Ultrasound ACR Accreditation: Roles of the Medical Physicist

ACR Requirements for Routine Quality Control

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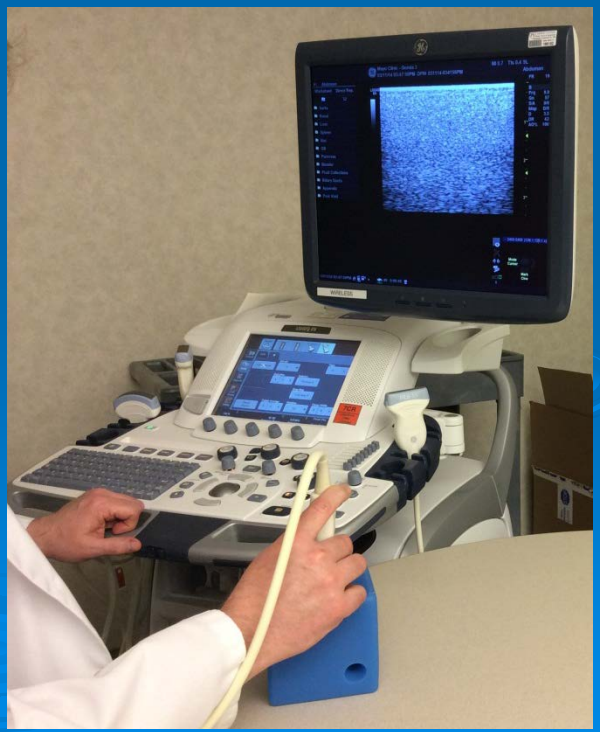


Learning Objectives

- Understand the current ACR ultrasound accreditation requirements for routine quality control, and methods for satisfying these requirements
- Understand the physicist's role in implementing and supervising a continuous ultrasound QC program

Outline of Topics

- Overview of ACR routine QC: required tests and frequencies
- How can practices meet these requirements?
  - Physical and mechanical inspection
  - Image uniformity and artifact survey
  - Geometric accuracy (mechanically scanned transducers only)
  - US scanner electronic image display performance
  - Primary interpretation display performance

Outline of Topics (continued)

- Routine QC documentation
  - Logbooks, procedures, sample findings
- How long does routine QC take?
- Evaluation of QC program in annual survey
- General quality improvement suggestions
- Personnel considerations
  - Who must/can do the QC work?
- Conclusion

Overview of routine QC

- Semiannual routine QC testing of scanner and all probes is required
  - Quarterly testing is recommended
- This is *in addition* to the annual survey
  - E.g. ~4 and 8 months > annual survey

Routine QC		
QC Test	**Description**	**Minimum Frequency**
1. Physical and Mechanical Inspection	Assures the mechanical integrity of the equipment, and the safety of patient and operator.	Semiannually
2. Image Uniformity and Artifact Survey	Identifies the presence of artifacts, often axial or lateral streaks in scans of uniform sections of a phantom. The use of "in-air" images (i.e., images acquired without the use of gel or phantom) may also be useful in detecting superficial artifacts. All transducer ports on each scanner should be tested using at least 1 transducer.	Semiannually
3. Geometric Accuracy (mechanically scanned transducers only)	Commonly involves use of the scanner calipers to measure known distances between test targets. Measurement is required only in the mechanically scanned directions.	Semiannually
4. Ultrasound Scanner Electronic Image Display Performance	Maintaining the performance of the image display is critical for providing the greatest diagnostic benefit of the scanner. They should also include worklist monitors only if used for primary interpretation (other than color analysis). Display characteristics that are evaluated may include gray scale response, presence of pixel defects, and overall image quality. These evaluations are typically performed using specialized test pattern images. See ACR Technical Standard for Electronic Practice of Medical Imaging.	Semiannually
5. Primary Interpretation Display Performance*	Primary diagnostic displays may be electronic soft-copy displays on a PACS workstation or hard-copy films. Display characteristics that are evaluated may include gray scale response and luminance calibration, presence of pixel defects, and overall image quality. These evaluations are typically performed using specialized test pattern images, and may also require photometric equipment. See ACR Technical Standard for Electronic Practice of Medical Imaging. (* Only required if located at the facility where ultrasound is performed.)	Semiannually, or as judged appropriate based on the specific display technology, or prior QC testing data

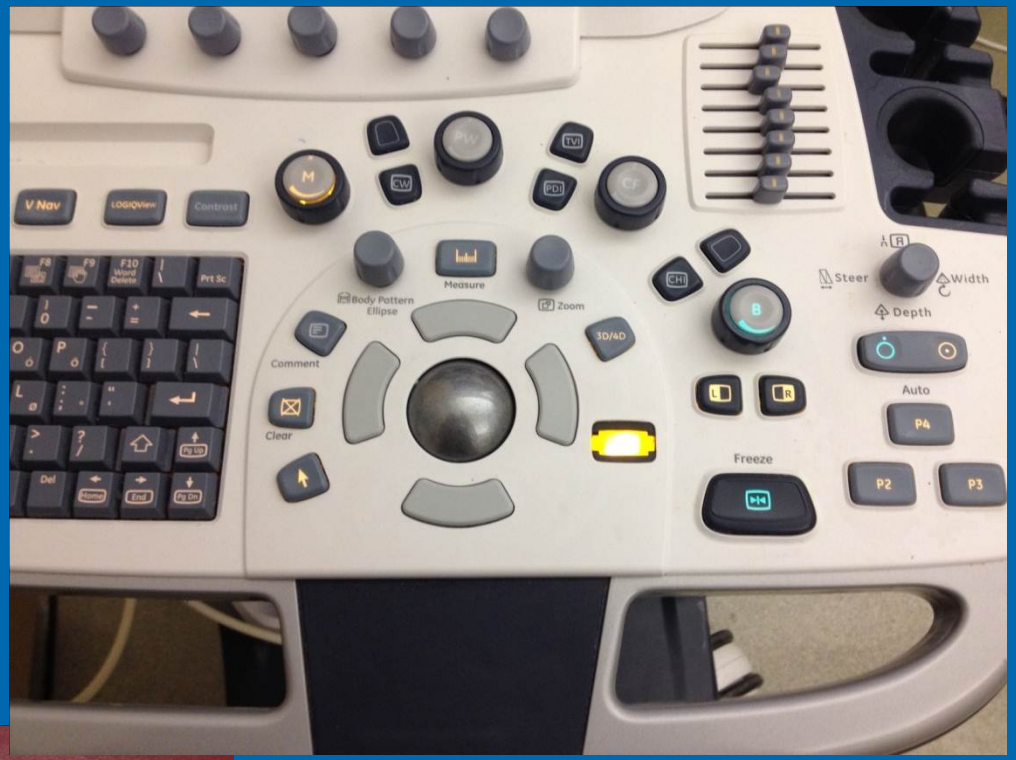
Annual survey:

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, and enables a comparison of QC practices with those of other ultrasound sites.

*

How can requirements be met?
Physical and mechanical inspection

- Same methods as for annual survey:
  Careful inspection of all equipment in the room
- Physicist guidance for routine QC
  - Provide a set of sample findings
  - Pass-fail decisions are often subjective
  - Encourage site to collect examples from their US systems, i.e. take photos of detected issues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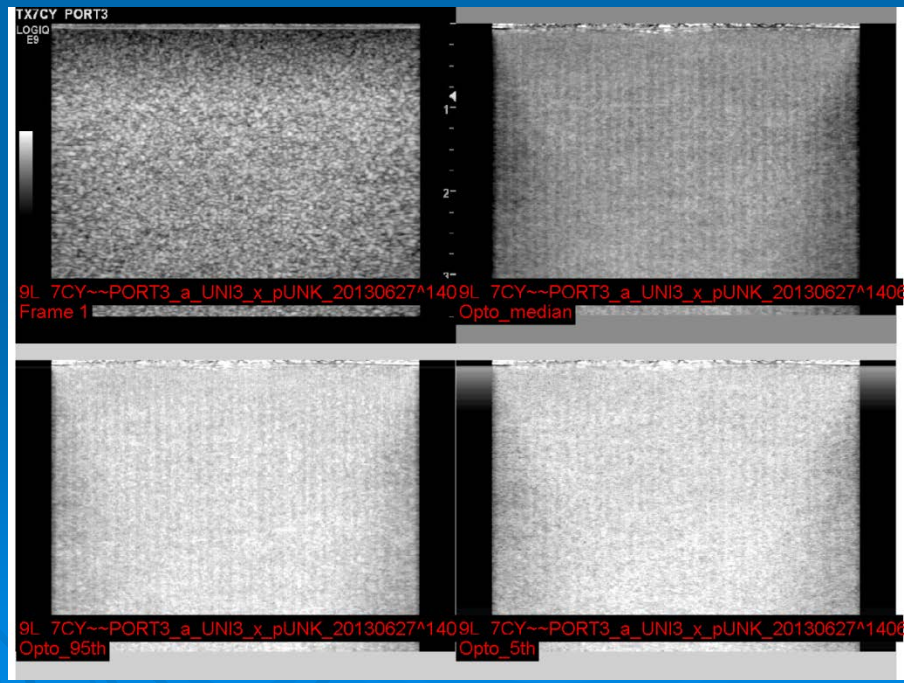
Width
Depth
Auto
P4
P2
P3
Freeze


