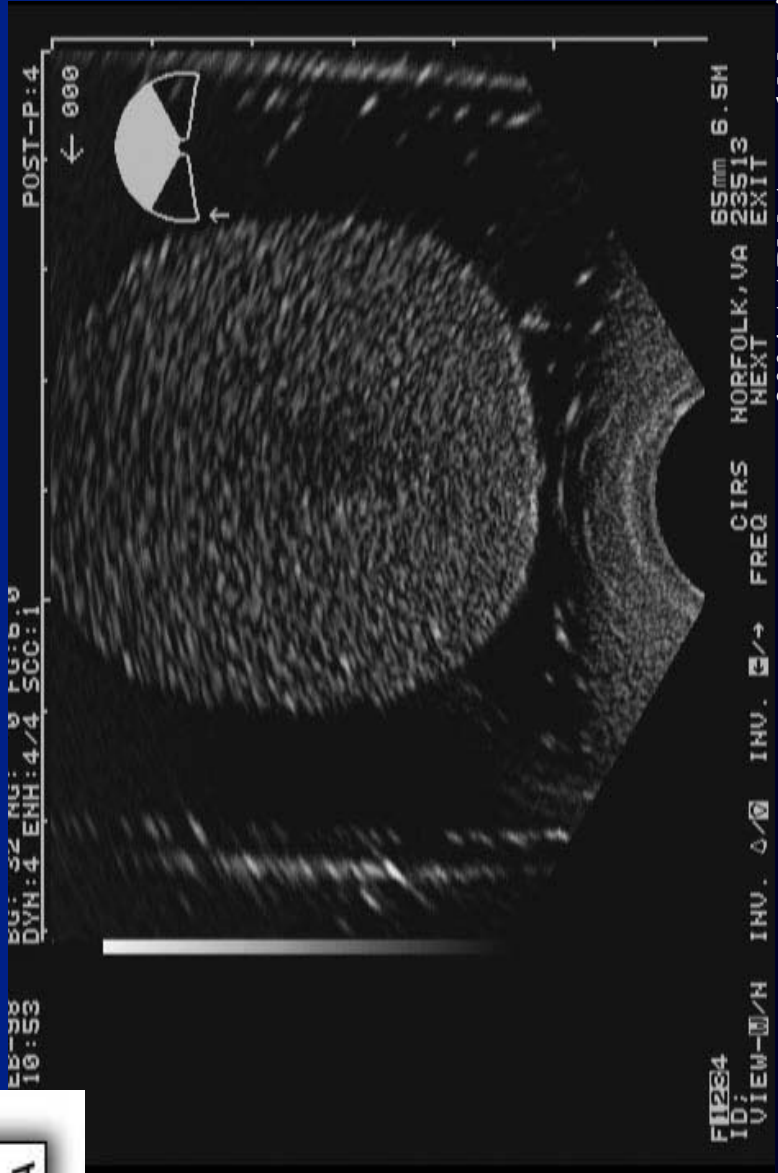


# Demonstrations

- **3D Systems**
  - Mainly fetal ultrasound
- **Brachytherapy Systems**
  - Demonstrate needle and seed visualization
- **Other Sales demonstrations**



# Brachytherapy



# QA/QC

- Equipment Selection
- Acceptance Testing
- Consistency checks
- Accreditation Programs
  - ACR
  - AIUM
  - ICAVL





# R&D Uses

- Product Development
- FDA Approval Process
- Basic Scientific Research

# Manufacturers

- ATS Labs, Bridgeport, CT
  - [www.atslabs.com](http://www.atslabs.com)
- CIRS, Norfolk VA
  - [www.cirsinc.com](http://www.cirsinc.com)
- Gammex RMI, Madison WI
  - [www.gammex.com](http://www.gammex.com)

