The association for medical ultrasound
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AMERICAN INSTITUTE OF ULTRASOUND IN MEDICINE

AIUM Routine Quality Assurance of Clinical Ultrasound Equipment

VERSION 2.0

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Introduction

This document outlines a basic quality assurance (QA) program for clinical ultrasound facilities, and it sets out procedures and examples for carrying out tests that follow the program. The procedures outlined are intended to address requirements for QA in the clinic set forth by laboratory accrediting agencies, such as the American Institute of Ultrasound in Medicine (AIUM) and the American College of Radiology. Although many accrediting bodies require a QA program to be in place for accreditation, they generally allow flexibility in defining the program. Version 2.0 also includes an example of a data log for reporting and saving results and for maintaining records concerning addressing system faults.

The basic program described herein for routine QA will help detect the most frequent scanner/transducer/display malfunctions that may reduce ultrasound image quality. Quality assurance steps also include safety and cleanliness checks that are followed under good laboratory practice. However, this document does not provide an exhaustive test of factors that measure ultrasound instrument performance. More complete descriptions of ultrasound equipment performance tests are found in the "References" section below.

What Is the Purpose of the AIUM Routine Quality Assurance Program?

The purpose of a QA program in medical ultrasound is to ensure that the equipment and clinical practices of a facility are consistently safe and that the information obtained from a clinical ultrasound procedure is as accurate and reliable as can be determined.

This document outlines a basic QA program for clinical ultrasound facilities. Sonographers, physicians, and other technical staff, including medical physicists and biomedical engineers, can carry out these procedures with minimal disruption to the facility.

For Whom Is This Document Intended?

The QA procedures outlined in this document address the QA requirements in the ultrasound scan facility as set forth by the AIUM Ultrasound Practice Accreditation Council. This document is intended to assist clinical ultrasound personnel who are setting up and responsible for maintaining an equipment QA program for their facilities as well as technical staff, including physicists and engineers, who contribute to this program.

What Tasks Are Involved in Ultrasound QA?

An effective part of a QA program includes tasks that are routinely carried out as good clinical ultrasound practice when preparing for or following up an ultrasound examination or procedure. These include, for example, inspection of transducers for cracks and other physical damage, being mindful of image nonuniformities caused by dead elements or lens delamination in transducers, and taking steps to ensure proper cleaning and disinfection of equipment and scan rooms.

In addition, ultrasound QA includes periodic tests designed to evaluate various aspects of equipment performance.[1–5] Individuals trained to carry out these tests and interpret the results are the most effective for these tasks. If a qualified medical physicist or biomedical engineer is available, this individual could help organize and carry out these periodic tests. This can be done in partnership with a designated QA sonographer.

Who Should Be in Charge of the QA Program?

The AIUM recommends that clinical facilities appoint an individual to be responsible for the program. A sonographer, physician, medical physicist, or biomedical engineer who is trained in ultrasound QA procedures may be designated to organize and run the program, including maintaining records.

Personnel Identified in This Document:

- Sonographer, physician, or other qualified ultrasound system user
- Housekeeping
- Environmental, health, and safety
- Medical physicist, biomedical engineer, or designated QA personnel

The tables in the "Routine QA Requirements" section below identify roles for each individual or group.

What Is the Equipment Manufacturer's Role?

The ultrasound equipment manufacturer provides valuable resources for the design of a clinical QA program. Most manufacturers provide a list of recommended QA procedures in the operator's manual for each machine and transducer. If available, this list should be consulted when designing a clinical QA program. The operator's manual provided by the manufacturer usually contains information on equipment operation and safety and cleaning methods, including recommendations for cleaning and disinfecting ultrasound transducers.

Parts of a QA program are sometimes achieved through a preventive maintenance plan associated with the ultrasound manufacturer or other technical representatives. Additionally, some ultrasound systems can be tested online via remote connections to the manufacturer's facility or the Cloud. If any of these are available, they can be a useful part of a routine QA program. It is important to verify, however, that the periodic tests described below under "Routine QA Requirements" are carried out.

In addition to this support, electronic transducer testing routines implemented by the manufacturer are becoming available on many scanners based upon the Food and Drug Administration ultrasound guidance document ("Marketing Clearance of Diagnostic Ultrasound Systems and Transducers").[6] These are discussed below under "Transducer Tests."