C15/4-2 Mini Transducer
ICT/8-5 Transducer

How can requirements be met?
Image uniformity and artifact survey

- Complexity of uniformity evaluation as done by physicist poses potential problems for sonogs
  - Software challenges
    - Providing, maintaining analysis SW
    - Availability of multi-frame clips
    - Real-time DICOM xmission difficulties
    - Delay with DVDs / thumb drives
    - Sparse, variable DICOM headers
  - Difficulty debugging and interpreting low-severity arts → potential wasted time



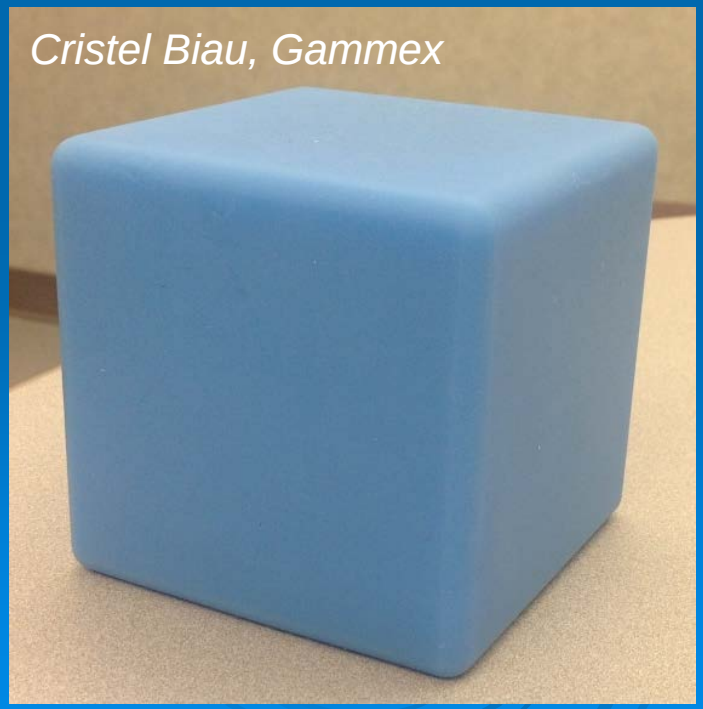
How can requirements be met?
Image uniformity and artifact survey

- Methods with *reduced sensitivity and increased efficiency* compared with those used for annual survey will likely be advantageous for routine QC
  - Pliable phantoms
  - Scan params closely derived from clinical presets
  - Visual inspection of images during live scanning (versus SW processing of images)

How can requirements be met?

Image uniformity and artifact survey

Mayo DIY

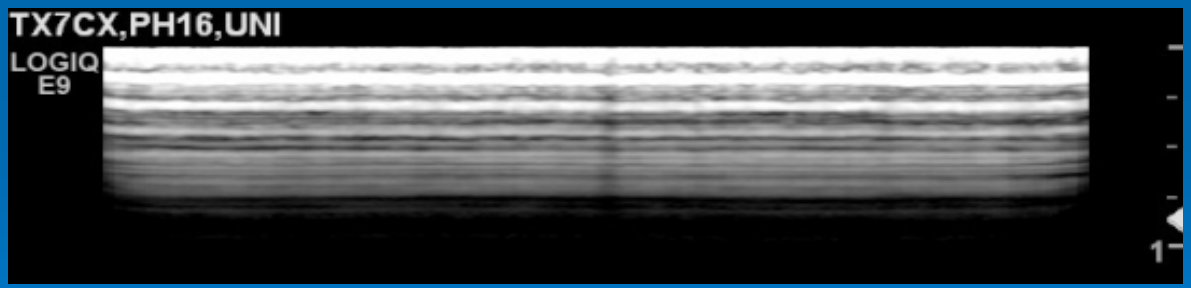


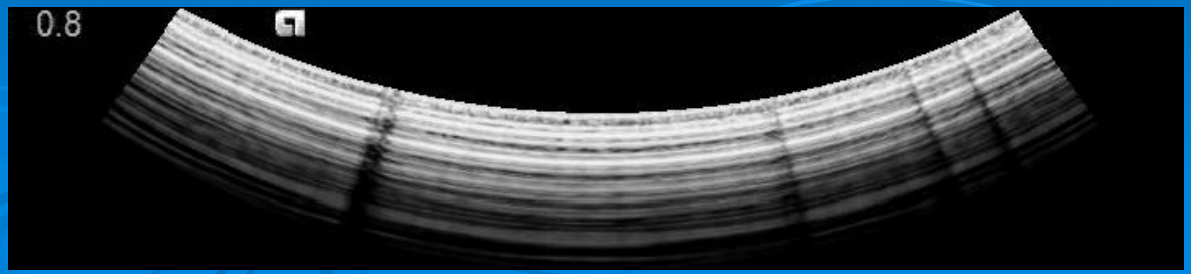
Cristel Biau, Gammex

How can requirements be met?

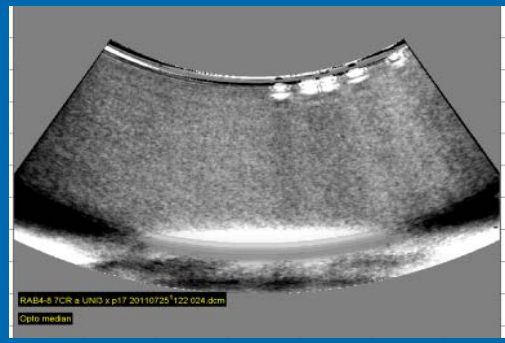
Image uniformity and artifact survey

- Feasibility of an in-air only approach for artifact detection during routine QC?
  - Sensitivity for detecting real artifacts?
  - Likelihood of false positives?

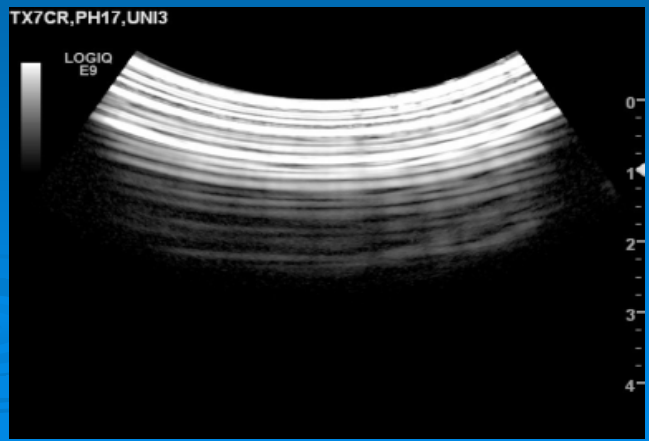




How can requirements be met?
Image uniformity and artifact survey



- Sensitivity for detecting real artifacts?
  In-air artifact detection study
  (Tradup et al, AIUM 2014)
  - Retrospectively reviewed most severe artifacts detected over past 3 years using phantoms and median processing:
    How many were visible in in-air images?