# **Diagnostic Ultrasound Physics and QC Workshop : QC Tests and Physics Reviewed**

# Workshop Outline

- QA/QC Introduction and Background
  - QA/QC Requirements
  - Ultrasound Accreditation
  - Resources
- QC Test / Physics Demonstrations
  - Depth of Visualization (Frequency and Frame Rate)
  - Axial and Lateral Resolution (Depth and Frequency)
  - Distance Accuracy
  - Dead Zone and Image Uniformity
  - Anechoic Object Perception
  - Doppler: Gate Angle, Gate Size, and Gate Position
  - Low Contrast Object Detectability

# QA/QC Requirements

- Levels of ultrasound QC testing
  - Level 1, Frequent testing
    - Operator's QC tests
  - Level 2, Semi-annual (or annual) testing
    - Physicist's QC tests
  - Level 3, Acceptance testing
    - Baseline values established

# QA/QC Requirements

- American Association of Physicists in Medicine
  - **Ultrasound Task Group No. 1, “Real-time B-mode ultrasound quality control test procedures”**
    - Authors/editors: MM Goodsitt *et al.*
    - Medical Physics, 25(8):1385-406, 1998 August
  - **AAPM Ultrasound Committee**
    - Annual continuing education courses
    - Annual workshops (hands-on and demonstrations)
  - **Remotely Directed Continuing Education (RDCE)**

# QA/QC Requirements

- American Institute of Ultrasound in Medicine
  - “Quality Assurance Manual for Gray Scale Ultrasound Scanners (Stage 2)”
    - Authors/editors: E. Madsen
    - AIUM, Laurel, MD, 1995
  - “Performance Criteria and Measurements for Doppler Ultrasound Devices: Technical Discussion”
    - 2<sup>nd</sup> Edition
    - AIUM, Laurel, MD, 2002



# QA/QC Requirements

- The Institute of Physical Sciences in Medicine
  - Report 70, “Testing of Doppler Ultrasound Equipment”
    - Authors/editors: PR Hoskins, SB Sherriff and JA Evans
    - York: ISPM, 1994
  - Report 71, “Routine Quality Assurance of Ultrasound Imaging Systems”
    - Authors/editors: R Price
    - York: ISPM, 1995

# Ultrasound Accreditation

- ACR Accreditation ([www.acr.org](http://www.acr.org))
  - Breast Ultrasound Accreditation Program
  - General Ultrasound Accreditation Program
    - Obstetrical
    - Gynecological
    - General
    - Vascular
    - Combination of the above
- AIUM Accreditation ([www.aium.org](http://www.aium.org))
  - Breast, Obstetrical, Gynecological, Abdominal/General

# Ultrasound Accreditation

- ACR QA/QC program specifics
  - Directed by medical physicist or supervising physician
  - Testing must be done at least **semi-annually**
    - Repeat tests and monitor changes over time
    - Implement corrective actions when necessary
    - Results must be documented and maintained on site
- ACR general US accreditation semi-annual tests
  - System sensitivity and/or penetration capability
  - Image uniformity
  - Photography and other hard copy recording
  - Low contrast object detectability (optional)
  - Assurance of electrical and mechanical safety
  - Vertical and horizontal distance accuracy

# Ultrasound Accreditation

- ACR Semi-Annual Breast QC Tests
  - Maximum depth of visualization
  - Distance accuracy (vertical and horizontal)
  - Uniformity
  - Electrical-mechanical cleanliness condition
  - Anechoic void perception
  - Ring down
  - Lateral resolution
  - Quality Control Checklist

# Resources

- Accreditation and QA/QC guidance
  - American College of Radiology<sup>®</sup> (ACR)
  - Intersocietal Commission for the Accreditation of Echocardiography Laboratories<sup>®</sup> (ICAEL) and Vascular Laboratories<sup>®</sup> (ICAVL)
- “Laboratory” demonstrations using physics test equipment and routine clinical equipment
  - Quality assurance phantom(s)
  - Clinical equipment and sonographers