What Types of Equipment and Operating Modes Are Covered?

Periodic QA test procedures listed in this manual are for ultrasound machines operating in a grayscale imaging mode. However, because recommended tests emphasize the performance and integrity of the transducer, the test results apply to a limited degree to performance in other scanning modes, including color and duplex Doppler and shear wave elastography.

Transducer Tests

Modern array transducers contain a large number of transducer elements, all of which must operate satisfactorily to obtain the most effective imaging performance from the ultrasound machine. Frequently, an individual element or a group of elements in an array may become nonfunctional because of damaged electrical connections, lowered sensitivity of the element(s), partially detached matching layer or lens materials, or reduced performance of specific electrical circuits in the machine.[7,8] So-called "dropout" of individual elements or groups of elements in the transducer is a frequent source of ultrasound equipment malfunction,[5] and sonographers, physicists, and engineers must be alert for this problem.

Obvious cases of transducer malfunction sometimes can be detected by sonographers when imaging a patient. Anytime transducer damage is suspected, for example, if it has been accidentally dropped, it is recommended that the transducer be tested for element dropout, as well as physical damage, before being used clinically. This can be done by imaging a uniform section of a phantom and inspecting the B-mode image, looking for subtle, and not so subtle, shadows that project from the transducer surface into the imaging field. The analysis may be done either subjectively or using image analysis techniques that have been developed for this purpose.

Following the United States Food and Drug Administration guidelines,[6] it is becoming increasingly common for ultrasound equipment manufacturers to include transducer test software routines on the system itself. When these test modes are available, users should develop an understanding of the methods for implementing them and how to interpret the results such software routines provide. A future version of this guide may address this in more detail.

An important component of a QA program is periodic testing to identify flaws in each ultrasound transducer used with a machine. Periodic QA tests should include inspection of all ultrasound transducers and connecting cables for damage to the housing, cable covering, and scan surface. In addition, they should include tests for element dropout using a phantom (see below) or other test modality. The latter includes special transducer testing devices[9] and, when available, transducer test routines provided directly on the machine.

What Is the Role of Phantoms?

Although daily QA steps done by sonographers do not require a phantom, more detailed checks of image display and performance are best done using a phantom or other test device. With a tissue-mimicking phantom, periodic test results are compared with initial baseline results of machine or transducer performance.

The baseline results are obtained either when a machine is accepted or when the QA program is initiated. Records are maintained of baseline and periodic test results, and Goodsitt et al[2] provide examples of forms for this purpose. Another example of a form that includes checks of cleanliness and safety is included below. Goodsitt et al[2] also list tolerance and action levels that guide clinical users if periodic QA test results vary from baseline levels. Equipment manufacturers may also recommend tolerance levels for some tests.

Users should follow the phantom manufacturer's guidelines when storing and caring for their phantoms. Phantoms have been known to deteriorate over time, so it is important to follow the phantom manufacturer's recommendation for certification or recertification schedules. It is recommended that the date of production and dates of recommended recertification of a phantom's properties be clearly indicated on the device.

Are There Computational Tools Available to Analyze Results of Ultrasound QA tests?

Some assessments of system and transducer performance using phantoms yield images that are interpreted subjectively, so test results depend on user judgment and experience. More objective interpretation of images that are obtained to evaluate parameters such as the maximum depth of penetration (DOP) can be done using computer algorithms. Several groups, including the American Association of Physicists in Medicine and the International Electrotechnical Commission,[4] have described algorithms to be used with phantom data. These resources can be consulted if facilities are planning to follow these approaches. In addition, some test routines that aid in deriving objective performance results are available commercially.[10] Reports showing experience with objective analyses have been published.[11,12]

Frequency of Tests

We recommend that equipment operators become familiar with the QA tasks listed in the lists below. In particular, those listed as "daily" are routine tasks that trained sonographers follow to help ensure patient safety and proper equipment operation. Less frequently performed "periodic" tests, such as phantom target detection, overall sensitivity, and close inspection of transducers, are done by medical physicists, biomedical engineers, or on-site personnel trained to perform QA tests. The AIUM recommends that such periodic tests be done at least annually, and the lists below follow this recommendation. Other groups, such as the American College of Radiology, may require more frequent performance testing, and users should follow the recommended frequency as indicated by their accrediting agencies.