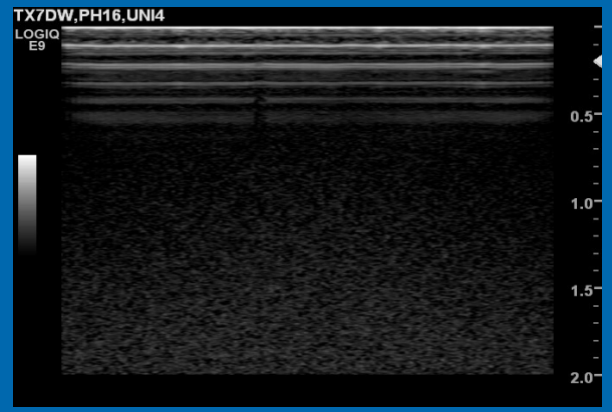
How can requirements be met?
Image uniformity and artifact survey

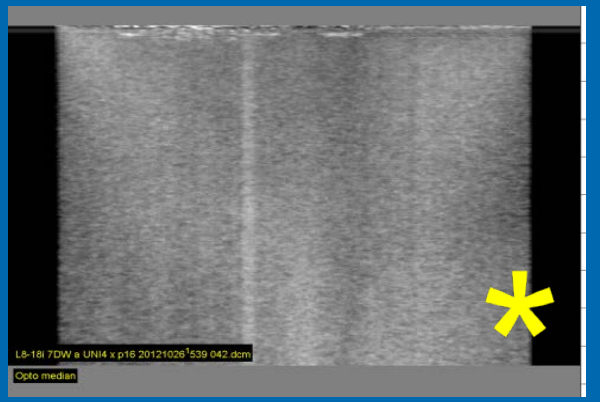
- Sensitivity for detecting real artifacts?
  In-air artifact detection study conclusions
  - The majority (71.2%) of the 52 artifacts in the study were detected in in-air images
    - Not all of the artifacts in the study would result in failure

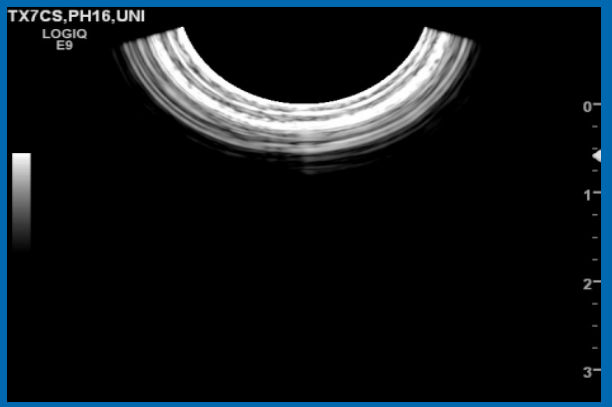
How can requirements be met?
Image uniformity and artifact survey

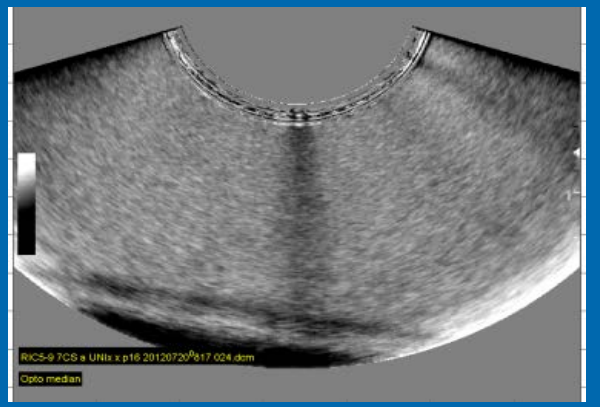
- Sensitivity for detecting real artifacts?
  In-air artifact detection study conclusions
  - Sector probes are a challenge
  - Most severe artifacts are most likely to be detected
  - In-air performance will likely improve if…
    - In-air image appearance is optimized
    - Baseline in-air images are available for comparison

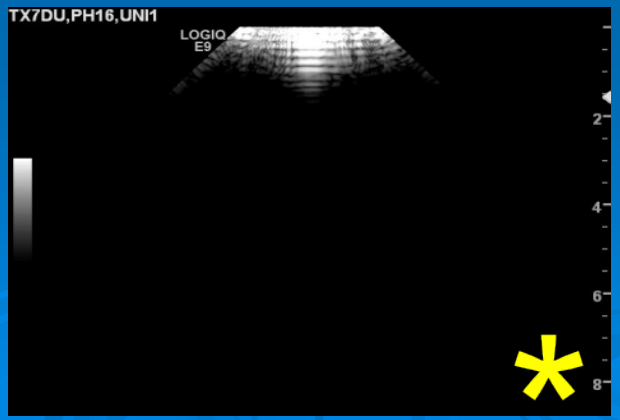
Sample in-air artifacts from linear, intracavitary, and sector array transducers, shown in the in-air and median images.

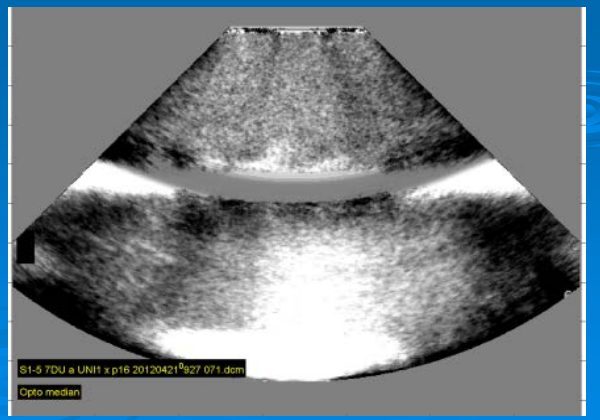








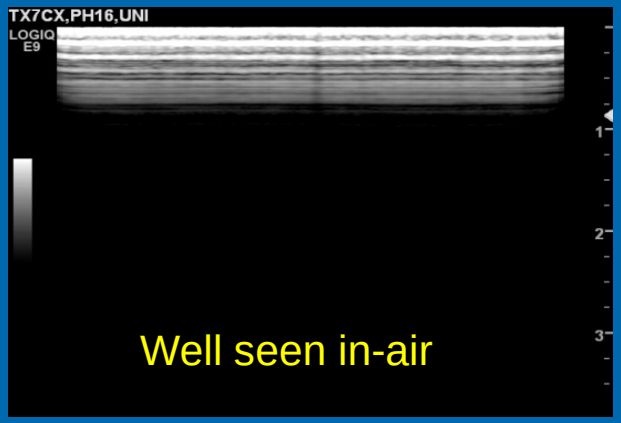


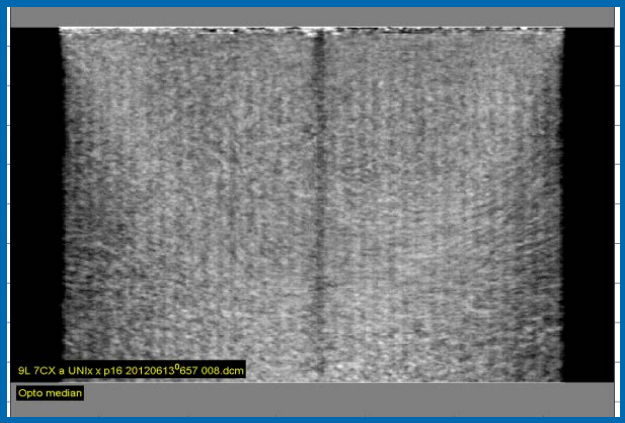


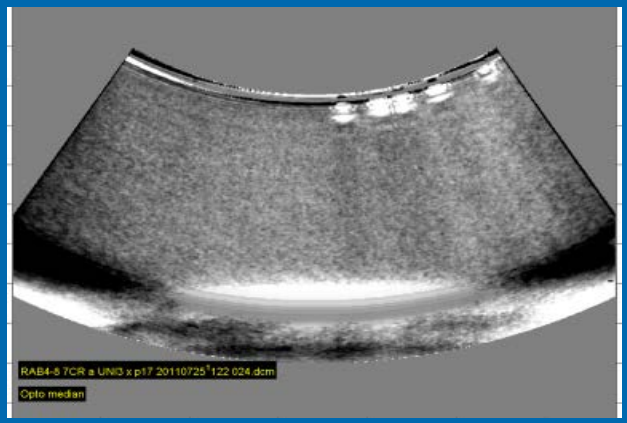
In-air images

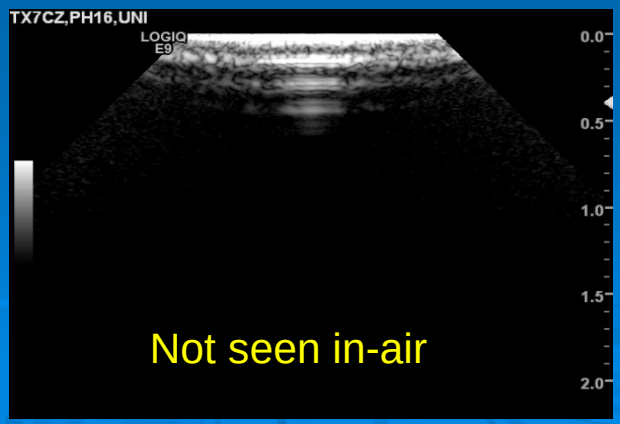
Median images

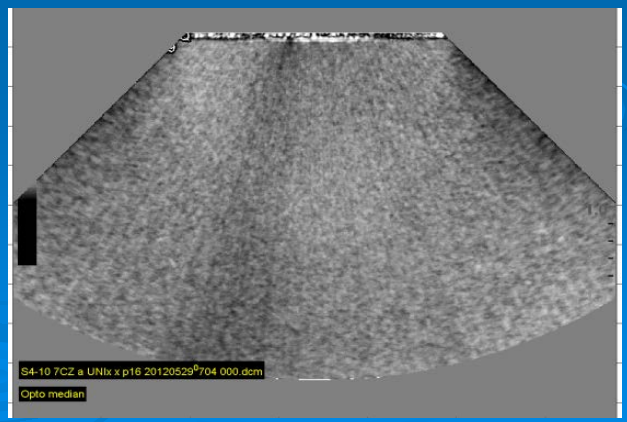
Shown here are examples of artifacts that were judged to be well-seen, subtle, or not seen, in the in-air images. Note, all artifacts are seen in the median images.