# Resources

- Educational and Research Organizations
  - American Institute of Ultrasound Medicine® (AIUM)
  - American Registry of Diagnostic Medical Sonographers® (ARDMS)
  - American Registry of Radiologic Technologists®
  - Commission on Accreditation of Allied Health Education Programs – Cardiovascular (CAAHEP-DMS) and Diagnostic (CAAHEP-DMS)
  - Joint Review Committee on Education in Diagnostic Medical Sonography (JRCEDMS)

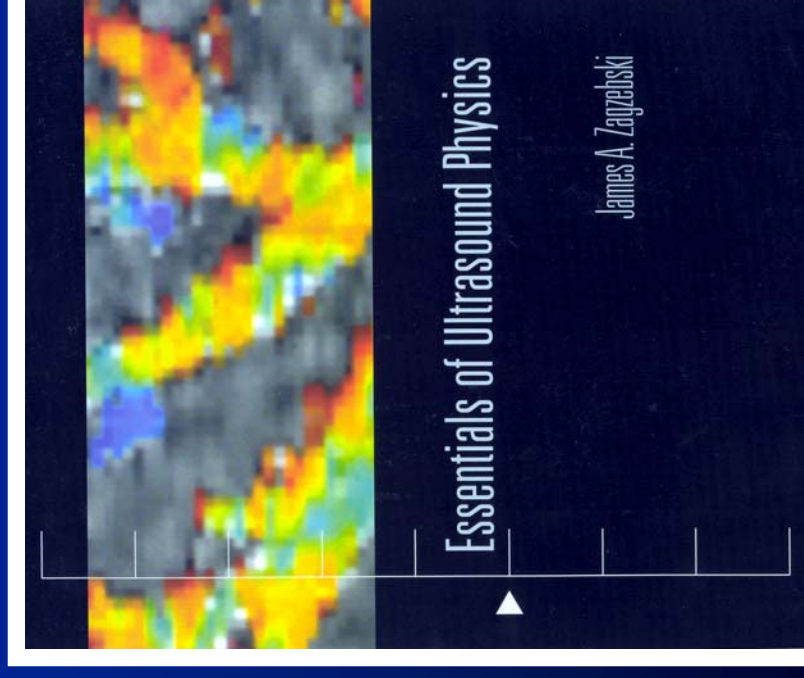
# Resources

- Clinical Ultrasound Physics:  
A Workbook for Physicists,  
Residents, and Students
  - Authors (AAPM US Committee):
    - James M. Kofler, Jr., Ph.D
    - Randell L. Kruger, Ph.D
    - Evan Boote, Ph.D
    - Zhengfeng Lu, Ph.D
    - J. Brain Fowlkes, Ph.D
    - Mark R. Holland, Ph.D
  - Published for the AAPM by Medical  
Physics Publishing (2001)



# Resources

- Many texts are available
  - Refer to workbook for a list of possible references
- Basic topics include
  - Physics review
  - Interaction with matter
  - Instrumentation
  - Image storage and display
  - Doppler ultrasound
  - QC, safety, and bioeffects





# Physics/QC Demonstrations

- Maximum Depth of Visualization QC test
  - The maximum depth of visualization is determined by comparing the gradually weakening echo texture to electronic noises near the bottom of the image
  - Use the same settings and monitor changes
  - Physics demonstration – frame rate and frequency
    - Frame rate is inversely proportional to the maximum depth
      - Frame rate decreases as imaging depth increases
    - Depth of penetration decreases as frequency increases
      - Higher frequency beam is attenuated more rapidly than one transmitted at a lower frequency