Routine Quality Assurance Requirements

The AIUM Routine Quality Assurance Program addresses 2 practice components:

Section A: Cleanliness and Safety lists routine checks and procedures carried out on a regular basis by the sonographer to ensure cleanliness and safety of scanning equipment. Sonographers also can readily detect some equipment malfunctions, such as extensive element dropout in array transducers. Quality assurance checks routinely done by the sonographer are listed here.

Section B: Image Display and Performance includes basic practical procedures to identify some malfunctions and to make sure the equipment operates consistently at its expected level of performance.

- When equipment physical or operational irregularities are observed, notify the individual responsible for your QA program for follow-up according to program protocols.

DESIGNATED PERSONNEL

[a]Sonographer, physician, or other qualified ultrasound system user

[b]Housekeeping

[c]Environmental, health, and safety

[d]Medical physicist, biomedical engineer, or designated QA personnel

Section A: Cleanliness and Safety

	IMMEDIATELY	AT THE END OF EACH EXAMINATION	DAILY	WEEKLY	MONTHLY	ANNUALLY*
Clean any spill of bodily fluids or hazardous materials.[a–c]	X					
Clean gel from transducers and ultrasound machine control panels.[a, 13]		X				
Disinfect transducer.[a, 13]		X				
Check transducer cables for damage.[a]			X			
Check transducer for cracks, separations, and discolorations.[a]			X			
Clean monitors and inspect for cracks.[a]			X			
Check for any damage to power cords or picture archiving and communication system (PACS) connections.[a]			X			
Identify and report improper operation of switches or knobs on machine console.[a]			X			
Identify and report any burned-out indicator lights.[a]			X			
Clean rooms for dust, dirt, and infection control.[b]			X			
Clean dust from machine console air filters.[a]				X		
Check machine for dents and other damage.[a]				X		
Thoroughly clean ultrasound machine console and other equipment in the examination room.[a]					X	
Inspect keyboards, control knobs, monitors, and air filters for cleanliness, operation of indicator lights, and functioning of trackball.[d]						X
Inspect mechanical integrity of the system, including wheels and wheel locks and security of attached accessories and cords.[d]						X

*To be included in the Annual Ultrasound QA Tests report; see the suggested report form below

Section B: Image Display and Performance

	DAILY	ANNUALLY
During routine scanning, visually assess images for vertical shadows and streaks commonly caused by dead elements or a delaminated lens in the transducer.[a, 14]	X	
Check brightness and contrast controls.[d]		X
Confirm machine monitor settings are at calibration points used for setting up primary image display workstations (i.e. PACS displays) and/or hard copy devices.		X

Assess monitors and grayscale setup.[d]

Materials: Stored TG18-QC (preferred) or Society of Motion Picture and Television Engineers (SMPTE) test pattern in the ultrasound scanner. If an SMPTE or TG18-QC pattern is not available on the scanner, the vendor should be contacted, as it can provide these test patterns on request.

Evaluate:

1. Display the TG18-QC (Figure 1, Top) or the SMPTE (Figure 1, Bottom) test pattern stored in the ultrasound machine.
2. Verify that:
   - The 0%–5% transition and the 95%–100% transitions are visible (arrows);
   - All line-pair patterns are distinct at center and corners;
   - The grayscale ramp is smooth (TG18 pattern only).
3. Send this image to the PACS network and repeat step 2 to verify that there is consistency between the scanner display and the PACS display.
4. Record results (see page A of the attached Report Form for an example of data to be recorded).



Figure 1, Top. TG18-QC.

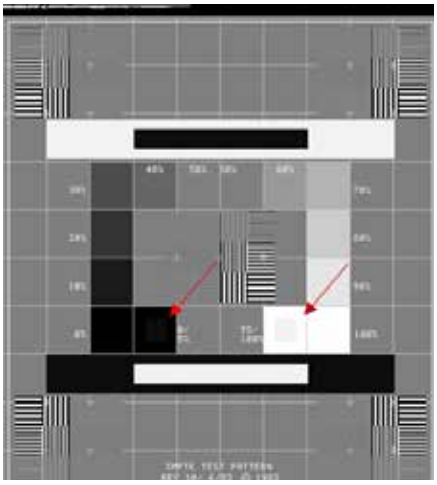


Figure 1, Bottom. SMPTE test pattern.