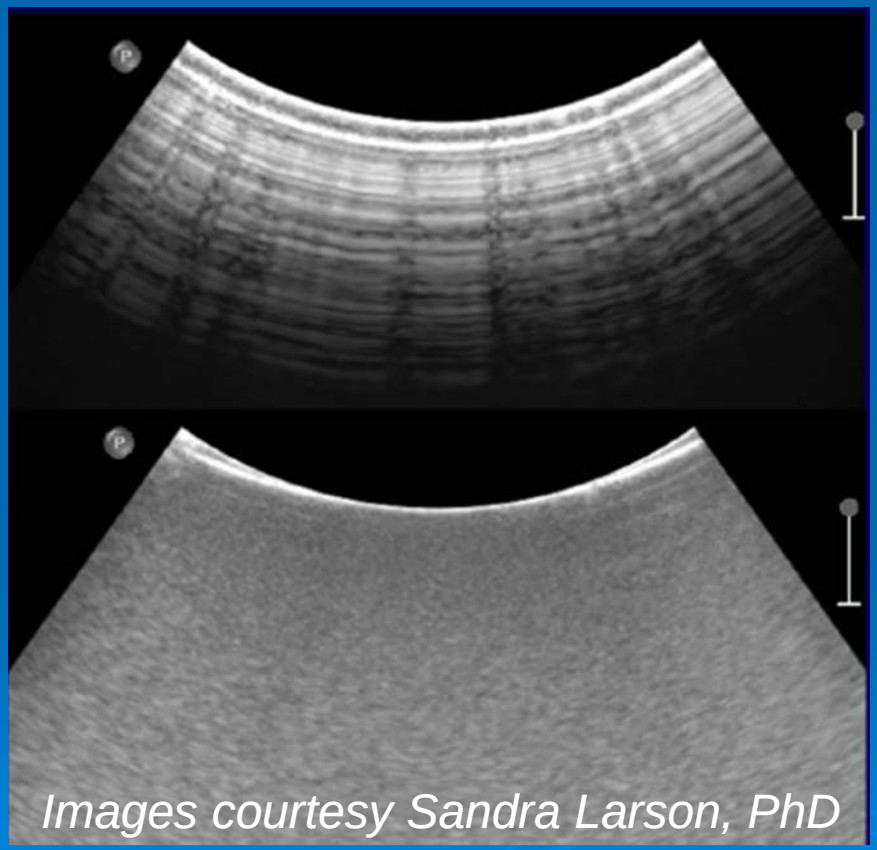


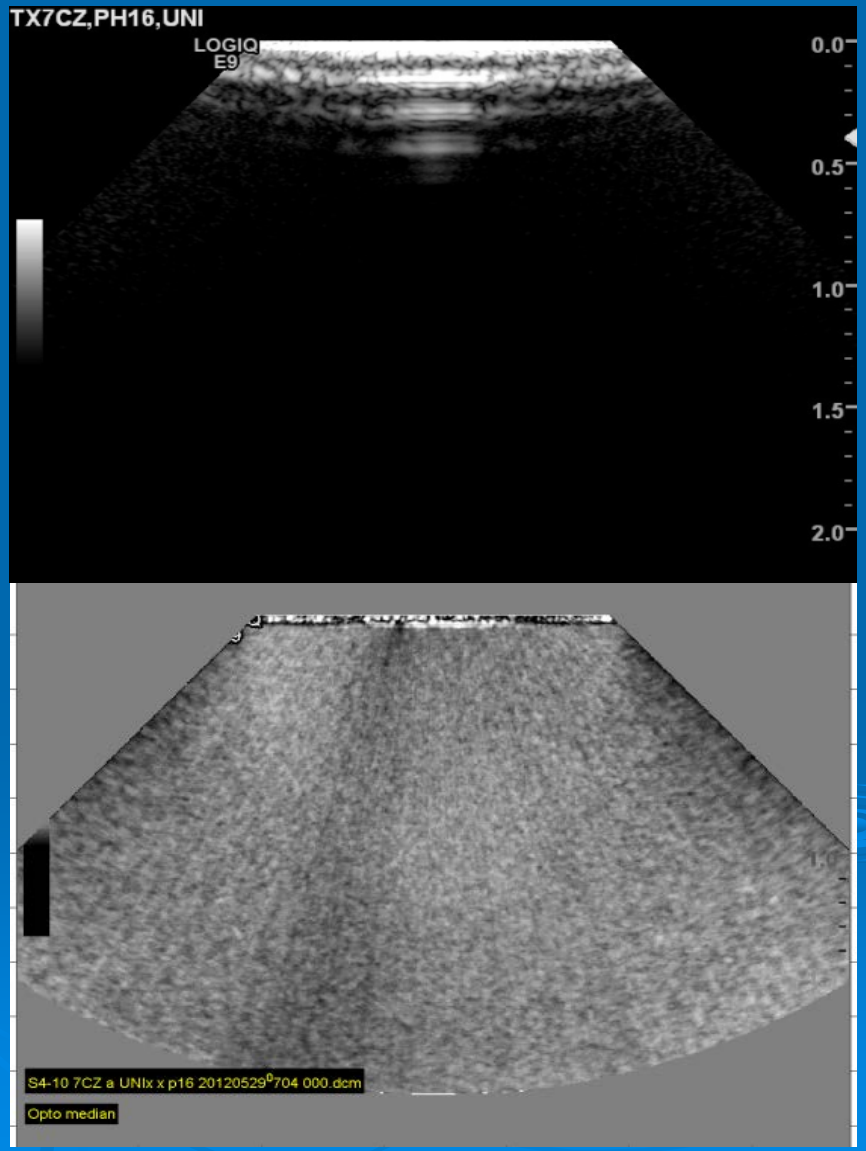




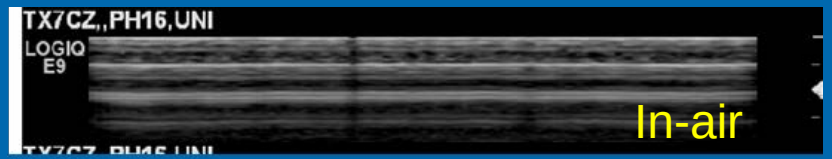


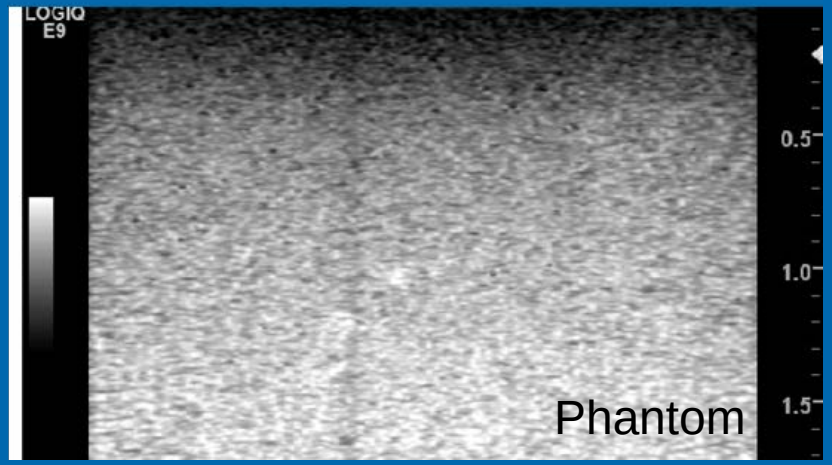
False positives are a definite possibility

