Outline

• Introduction
• ACR ultrasound accreditations
• Ultrasound QC testing procedures
• Efficacy of ultrasound QC program

• The goal of an ultrasound quality assurance program is to maintain clinical ultrasound imaging equipment at an optimal and consistent level of performance.
• One crucial aspect of such programs is to include comprehensive quality control (QC) testing so equipment defects can be detected and corrected before they affect clinical outcomes.
Ultrasound Phantoms

Tissue-mimicking
- Speed of sound propagation
- Attenuation coefficient
- Backscatter coefficient (echogenicity)
- Nonlinearity parameter (B/A)
- Shear wave elasticity properties
- Thermal properties for HIFU

Water-based versus rubber-based
- Caution about phantom desiccation
- Caution about sound speed effect

Water-based: Phantom Desiccation

- Water-based phantom has a potential dehydration problem over time.
  - This problem can be minimized by properly handling the phantom.

Rubber-based: Sound Speed Effect

- No phantom desiccation; thus good for long-term consistency tests
- Slower sound speed that creates problems in beam defocusing

Q Chen and JA Zagzebski, UMB, 30(10):1297-306, 2004
NJ Dudley et al, UMB, 28(11-12):1561-4, 2002
Various Levels of QC Testing

<table>
<thead>
<tr>
<th>Level</th>
<th>Testing Time</th>
<th>Testing Frequency</th>
<th>Testing Personnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>• Quick check; • no special tool needed;</td>
<td>Daily or weekly or monthly</td>
<td>By ultrasound system users and overseen by medical physicists</td>
</tr>
<tr>
<td>Level 2</td>
<td>Quick QC tests with a simple phantom;</td>
<td>Quarterly or semi-annually</td>
<td>By ultrasound system users and overseen by medical physicists</td>
</tr>
<tr>
<td>Level 3</td>
<td>Comprehensive QC tests with phantoms;</td>
<td>Annual or every two years</td>
<td>By medical physicists</td>
</tr>
</tbody>
</table>

Outline

• Introduction
• ACR ultrasound accreditations
• Ultrasound QC testing procedures
• Efficacy of ultrasound QC program

ACR Accreditation

• Breast Ultrasound Accreditation Program (including Ultrasound-guided Breast Biopsy)
• General Ultrasound Accreditation Program
  • Obstetrical
  • Gynecological
  • General
  • Vascular
  • Combination of the above

• ACR QC requirements are same now for both ultrasound accreditation programs
• Includes descriptions of acceptance testing, annual survey, continuous QC, and preventative maintenance
• There is no ACR designated ultrasound phantom
• There is no ACR ultrasound QC manual
ACR Continuous QC

<table>
<thead>
<tr>
<th>QC Test</th>
<th>Description</th>
<th>Minimum Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Physical and Mechanical Inspection</td>
<td>Assesses the mechanical integrity of the equipment, and the safety of patient and operator</td>
<td>Semi-annually</td>
</tr>
<tr>
<td>2. Image Uniformity and Artifact Survey</td>
<td>Identifies the presence of artifacts, often seen in lateral views in images of the ACR phantom with lesions, or images acquired without the use of gel or phantom. The test is used to reveal any systematic artifacts.</td>
<td>Semi-annually</td>
</tr>
<tr>
<td>3. Geometric Accuracy (mechanically scanned transducers only)</td>
<td>Commonly involves use of the scanner collars to measure the perpendicularity of two targets. Measurement is required only in the mechanically scanned directions.</td>
<td>Semi-annually</td>
</tr>
<tr>
<td>4. Ultrasound Scanner Electronic Image Display Performance</td>
<td>Maintaining the performance of the image display is critical for providing the proper diagnostic benefit of the scanner. They should also include world-map views and the primary orientation (other than color scale) viewed, decade chargers that are indicated on the display and lateral orientation, centered and zoomed views.</td>
<td>Semi-annually</td>
</tr>
<tr>
<td>5. Primary Interpretation Display Performance*</td>
<td>The images displayed on the monitor should not contain any ACR phantom or hard copy film. Display characteristics like color balance, contrast, brightness, and overall image quality. These evaluations are typically performed using specialized test patterns and ultrasound equipment.</td>
<td>Semi-annually or annually based on the specific display technology or prior testing results.</td>
</tr>
</tbody>
</table>