Assess cables, housing, and transmitting surfaces of each transducer.[d]

1. Confirm there are no cracks, separations, or discolorations.

Assess transducer uniformity for each transducer.[d]

Materials: Phantom

Adjust system settings:

1. Disable spatial compound imaging (cross beam; sonoCT; Sie Clear; etc). Note: See system's user manual for instructions on disabling.
2. Apply an appropriate depth setting that provides good spatial detail for the transducer being tested (frequency and type of transducer dependent).
3. For systems having a user-controlled transmit focus, use a single transmit focal depth.
4. Adjust sensitivity (output, gain, and dynamic range) to produce an image with a uniform gray level.
5. Use maximum persistence (frame-averaging) settings.

Evaluate:

1. Scan a uniform region of the phantom. Be sure the transducer is fully coupled with acoustic gel to the phantom surface, with no gaps, etc.
2. Look for shadows emanating from the transducer surface.
3. Rate the transducer 1, 2, 3, or 4 (Figures 2–5; see rating criteria below).
   - *Transducers rated "1" (no visible flaws) or "2" (1 or 2 minor flaws):* Still operational
   - *Transducers rated "3":* Place on a "replace when possible" list, and use with caution.
   - *Transducers rated "4":* Immediately remove from service.

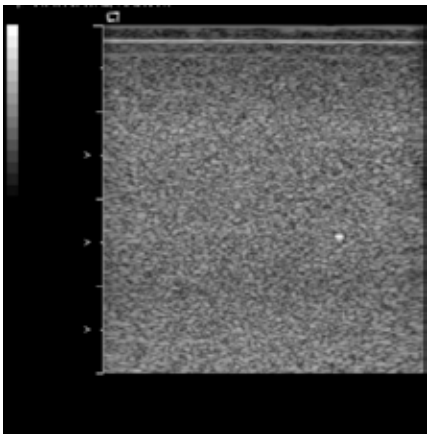


Figure 2. Transducer uniformity rating = "1." The image is uniform; the transducer does not have any signs of element dropout. It is considered to be operating well. (From *AIUM Quality Assurance Manual for Gray Scale Ultrasound Scanners.*[1])

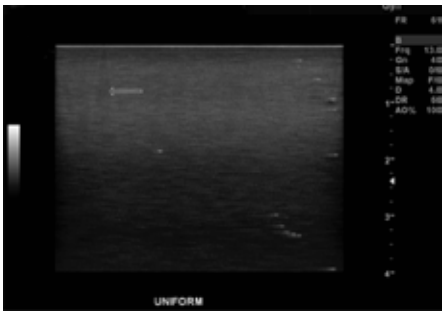


Figure 3. Transducer uniformity rating = "2." One or 2 minor nonuniformities are present; generally, the transducer is classified as "watch and wait" and is still usable. (From *AIUM Quality Assurance Manual for Gray Scale Ultrasound Scanners.*[1])



Figure 4. Transducer uniformity rating = "3." This rating is given when there are 3 or more minor nonuniformities or 1 or more major flaws, as in this example; although the transducer can be operated, users should plan to replace it. Avoid Doppler beams that project from the dead element region.

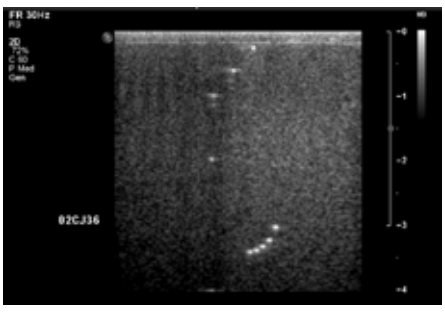


Figure 5. Transducer uniformity rating = "4." Sufficient damage exists to replace the transducer. This transducer was taken out of service immediately after QA testing.

When a rating of "3" or "4" is found, it is useful to check whether the fault is due to poor coupling or to an air bubble, etc. When the location of the shadow is fixed as the transducer is moved, it is likely due to bad elements. Also, it may be useful to disconnect the transducer from the scanner and reconnect it in the same port to verify that the shadow is not due to dust, etc, in the connector or port. If the shadow persists, try connecting the transducer to a different port or even a different scanner when available to see if the issue is with the port on the scanner, as opposed to the transducer. Also, flex the transducer cable while viewing the artifact to see if the cable is defective.

Assess the maximum depth of visualization for each transducer.[a,d]

Materials: Phantom containing material that has acoustic properties mimicking soft tissue.