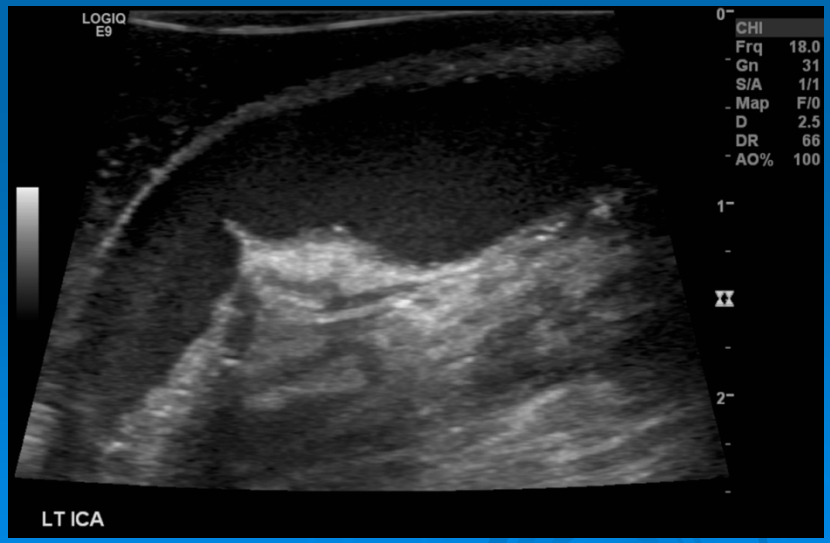


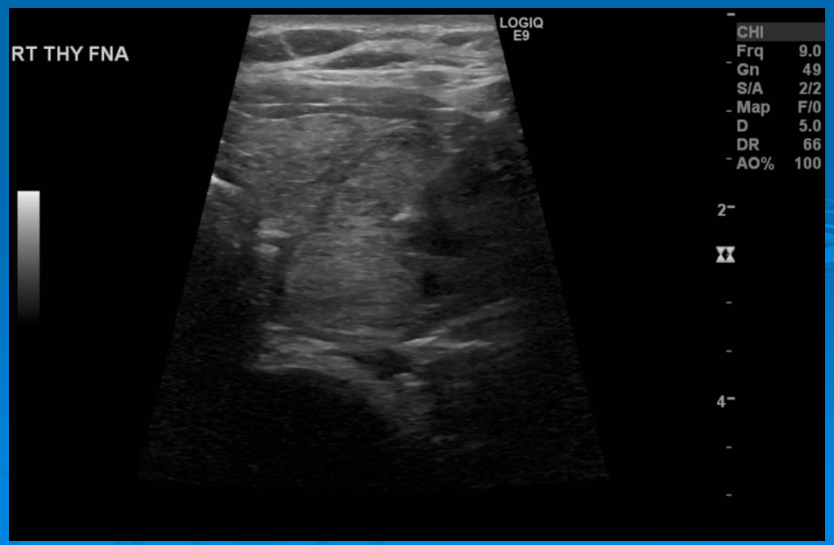


All detected artifacts are not clinically significant



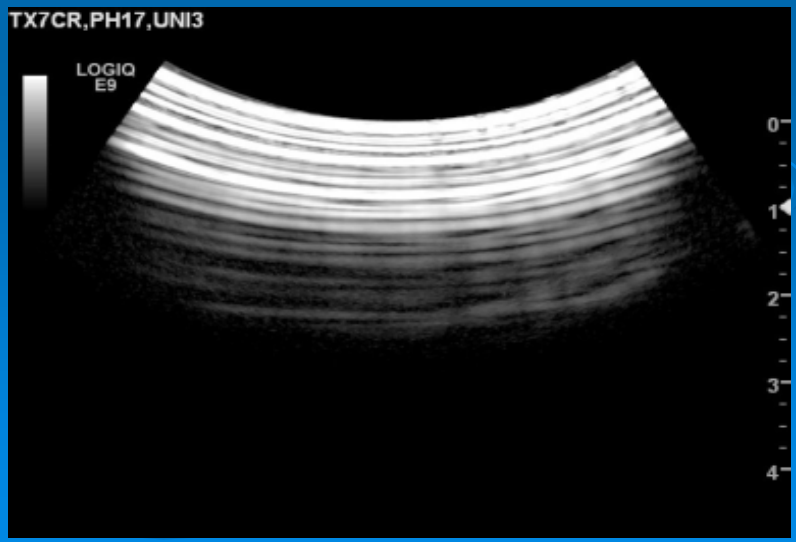






How can requirements be met?
Image uniformity and artifact survey

- Feasibility of an ***in-air only*** approach for artifact detection during routine QC?
  - Acceptable for ACR routine QC, but…
    - Physicist should use a phantom for uniformity assessment during the annual survey
    - Decide pass-fail status only after assessing artifact in anatomical image



Performance criteria:
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

    (Mårtensson M, Olsson M, Segall B, et al. High incidence of defective ultrasound transducers in use in routine clinical practice. Eur J Echocardiogr 2009, 10:389-94.)

When to fix or replace?

- These factors should be considered *(cont.)*:
  - Use for procedures
    - Artifact impact on consistent visibility of needle/device
  - Reduced functionality and effectiveness
    - Limited useful FOV
    - Spectral Doppler (?)
  - Quality indicator of practice
    - Visibility of artifacts in exams to patient and outside MDs
    - Visibility of mechanical issues and DIY fixes to patient
  - Service contract / financial considerations

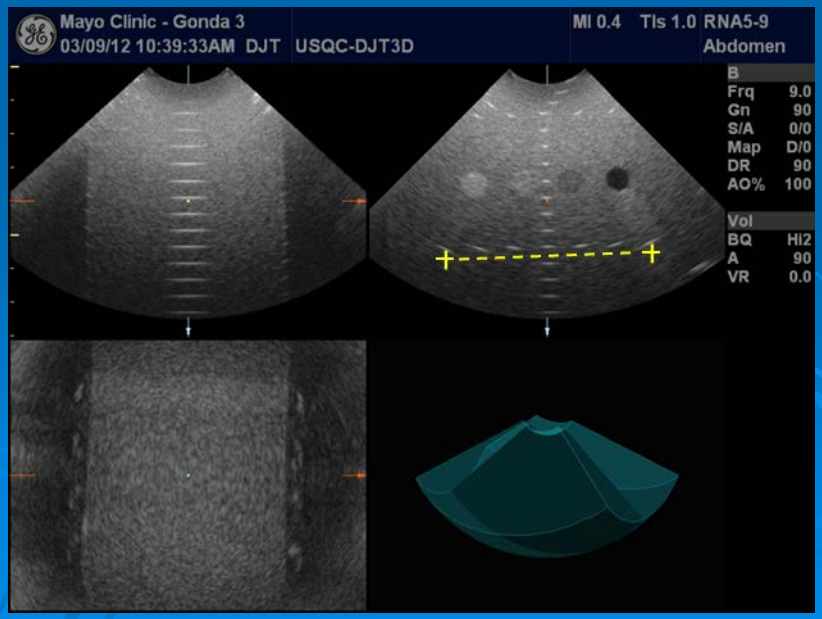
When to fix or replace?

- Practical impact to clinical ultrasound practice can be lessened by notifying users of the issue
  - Greater care when cleaning or disinfection
  - Avoid use of probe for procedures
  - Avoidance of problem regions of array
- Sonographers/MDs are used to recognizing and effectively dealing with many artifacts in every exam
- *Discuss "gray area" potential equipment failures with the practice*

How can requirements be met?