Optional

ACR Continuous QC Program (Level 1&2)

- A continuous QC program is essential to identify problems before the diagnostic utility of the equipment is impacted.
- To be performed by trained sonographers or service engineers
- Semi-annual
- Any issue revealed by the continuous QC should trigger more advanced testing
- List of tests:
  1. Physical and Mechanical Inspection
  2. Image Uniformity and Artifact Survey
  3. Geometric Accuracy (mechanically scanned transducers only)
  4. Ultrasound Scanner Electronic Image Display Performance
  5. Primary Interpretation Display Performance
ACR Acceptance Testing

- To be done before clinical usage
- Should be comprehensive to provide complete baseline for comparison with future test results
- Include new system, new transducer, major repair and major equipment upgrade as well as an existing equipment pulled from storage

Optional

ACR Annual QC Program (Level 3)

- Effective June 1, 2014, QC documentation is required.
- Annual survey reports and corrective actions must be documented and provided as part of accreditation application.
- The required QC tests must be performed at least annually on all machines and transducers in routine clinical use.
- To be performed by a qualified medical physicist or designee

Required

Question:

For ACR ultrasound accreditation, who is eligible to perform the required annual survey?

1. A medical physicist
2. A service engineer
3. A sonographer
4. A physician
5. All of the above
The ACR strongly recommends that QC be done under the supervision of a qualified medical physicist. The qualified medical physicist may be assisted by properly trained individuals in obtaining data, as well as other aspects of the program. These individuals should be approved by the qualified medical physicist, if available, in the techniques of performing tests, the function and limitations of the imaging equipment and test instruments, the reasons for the tests, and the importance of the test results. The qualified medical physicist should review, interpret, and approve all data. If it is not possible for a qualified medical physicist to perform the tasks designated for a medical physicist, these tasks may be performed by other appropriately trained personnel with ultrasound imaging equipment experience. These individuals must be approved by the physician(s) directing the clinical ultrasound practice.

ACR Annual QC Program (Level 3)

- List of tests:
  1. Physical and Mechanical Inspection
  2. Image Uniformity and Artifact Survey
  3. Geometric Accuracy (optional)
  4. System Sensitivity
  5. Ultrasound Scanner Electronic Image Display Performance
  6. Primary Interpretation Display Performance
  7. Contrast Resolution (Optional)
  8. Spatial Resolution (Optional)
  9. Evaluation of QC Program (if applicable)

Required

Outline

- Introduction
- ACR ultrasound accreditations
- Ultrasound QC testing procedures
- Efficacy of ultrasound QC program
1. Physical and Mechanical Inspection
- to assure mechanical integrity and patient safety

Transducer
• Cables
• Housings
• Transmitting surfaces
• Plug-in easy and secure?
• Prongs bent or loose?

Power Cord
• Cracks?
• Discoloration?
• Damage?

Operator’s Console
• Buttons and knobs
• Burnt out lights?
• Any cracks?

System
• Monitor clean?
• Monitor no scratch?
• Dust filter clean?
• Wheels moved smoothly?
• Wheel locks secure?
• Accessories secure?

---

Examples of deficiencies revealed by visual inspection

---

2. Image Uniformity and Artifact Survey

---
Image Uniformity  
(Automated QC Software)

Create a profile from the median image

S. Larson et al., AAPM Ultrasound Task Group

Debugging uniformity artifacts

- Many artifacts seen are not reproducible (e.g., due to dirty contacts in connector)
- Artifacts may be due to problems with the probe (elements, conductors, connector) or scanner (port, components of data channel)
- Want to be sure we're dealing with a real equipment problem, and ordering repair or replacement of the right component

Nicholas Hangiandreous, AAPM 2013 Annual Meeting
Debugging uniformity artifacts

- When an artifact is initially noted, try...
  - Assuring good coupling to the phantom
  - Checking for dirt/debris on probe face, probe connector or scanner port
    - Inspect equipment for dirt, etc.
    - Remove and re-seat probe in same scanner port
    - Blow out probe connector & scanner port with canned air
  - Checking different combinations of probes and ports (and scanners if possible)
  - Rebooting the scanner, and retesting
  - Flexing the probe cable to assess artifact stability...