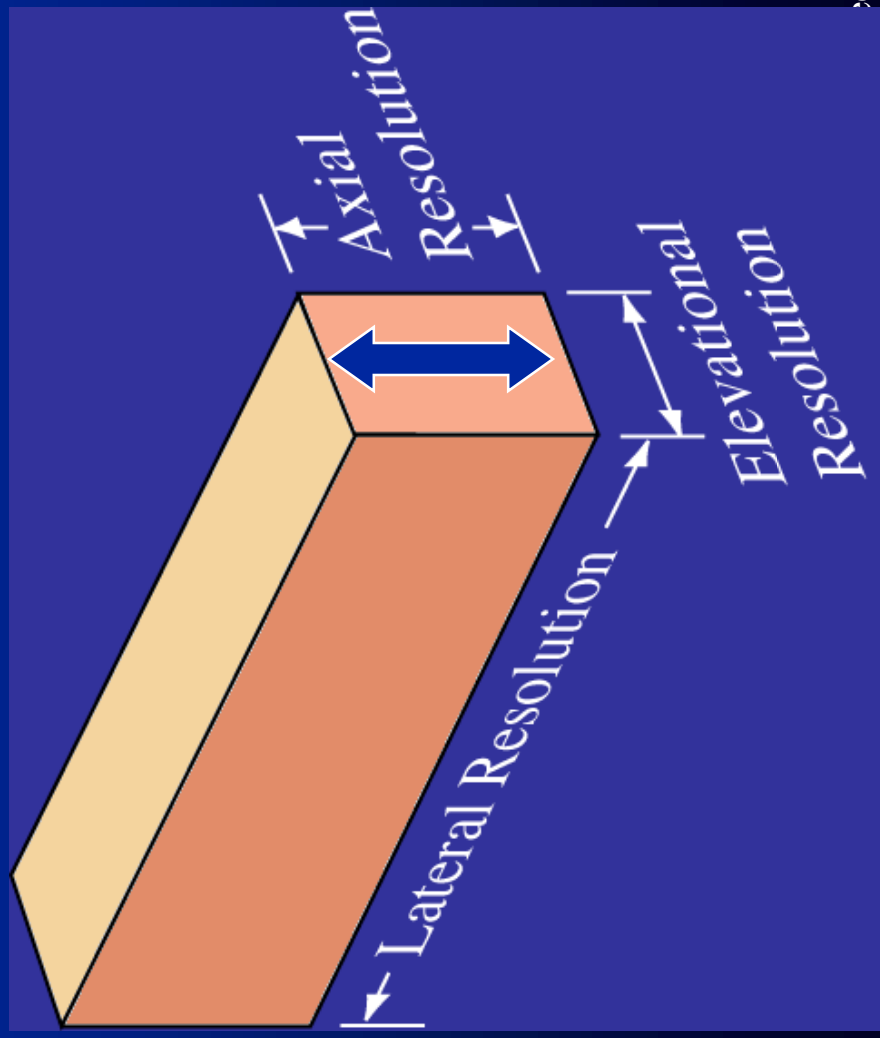
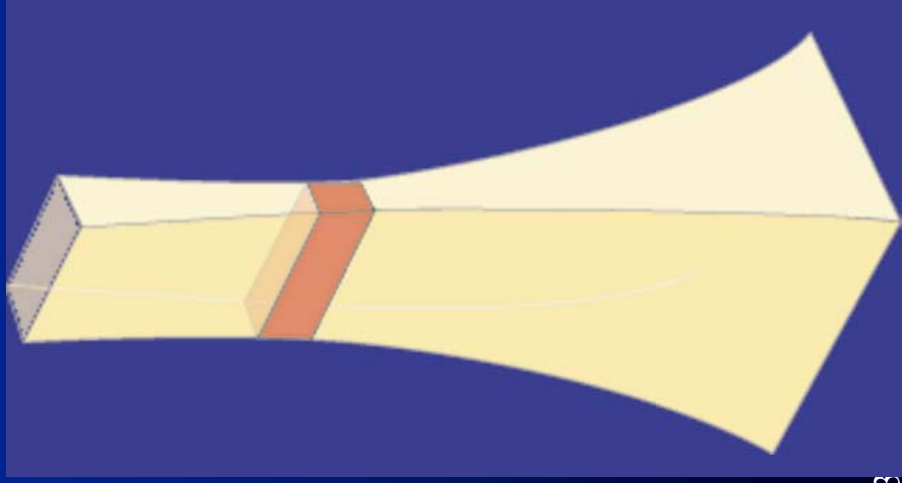
# Physics/QC Demonstrations