Geometric accuracy

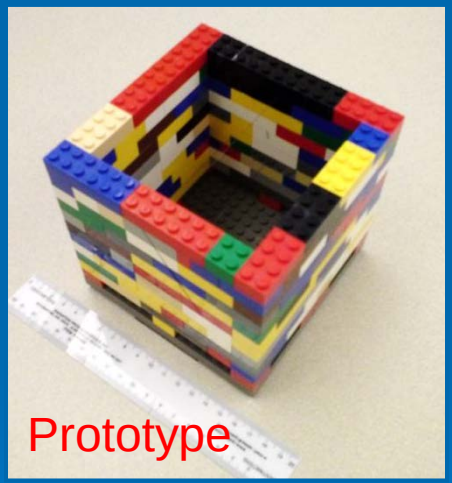
- Very limited requirement:
  - Mechanically scanned probes *only* (mechanical 3D4D probes, mechanical sector scan probes)
  - Measure *only* in the mechanically scanned direction

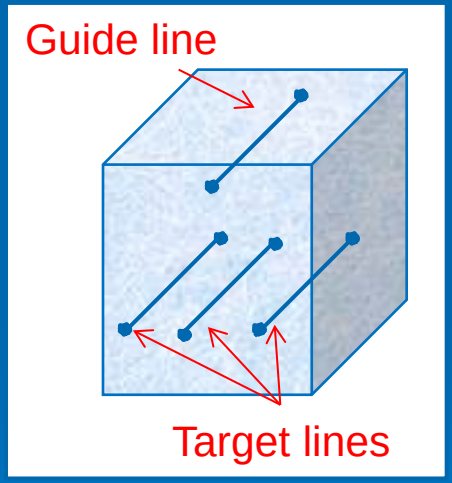


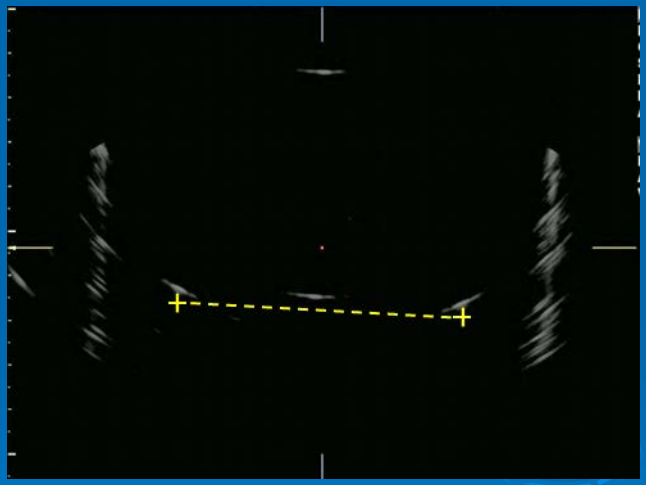
How can requirements be met?

Geometric accuracy

- Inexpensive custom phantoms can provide ≥ repeatability and sensitivity (AIUM 2014)







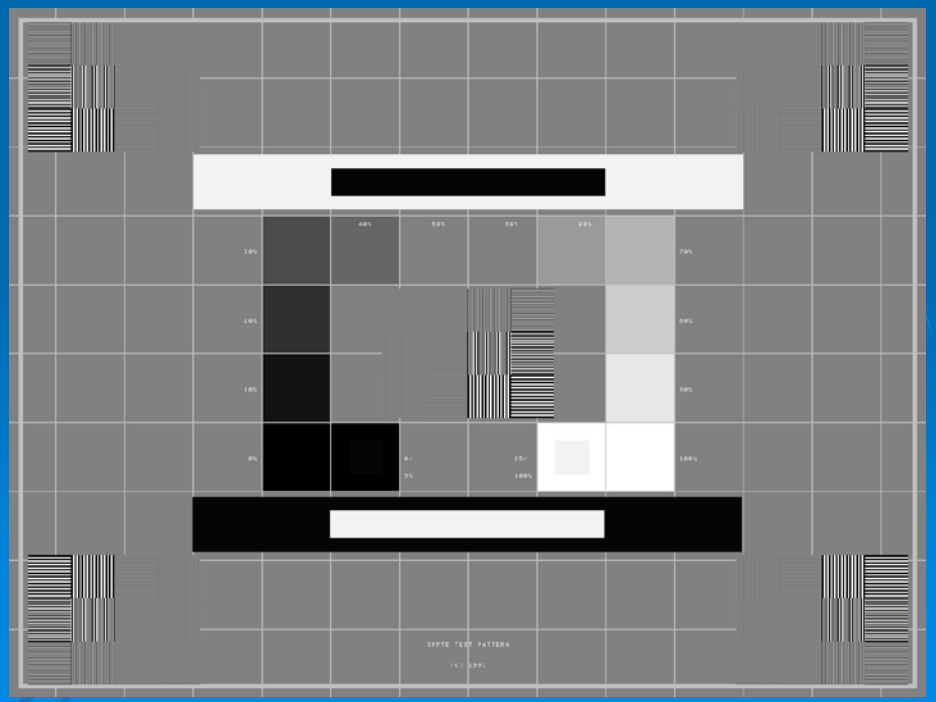
- *Due to low "yield" this test may be made optional for routine QC in the near future*
  (watch ACR website for updates)

How can requirements be met?

US scanner electronic image display performance

- Importance of scanner display quality
  - Detection of occult findings by sonographer

- No photometer needed
  → qualitative test only
- Annual survey methods for qualitative evaluation with test patterns



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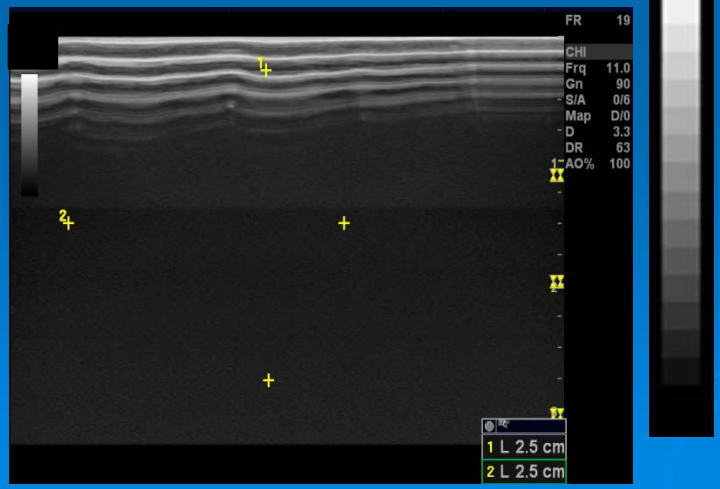
How can requirements be met?
US scanner electronic image display performance

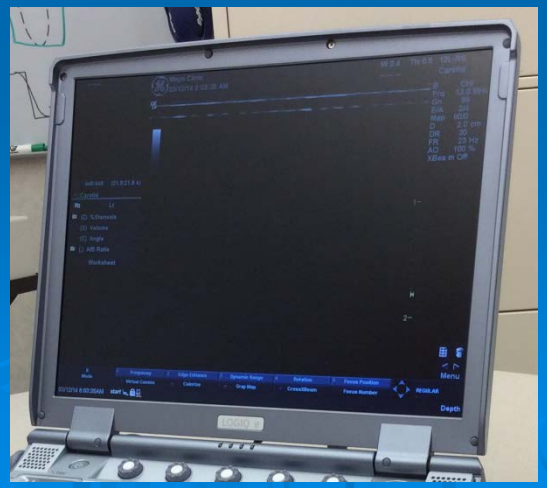
- What if no monitor test patterns are available?
  Do something, even if extremely limited…
  - General image quality (geometric distortion, blur, etc)
  - Gray scale contrast
  - Artifact survey
- ***Press scanner vendors to provide test patterns***

How can requirements be met?

US scanner electronic image display performance

- May be *possible* to create ~test pattern exam *(valuable?)*
  - General image quality (geometric distortion, blur, etc)
  - Gray scale contrast (function of map)
  - Artifact survey