Adjust system settings:

1. Increase the acoustic power output to 100% (maximum output).
2. For multifrequency transducers, use a midfrequency setting; eg, for a transducer that provides imaging at 2.5, 4.5, and 5 MHz, choose 4.5 MHz.
   - Important: Use the same frequency for subsequent testing.
3. Place the transmit focus (or multiple focal zones) as deeply as possible to maximize visualization of the image texture (resulting from the microscopic scatterers in the phantom).
4. Increase the system gain to the level where electronic noise is just barely perceptible.

Evaluate:

5. Scan a region of the phantom, and freeze an image.
6. Use the electronic calipers to estimate the maximum distance over which you can visualize the background texture pattern (see Figures 6 and 7).
   - Call this measurement the maximum DOP.
   - Use this number to compare performance from one QA session to the next.

It is recommended that the process be carried out using both fundamental-frequency imaging and harmonic imaging for each transducer.

Page B of the example report form has spaces for recording results.

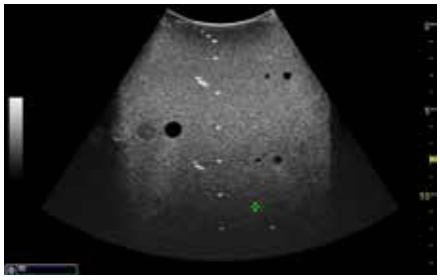


Figure 6. Setup to estimate the maximum DOP for a curvilinear array transducer. The value displayed here is 10.88 cm. Caliper positions are used to estimate the maximum DOP.

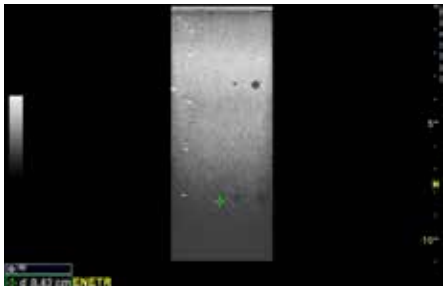


Figure 7. Setup for measuring the depth of visualization with a linear array transducer. The value displayed here is 8.43 cm.

Assess distance measurement accuracy for each transducer.[a, d]

Materials: Phantom containing discrete targets embedded in a material that has acoustic properties mimicking soft tissue.

Evaluate:

1. For vertical distance measurement accuracy, scan a phantom, viewing a column of targets axially, with the transducer positioned to image the targets near the center of the displayed field (Figure 8). If a user-adjustable transmit focus is present, ensure the focal zone caret (if displayed) is located at the level of the intended measurement.
2. Place digital calipers to measure the "leading edge–to–leading edge" distance between 2 targets. Using targets most distant from each other minimizes caliper positioning error.
3. Compare the measured distance with the known separation between the targets. The variance should be less than 2% or less than 2 mm, whichever is greater.

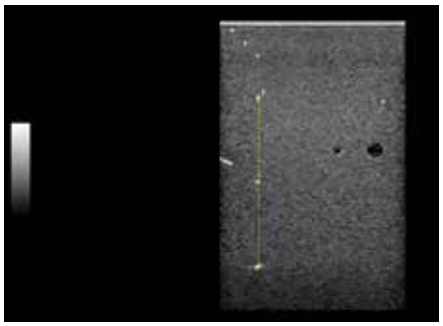


Figure 8. Vertical distance measurement checks. Caliper markers are placed to measure from the leading edge to the leading edge of 2 targets separated by 4 cm. The digital caliper readout (4.06 cm) agrees very well with this expected distance. The error is 0.06 cm, or 1.5%, and is less than 2%, which would be considered defective.[2]

4. Repeat for horizontal measurement accuracy, imaging targets with known horizontal spacing. For systems with an adjustable transmit focus, ensure the focal zone caret (if displayed) is located at the level of the intended measurement.
5. Place digital calipers to measure from the center to the center of 2 of these targets (Figure 9).
6. Compare the measured distance with known separation. The variance should be less than 3% or less than 3 mm, whichever is greater.
7. For 3-dimensional (3D) transducers, repeat for targets viewed in an elevational plane constructed from the volumetric data. Scan the phantom using a transducer orientation such that the acquisition plane produces an image of line targets as in Figure 10, top left. A reconstructed elevational plane will appear as in Figure 10, top right. Place calipers to measure from the center to the center of 2 targets viewed laterally in this reconstructed plane. The variance should be less than 3% or less than 3 mm, whichever is greater.