Performance criteria for uniformity artifacts (and other tests):
When to fix or replace?

- Risk versus cost equation can be very subjective & can potentially vary over time

- These factors should be considered:
  - Patient and operator safety
    - Abrasion or pinching, electrical, infection/cleaning
  - Risk of incorrect diagnosis


Communicate with the sonographers and the clinicians!
Question: Must all transducer ports be checked for ACR accreditation?
Answer: Ideally each transducer and port should be tested. In the case of single probe, it is likely left plugged into the same port all the time, and other ports are not used. Due to this, not testing the other ports would be acceptable.

http://www.acr.org/Quality-Safety/Accreditation/Ultrasound

3. Image Geometry: Distance Accuracy

- 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;
- Action Level: 1.5mm or 1.5% for Vertical; 2 mm or 2% for Horizontal (AAPM TG1 Report, Goodsitt et al. 1998. http://www.aapm.org/pubs/reports/RPT_65.pdf)
More Image Geometry

- 3-D calibration
- Extended FOV

3D Wire Phantom
3D Egg Phantom
(Courtesy of Dr. JA Zagzebski, UW-Madison)

AIUM 2004

4. System Sensitivity/Penetration

This test should be done with the following settings:
- maximum transmit power,
- proper receiver gain and TGC that allows echo texture to be visible in the deep region,
- transmit focus at the deepest depth.

System Sensitivity/Penetration
(Automated QC Software)


E. Madsen et al, AIUM QA Manual 2014
5. Ultrasound Scanner Electronic Image Display Performance

- Use the built-in test patterns on ultrasound scanner
- Reference to "ACR-AAPM-SIIM Technical Standard for Electronic Practice of Medical Imaging"
- QC: Verify luminance response; Visual assessment of general display quality; Artifact survey

For quick checks, the gray scale bar may be used.
6. Primary Interpretation Display Performance
- This means the workstation monitors in the reading room for ultrasound imaging diagnosis
- This doesn’t include those remote workstations
- This also includes the hard copy devices

AAPM TG-18 Report, 2005

7. Contrast Resolution (optional)
- Low contrast lesions
- Anechoic targets
- Cylindrical targets vs spherical targets

1 ½ D (Matrix) Transducer

Conventional Linear Array Transducer

Spherical Lesion Detectability

Courtesy of Dr. J. A. Zagzebski, UW-Madison
8. Spatial Resolution (optional)

9. Evaluation of QC Program

– Provides an independent assessment of the QC program
– Checks that appropriate actions are taken to correct problems
– Identifies areas where quality and QC testing may be improved
– Enables a comparison of QC practices with those of other ultrasound sites

http://www.acr.org/Quality-Safety/Accreditation/Ultrasound
More QC Tests Not on ACR List:
Ring Down: Can the targets near surface be detected?

Courtesy of Douglas Pfeiffer, Boulder Community Foothills Hospital

Side Lobe Artifacts

Courtesy of Douglas Pfeiffer, Boulder Community Foothills Hospital

Ultrasound Doppler QC Testing

Doppler QC tests include
– Doppler signal sensitivity;
– Doppler angle accuracy;
– Color display and Gray-scale image congruency;
– Range-gate accuracy;
– flow readout accuracy.
Outline

- Introduction
- ACR ultrasound accreditations
- Ultrasound QC testing procedures
- Efficacy of ultrasound QC program

Efficacy of Ultrasound QC Tests

- NM Donofrio et al, JCU 12: 251-260; 1984
  (They found QC tests such as depth of penetration, axial resolution, gray scale efficacious.)

- SC Metcalfe et al, BJR 65: 570-575; 1992
  (They found poor correlation between subjective operator assessment and QC parameters including lateral resolution, dynamic range and slice thickness.)