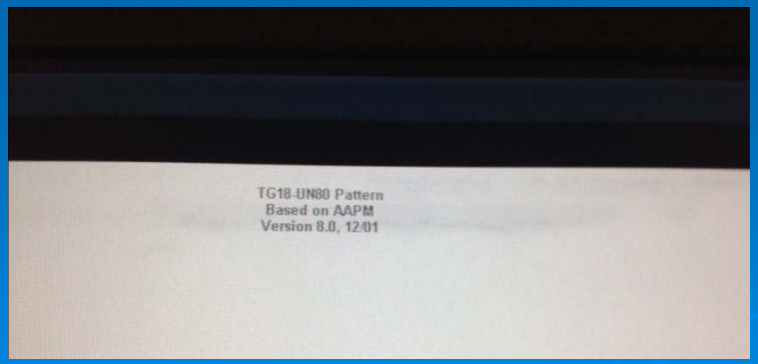


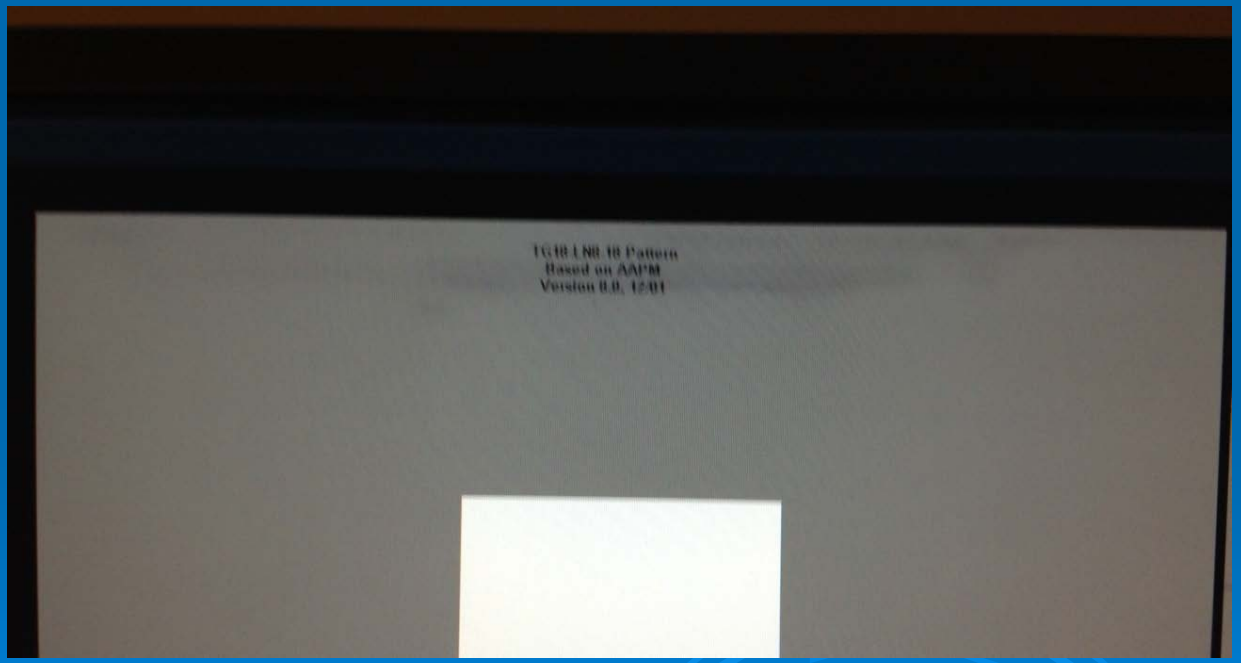


How can requirements be met?

US scanner electronic image display performance

- Other artifacts
  - Ultrasound image region not involved





How can requirements be met?

Primary interpretation display performance

- Only required for *on-site* dx display devices
- No photometer needed → qualitative test only
- Avoid re-work: Is another group already doing this testing? (e.g. IT, PACS support, field service)
  - If so, physicist can attest to appropriate methods and frequency, and refer to responsible personnel who can provide details during inspection
  - *If not,* follow same methods as for scanner display, and physicist recommends appropriate frequency

Routine QC documentation

- Never need to send ACR specific routine QC test results or findings
  - QC program status communicated to ACR through QC program evaluation results documented in submitted physicist annual survey report
  - Must also submit “documentation of corrective action” for deficiencies found at annual survey and routine QC (e.g. copies of closed work orders)
  - All documentation is fair game during ACR site visit

*

Routine QC documentation

- No ACR standard form for routine QC
- Develop a simple custom form (.xls)
  - Scanner worksheet
  - Probes worksheet
  - Notes worksheet
  - *Worksheet with baseline in-air uniformity images?*
  - *Worksheet with electronic copies of closed service work orders?*

Routine US QC: Scanner Evaluation (v1.0)

US Scanner Location

Building
Room

US Scanner Description

ACR UAP Number:
Service database system ID

Manufacturer
Model Name:
Serial #
Equipment ID
Color ID

Date							
Initials							

Physical & Mechanical Inspection

P = Pass F=Fail NA= Not Applicable

Results							

US Electronic Image Display Performance: Qualitative Image Quality Evaluation

P = Pass F=Fail NA= Not Applicable

Normal Viewing Conditions							
Monitor Cleanliness							
INITIAL Brightness / Contrast Settings							
Contrast, darks							
Contrast, brights							
FINAL Brightness / Contrast Settings							
Display Artifacts							

***See Notes Page for any failed (F) items, or results marked with an asterisk (*).**

Routine US QC: Scanner Evaluation: This page can record results for seven QC sessions. For additonal QC sessions, copy this page, delete existing data on the copy page, and rename the worksheet page with the next higher number, e.g. "**Scanner Evaluation (2)**".

US Scanner Location: Check the scanner's **Equipment ID** to verify that it is in the correct location and has the correct **Room ID**. Scanners are mobile and may have been swapped around to accommodate last minute service or clinical needs. If the scanner's location has been reassigned, change the **Building** and **Room ID** data to the current location on the **Routine US QC: Scanner Evaluation** page and add a comment on the **Routine US QC: Notes** page.

Physical & Mechanical Inspection: Inspect all the equipment, considering all of the items listed, and also any other or that any other physical or mechanical issues that you may notice. Record P (Pass) or F (Fail) for the **Physical & Mechanical Inspection** in the box provided.

A failure is not the absence of perfection. *Issues that directly affect the safety of the equipment , and/or significantly affect image quality, and/or significantly impact the usability should be marked as F*, and a short description of the issue should be added to the **Routine US QC: Notes** page. In-house or vendor service should be notified to correct the issue. Once the issue has been fixed, add a P in the table along with the date (and NAs for other tests in that date column), and add a note to the **Routine US QC: Notes** page indicating the issue has been fixed.

For issues that are seen that are not severe enough to fail but might be useful to document, add a P* to the table and describe the issue on the **Routine US QC: Notes** page.

It is sometimes not clear if an issue that is found is severe enough to warrant immediate repair or replacement, especially if these actions involve considerable expense to the practice. Initially these issues should be marked as either *P** or *F* according to your best judgement, and documented as described above. Check uniformity to see if image quality is impacted. Then consult with equipment service (or the vendor) to hear their their impression of the severity of the issue and the estimated cost to address it. Finally consult with practice management to describe the problem and determine the proper course of action. Options will include immediate fix or replacement, or delaying fix or replacement. If the initial *P** or *F* mark needs to be changed, this should be recorded in a new data cell in the logbook, and a descriptive note should be added to the **Routine US QC: Notes** page.

See "*Physical & Mechanical Inspection.pptx*" for examples of physical and mechanical issues you may encounter.

US Electronic Image Display Performance: Adjust the room lighting similar to what would be used for clincial scanning and add a P to the table. Clean the scanner monitor with a damp cloth and wipe dry and add a P to the table. Refer to specific instructions for your scanner model in "*ScannerModel_Display_Performance_Eval.doc*" to complete the remaining evaluation steps.

Scanner worksheet

Routine US QC: Probe Evaluation (v1.0)

Date: _____ **Initials:** _____

Inventory Verification, Mechanical Inspection, Image Uniformity

P=Pass F=Fail

Inventory				Physical & Mechanical Inspection	Image Uniformity and Artifact Survey
Probe Model (location info, if not on scanner)	Probe ID	Probe Serial Number	Probe Located		
			P/F	P/F	P/F
S1-5					
S4-10					
C1-5					
9L					
ML6-15					
RIC5-9					

Geometric Accuracy: Elevational *(3D transducers only)*

P=Pass F=Fail

Probe Model:	Probe ID:	Reconstructed Horizontal Distance			
		Measurement (cm)	LCL	UCL	P/F
RIC5-9					

LCL= lower control limit, UCL= upper control limit

*See Notes Page for any failed (F) items, or results marked with an asterisk (*).

Probes worksheet

Routine US QC: Transducer Evaluation: This page is used once for each QC testing session. A new, blank page should be made and named with the date that testing was performed for subsequent testing. This should include replacement transducers or new transducer models added to the excisting transducer fleet.

Transducer: Inventory Verification, Mechanical Inspection, Image Uniformity

Transducer Inventory:

The **Xducer Id** and **Xducer Serical Number** should be verifed for each of the transducers assigned to the scanner being tested.

Place a **Y** or **N** in the **Xducer Located** box for each of the assigned transducers.

(Of note, some transducers are shared with other scanners but assigned to specific scanners and their loaction should be noted.)

Physical & Mechanical Inspection (Transducer):

Visual inspection of the US in
two goals.

The 1st goal of this step is to
debris on the probe face, in th
transducers stored in a rack w
cause electrical contact issue
not indicative of equipment de

The 2nd goal of this step is t
loose grommets & fittings, ca
which can cause associated
Perform the **Physical & Mec**
Mechanical Inspection box.
F entries should be discribed
(See *"Physical & Mechanical*

Image Uniformity and Artifa
Perform the **Image Uniformi**
Place a **Y** or **N** in the **Artifact**
If no artifact is witnessed plac
If artifact is noted but is not s
If an artifact is noted that req
F entries should be discribed
(See *"US QC Uniformity and*
documents.)