Live Demonstration of QC Test or Physics Concept

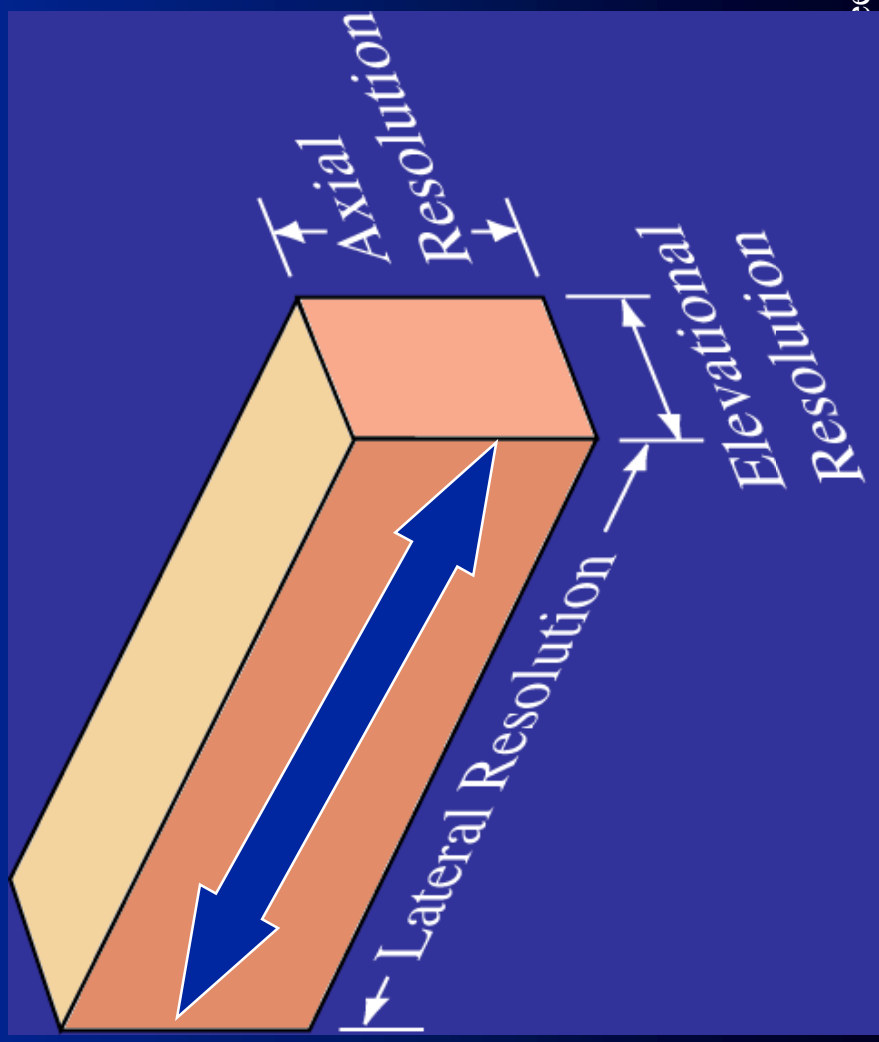
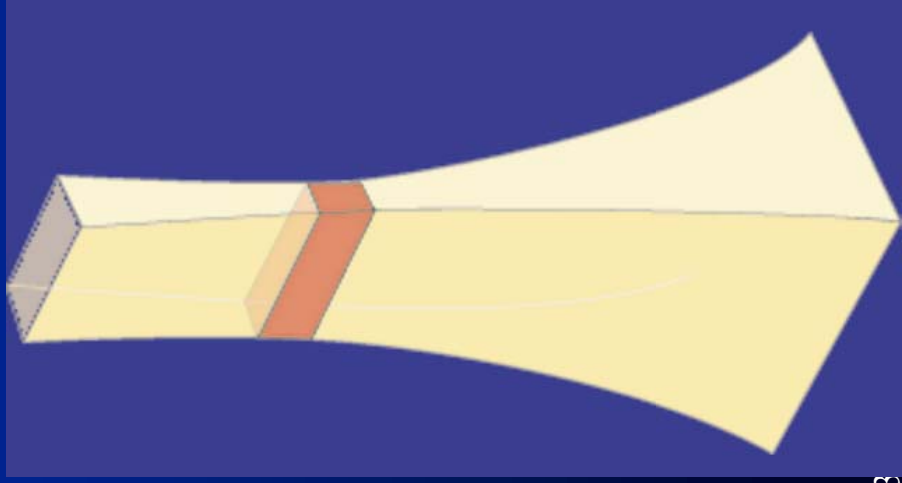
# Physics/QC Demonstrations