  (They emphasize the importance of rigorous testing of circumference measuring calipers in obstetric ultrasound applications.)

- NJ Dudley et al, EJU 12: 233-245; 2001
  (The analysis of an ultrasound QA program results lead to adjust of testing frequency)

Efficacy and Sensitivity of Current QC

Four-year experience with a clinical ultrasound quality control program
- More than 45 scanners and 265 transducers were included.

- QC frequency was semi-annual at the beginning and quarterly towards the end of the four-year study period.
- 88.2% of the failures were transducers and the rest scanner components.
- The phantom uniformity evaluation detected 66.3% of all failures.
- The mechanical integrity check detected 25.1% of all failures.
- Depth of penetration and distance accuracy tests were not effective in detecting equipment failures.
If the transducer defect is the main cause of ultrasound system performance degradation, tests should be done periodically to check all the transducers.

Efficacy and Sensitivity of Current QC


- Used the transducer testing device on annual basis in 13 clinics at 5 hospitals in the Stockholm area.
- Initial failure rate of 39.8% was found among transducers in routine clinical practice.
- Three years after the introduction of annual transducer testing, the failure rate was lowered to 27.1%.
- It is difficult for the user to realize when the transducer function is deteriorating.
- Main causes for transducer failure: transducer handling, workload.
- Transducer failure happened to both newer and older ones.
Accuracy of Volumetric Flow Rate Measurements (K Hoyt et al, J Ultrasound Med 2009; 28:1511-1518)

- 5 ultrasound scanners, 3 experienced operators, 1 Doppler flow phantom and control system
- Flow rate from 100 – 1000 ml/min. Accuracy is better at lower flow rate
- Some scanner is poorer than others in flow rate accuracy
- Doppler QC is needed to ensure accurate flow rate measurements

AIUM Accreditation

www.aium.org

- Ultrasound practices in various specialties:
  - Abdominal/General
  - Breast
  - Gynecologic
  - Urologic
  - Head/Neck (start 1/1/2015)
  - Dedicated Musculoskeletal
  - Dedicated Thyroid/Parathyroid
  - Fetal Echocardiography
  - Obstetric or Trimester-Specific Obstetric

- Ultrasound equipment quality assurance:
  - QA Program should be in place.
  - Routine calibration is required at least once a year.
  - Practices must meet or exceed the AIUM quality assurance guidelines.

Examples: Level 1 QC Tests

Failure in Level 1 tests may activate level 2 or level 3 tests
Standards and Guidelines

**AIUM**

**AAPM**

**ACR**
- ACR technical standard for diagnostic medical physics performance monitoring of real time ultrasound equipment, Revised 2011 (Resolution 3).

**IPSM**
Standards and Guidelines

IEC
• IEC/TR 60854 Ed. 1.0 (1986): Ultrasonics – Methods of measuring the performance of ultrasonic pulse-echo diagnostic equipment
• IEC/TR 61390 Ed. 1.0 (1996): Ultrasonics – Real-time pulse-echo systems – Test procedures to determine performance specifications
• IEC 61391-1 Ed. 1.0 (2006): Ultrasonics – Pulse-echo scanners – Part 1: Techniques for calibrating spatial measurement systems and measurement of systems and measurement of system point spread function response
• IEC 61391-2 Ed. 1.0 (2010): Ultrasonics – Pulse-echo scanners – Part 2: Measurement of maximum depth of penetration and local dynamic range
• IEC 61685 Ed. 1.0 (2001): Ultrasonics – Flow measurement systems – Flow test object
• IEC 61895 Ed. 1.0 (1999): Ultrasonics – Pulsed Doppler diagnostic systems – Test procedures to determine performance
• IEC/TC 62558 Ed. 1.0 (2011): Ultrasonics – Real-time pulse-echo scanners – Phantom with cylindrical, artificial cysts in tissue-mimicking material and method for evaluation and periodic testing of 3D distributions of void-detectability ratio (VDR)

Any Questions? Or Comments?

References