Geometric Accuracy: Ele
Complete the **Transducer: I**
QC testing proir to performin
Using the perscribed scan pa

Mayo

Routine US QC: Notes (v1.0)

Scanner ID: _____

Note Item#: Date: Initials:

Note Item#: Date: Initials:

Note Item#: Date: Initials:

Note Item#: Date: Initials:

Note Item#: Date: Initials:

Note Item#: Date: Initials:

Note Item#: Date: Initials:

Note Item#: Date: Initials:

Notes worksheet

How long does routine QC take?

- Assumptions
  - Familiar scanner with 6 probes
  - Some routine QC experience
  - PACS group tests dx displays
  - No involved “debugging”
- Time estimates
  - 30 min / system (uniformity phantom)
  - 20 min / system (in-air uniformity)

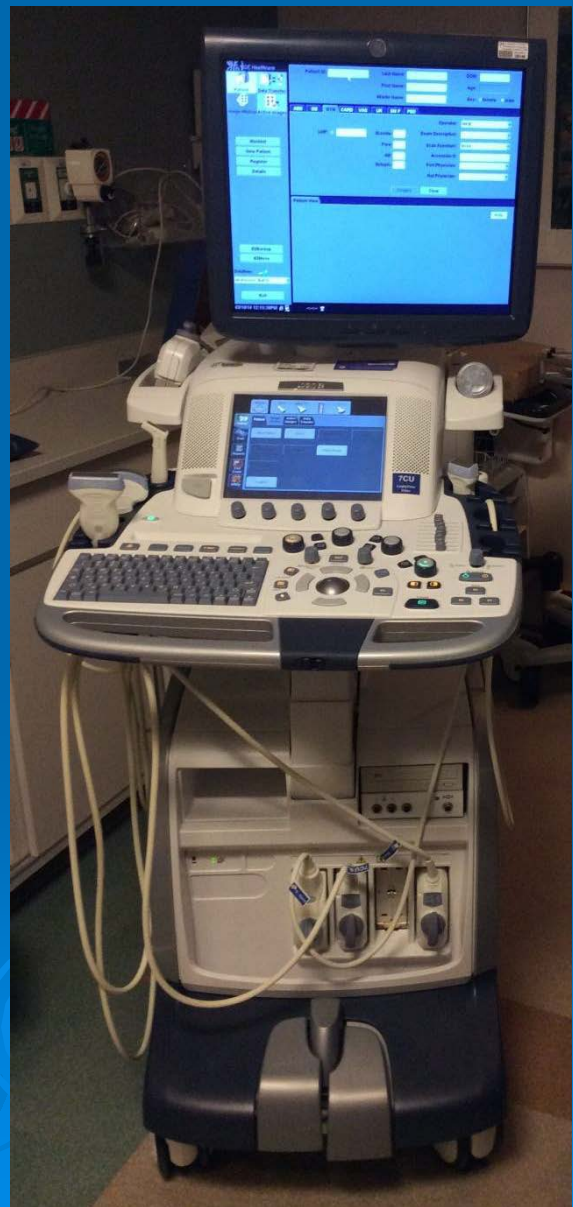
As little as 40-60 minutes / year / US system

Evaluation of QC program in annual survey

- Main goal: Quality improvement (not punitive)
- Review routine QC documentation
  - Are tests being performed at acceptable frequency?
  - Are tests being performed and interpreted properly?
  - When equipment problems are noted, is follow-up action by service or the practice documented?
- Address program deficiencies with education and training, and consultation when needed

General quality improvement suggestions

- Define short IDs and attach color-coded tags to scanner & probes
- Post QC/service contact info
- Review probe storage
  - Are connectors protected from dust? (plugged in scanner port, pointed down in wall rack, covered)
  - Are cables up off of the floor? (on cart or in rack)

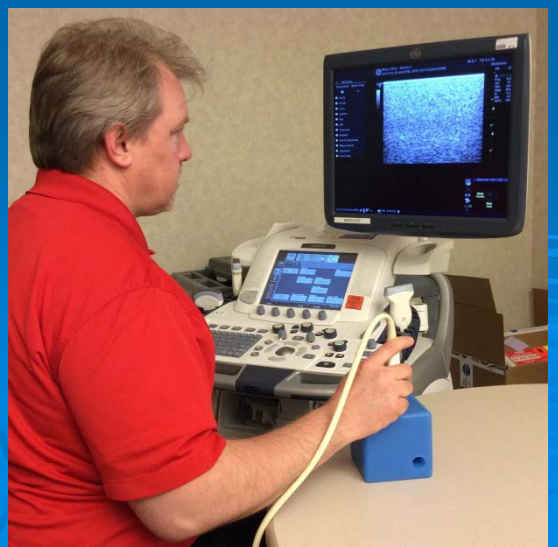


General quality improvement suggestions

- Implement a periodic (~1-4 week) “room check”
  - Probe inventory, and matching to the correct scanner
  - Clean scanner display and air filter
  - Thoroughly clean dust, gel
  - Restock gel, towels, linens (covered storage?), hand sanitizer, system cleaning products
  - Step stool caps
  - *Other issues related to ~TJC Environment of Care…*

Personnel considerations:
Who must/can do the QC work?

- ACR allows a variety of “appropriately/properly trained personnel” with “ultrasound imaging equipment experience” who are “approved by the physician(s) directing the clinical ultrasound practice” to perform various aspects of QC*
  - Physicist involvement is “strongly recommended” but not required
- *Many personnel models are possible….*



Possible personnel models

	"Physicist-heavy"	Large hub practice	Satellite practice 1	Satellite practice 2
QC Program Component	**Responsible personnel**	**Responsible personnel**	**Responsible personnel**	**Responsible personnel**
QC Program set-up and supervision	Medical physicist	Medical physicist	Medical physicist	Medical physicist
Acceptance Testing				
Systems	Medical physicist	Physics assistant*	Physics assistant*	Physics assistant*
Probes	Medical physicist	Physics assistant*	Lead sonographer**	Service engineer
Annual survey testing	Medical physicist	Physics assistant*	Physics assistant*	Physics assistant*
Routine QC testing	Lead sonographer	Physics assistant*	Lead sonographer	Service engineer
Performance benchmarks and pass-fail determinations	Medical physicist and clinical practice	Medical physicist, physics assistant, and clinical practice	Medical physicist, physics assistant, and clinical practice	Medical physicist, physics assistant, and clinical practice
Preventive maintenance	Service engineer	Service engineer	Service engineer	Service engineer

** Medical physicist reviews and interprets all results*

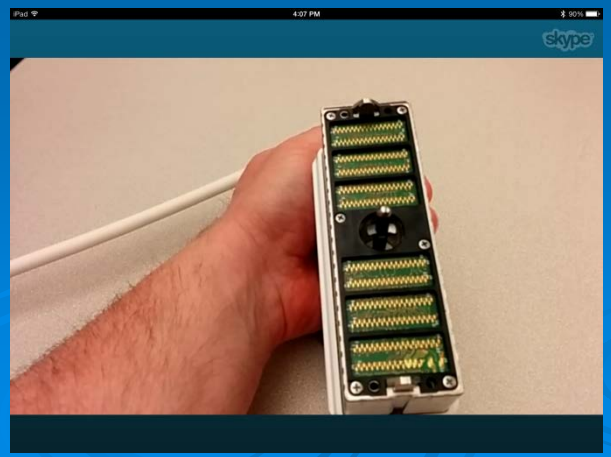
*** Acceptance tests are completed, if needed, at next annual survey*

Personnel considerations:
Who must/can do the QC work?

- Collaborating with the in-house or vendor field service engineering group
  - These professionals are valuable partners, and "own" the preventive maintenance component
  - When service also involved with routine QC or AT…
    - Physicist must approve test methods, and assess their compliance with ACR requirements, *and will review routine QC results as part of the annual survey*
    - Clinical practice must establish standards for acceptable system performance, and make final Pass-Fail decisions

Personnel considerations:
Who must/can do the QC work?

- Maximize availability of physicist for consultation
  - Cell phone and tablet cameras, photos and video
  - DICOM images via PACS (or email)
  - Shared network location for QC logbooks, closed service work orders, image pass-box, …



Conclusions

- Routine US QC is an essential component of overall practice quality program
  - Physicist assistance at start-up and ongoing supervision will allow an effective routine QC program to be implemented without excessive resource requirements

Some elements of the ACR ultrasound QC requirements are being revisited and may change somewhat – always refer to the ACR website for the most current requirements