- Axial and lateral resolution QC testing
- Spatial resolution may be evaluated by either of the following ways:
  - Count the number of the pins distinguished without overlap in lateral and axial direction;
    - Minimum target spacing is documented
  - Measure the size of the pin in lateral and axial direction
- Physics demonstration: imaging depth and frequency
  - Compare depth and frequency to measured lateral resolution
  - Demonstrate better axial resolution at a higher frequency

# Physics/QC Demonstrations



# Physics/QC Demonstrations



# Physics/QC Demonstrations

Live Demonstration of QC Test or Physics Concept

# Physics/QC Demonstrations

- Distance accuracy QC testing
  - Scan the phantom with a vertical column and a horizontal row of reflectors
  - The digital caliper readout on screen is checked against the known distance between reflectors
    - Vertical: 1.5% of the actual distance or 2 mm, whichever is greater
    - Horizontal: 3% of the actual distance or 3 mm, whichever is greater

# Physics/QC Demonstrations

Live Demonstration of QC Test or Physics Concept



# Physics/QC Demonstrations

- Dead zone (ring-down) QC testing
  - A group of reflectors consisting of fibers are placed at different separations from the top of the phantom ( $\sim 1-8$  mm)
  - As the transducer scans across the top, the distance from the transducer to the first reflector completely imaged is the dead zone distance (ring down)
  - Record and monitor performance

# Physics/QC Demonstrations

Live Demonstration of QC Test or Physics Concept

# Physics/QC Demonstrations

- Image uniformity QC testing
  - Adjust the TGC controls and other sensitivity controls to obtain an image as uniform as possible
  - Inspect the image for:
    - Vertical or radial oriented streaks
    - Dropouts
    - Reduction of brightness near edges of the scan
    - Brightness transitions between focal zones
  - Record and monitor performance

# Physics/QC Demonstrations

Live Demonstration of QC Test or Physics Concept

# Physics/QC Demonstrations

- Anechoic object perception evaluation
  - This test evaluated the system's ability to detect and accurately display round, negative contrast objects (cyst) of various sizes
  - Use calipers to measure height and width of object
  - Performance criteria and corrective action limits
    - Major distortion: height and width differ by >20%
    - A consistent measurable change from the baseline

# Physics/QC Demonstrations

Live Demonstration of QC Test or Physics Concept

# Physics/QC Demonstrations

- Low contrast object detectability evaluation
  - Scans of a low contrast resolution phantom can reveal the low contrast object detectability
    - Monitor and track performance
    - Describe noise and contrast
  - An optional test on the ACR semi-annual QC test list for general ultrasound accreditation