Record results for each transducer using the report form.

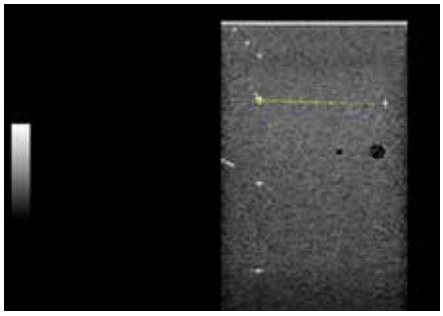


Figure 9. Horizontal distance measurement test. Caliper markers are placed to measure from the center to the center of the 2 targets positioned horizontally to one another. The known distance between the targets is 3 cm, and the readout (2.97 cm) agrees with this distance to within 0.03 cm or 1%. An error of 3% would be considered a defect for horizontal distance measurements.[2]

RECOMMENDED BUT NOT MANDATORY:

Evaluate the target resolution for each transducer.[a,d]

Materials: Phantom choice is at the discretion of the facility.

Evaluate:
A common approach for evaluating spatial resolution is to use phantoms that contain groups of line targets that are separated at different distances in the lateral and/or axial direction. Users scan each section of the phantom and judge the closest target spacing at which target images do not overlap

Another method being used for estimating lateral resolution versus depth is to use images of columns of line targets whose axes are perpendicular to the image plane. Measuring the widths of displayed echo signals from the line targets, such as the full width at half the maximum amplitude or the width at levels that are 20 dB below the maximum echo signal amplitude, are commonly used. Some users employ software, such as UltraIQ,10 which has apps specifically designed for resolution assessments that are based on displayed widths of point targets. Records are maintained of results for comparisons over time.

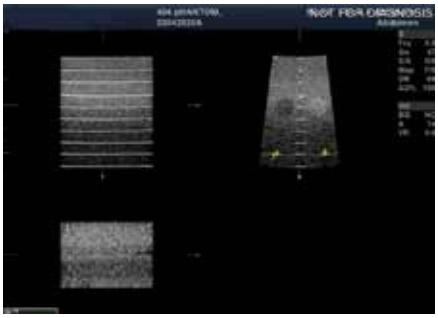


Figure 10. Measurement accuracy for a reconstructed plane using a 3D transducer. The image on the top left is one of the scan planes comprising a 3D volume, and the lower left is a "C-plane" (constant depth plane) constructed from the volumetric data. The top right is an elevational plane, also constructed from the volumetric data, with a view of the line targets in the phantom that displays their geometric arrangement. Cursors are positioned to measure the separation between 2 targets separated laterally in this image plane. The known separation is 2.0 cm. The readout is 1.98 cm, well within acceptable limits.

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AIUM Annual Ultrasound QA Tests: Summary Report

SITE/LOCATION | **SURVEY DATE**

SCANNER MAKE, MODEL | **SCANNER SERIAL NO:**

PACS ID | **PACS NAME**

TESTS DONE BY | **SIGNATURE**

EQUIPMENT EVALUATION SUMMARY

Test		Pass/Fail?	Tester's Comments & Recommendations	Date Resolved (For QA manager)
1	Physical and mechanical inspection of scanner; cleanliness			
2	Scanner display monitor performance, and agreement with PACS monitors			

Number of transducers tested with this system and listed on page D of this form: _____

For each test, indicate the number of transducers that pass (test OK) and the number that fail for the following:

3	Visual inspection of transducer for cracks, delaminations, damage to housing, cable damage	_____ Transducers PASS _____ Transducers FAIL		