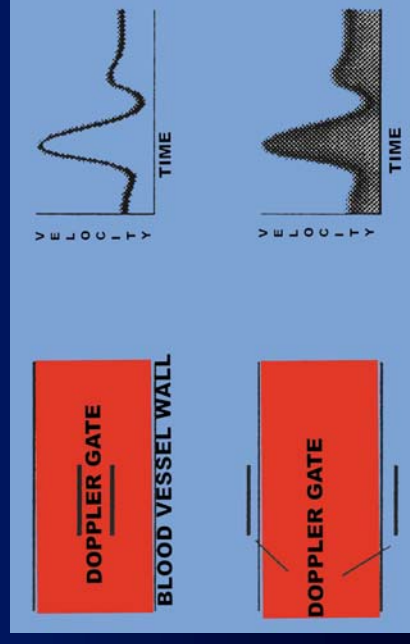
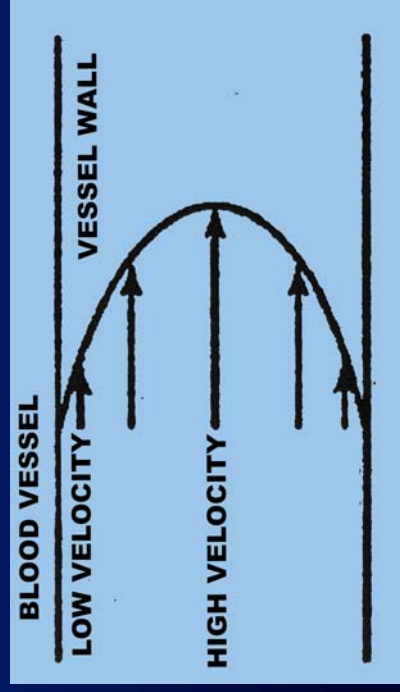
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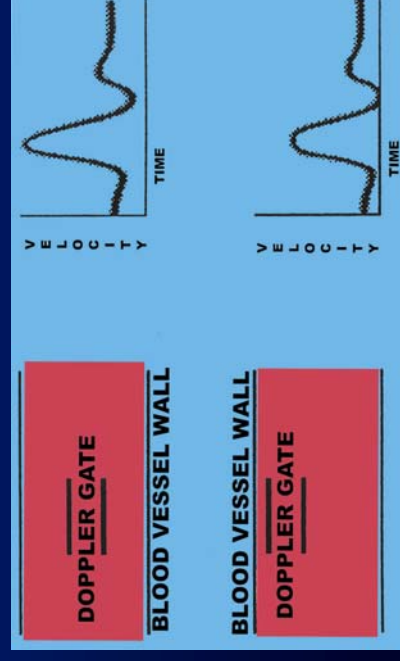
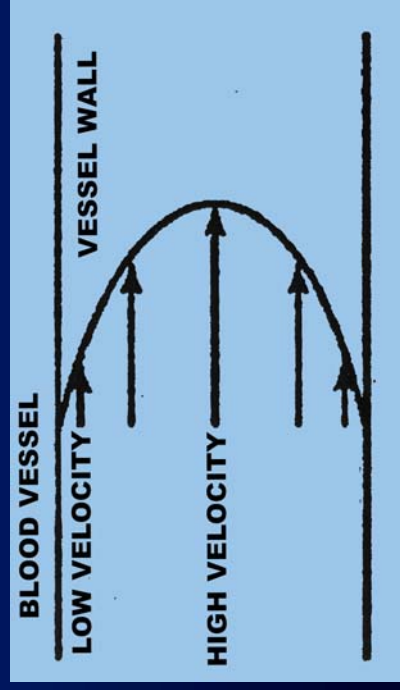
# Physics/QC Demonstrations

- Doppler demonstrations; gate-size and –position
  - Gate size determines the size of the sample volume
  - Blood flow is non-uniform across the vessel cross-section
  - Small gate size: range of velocities is small, spectra is narrow
  - Large gate size (encompasses entire vessel), spectra is wider



# Physics/QC Demonstrations

- Doppler demonstrations; gate-size and -position
  - Similar to gate size, position also influences data
- Blood flow is non-uniform across the vessel cross-section
- Placing gate in center of vessel - higher velocity
- Placing gate at the vessel wall - lower velocity



# Physics/QC Demonstrations

Live Demonstration of QC Test or Physics Concept

# Questions?

Thank You!