AIUM ANNUAL ULTRASOUND QA TESTS: SUMMARY REPORT CONTINUED

Test		Pass/Fail?	Tester's Comments & Recommendations	Date Resolved (For QA manager)
4	Image uniformity and test for dead elements using a phantom or using transducer tester	_____ Transducers PASS (RATING 1 OR 2) _____ Transducers FAIL (RATING 3 OR 4)		
5	Sensitivity test for each transducer using the maximum relative DOP	_____ Transducers PASS (<1-CM CHANGE) _____ Transducers FAIL (>1-CM CHANGE)		
6a	Geometric accuracy, vertical	_____ Transducers PASS _____ Transducers FAIL (ERROR IS >2% OR >2 MM, WHICHEVER IS LESS)		
6b	Geometric accuracy, horizontal	_____ Transducers PASS _____ Transducers FAIL (ERROR IS >3% OR >3 MM, WHICHEVER IS LESS)		
6c	Geometric accuracy, elevational (3D transducers only)	_____ Transducers PASS _____ Transducers FAIL (ERROR IS >3% OR >3 MM, WHICHEVER IS LESS)		
7	Resolution test (optional)	_____ Transducers PASS _____ Transducers FAIL		

General Machine Cleanliness:

Keyboard, knobs, controls clean, functional?	☐ Yes	☐ No	
Monitors clean?	☐ Yes	☐ No	
Air filters clean?	☐ Yes	☐ No	☐ Cleaned

Mechanical and Electrical:

Wheels fastened securely and rotate easily?	☐ Yes	☐ No
Wheel locks work well?	☐ Yes	☐ No
Accessories fixed securely?	☐ Yes	☐ No
Cords attached securely?	☐ Yes	☐ No

Image Displays on Scanner and PACS Workstation: Level of Agreement

Quality of agreement between scanner and workstation for low-level and high-level signals:

☐ 1 poor ☐ 2 ☐ 3 average ☐ 4 ☐ 5 excellent

Assessment Using TG18-QC or the SMPTE Test Pattern

Is the 0%–5% contrast transition visible?

System monitor:	☐ Yes	☐ No
PACS reading room monitor:	☐ Yes	☐ No

Is the 95%–100% contrast transition visible?

System monitor:	☐ Yes	☐ No
PACS reading room monitor:	☐ Yes	☐ No

Is the grayscale ramp smooth (TG18-QC pattern)?

System monitor:	☐ Yes	☐ No
PACS reading room monitor:	☐ Yes	☐ No

Are all line pair patterns distinct at the center and corners?

System monitor:	☐ Yes	☐ No
PACS reading room monitor:	☐ Yes	☐ No

Comments: _____

(Attach to Scanner Summary Report)

Transducer Inspection (for Each Transducer):

Check **transducer physical condition** for frayed, discolored, or cracked cable, cracked or damaged housing, and cracked or delaminated lens face. Check **image uniformity** with a single, shallow transmit focus setting. Rate as follows:

1. Uniform: no visible flaws.
2. Minor inhomogeneity (1–3 minor flaws): transducer is still operational.
3. Significant inhomogeneity (>3 minor flaws as above, or at least 1 significant dip): transducer is functional, but it should be placed on the "replace when possible" list and used with caution.
4. Immediately remove from service (>4 minor dips or any 3-dip combination of minor and significant or 2 significant or 1 major dip).

Check DOP with maximum sensitivity and transmit focal setting, and measure the maximum distance for which you can view texture echoes in the phantom.

Measure the **distance** between 2 vertically spaced (**V**) and 2 horizontally spaced (H) reflectors that are at least 6 cm apart for the general abdominal transducers and at least 2 cm apart for the small-part transducers. *If the tested transducer is a 3D transducer, also measure for an elevational direction (**E**). Acceptable results are variances <2% or <2 mm (whichever is greater) for **V** and variances <3% or <3 mm (whichever is greater) for **H** and **E**.

Transducer ID, serial number, preset for DOP	Cables/ cracks/ delaminate		Uniformity rating (1–4) (see above)	Sensitivity (DOP) Enter: frequency and DOP, ie, MHz/__cm). Do for fundamental (F) and harmonic (H).	Geometric accuracy Enter: H: cm/ actual cm V: cm/actual cm E: cm/actual cm (3D transducers only).	Conclusions, observations, and recommendations Are DOP results consistent with previous tests (<1 cm change) or with those of similar transducers? Is measurement accuracy OK?
	OK	No				
	☐	☐		F__ MHz/__ cm H__ MHz/__ cm	H: cm/ cm V: cm/ cm E: cm/ cm	Operating OK?
	☐	☐		F__ MHz/__ cm H__ MHz/__ cm	H: cm/ cm V: cm/ cm E: cm/ cm	Operating OK?
	☐	☐		F__ MHz/__ cm H__ MHz/__ cm	H: cm/ cm V: cm/ cm E: cm/ cm	Operating OK?