ACT Government | Canberra Health Services

Quality Assurance of Breast Ultrasound

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Acknowledgements

I would like to thank Andrew Blair from Christchurch Hospital for permission to use data and images from his 2020-2023 New Zealand ultrasound audit.

I would like to thank Chris Williams from Canberra Health Services for advice and review.

The role of ultrasound in breast assessment

Ultrasound imaging may be used to:

- evaluate palpable masses not seen in mammography
- better visualise breast abnormalities seen in mammography
- differentiate between fluid-filled or solid lumps
- perform image-guided biopsies
- provide improved visualisation of lesions/masses which may be obscured by dense breast tissue in mammography

Why is a QA program important for breast ultrasound?

Breast ultrasound equipment must meet the following image quality requirements:

- Good contrast despite small changes in tissue properties
- High spatial resolution
- Good near-field resolution for assessment of superficial lesions and breast changes

Why is a QA program important for breast ultrasound?

The BreastScreen Australia National Accreditation Standards (NAS) outlines QA Program requirements for breast imaging systems.

With respect to ultrasound QA:

- Designated Radiologist – responsible for ensuring standards and testing procedures are being met
- Designated Radiographer – responsible for ensuring testing is implemented and liaising with Medical Physicist re technical issues
- Medical Physicist – responsible for testing and providing advice for equipment and technical matters, ensuring equipment safe to use
- Sonographers or Service Engineer – periodic testing under supervision or with assistance of a Medical Physicist

What are the goals of periodic testing in a QA program?

- To assess consistency and stability over the lifetime of the system.
- To ensure image quality is maintained.

By having a QA program with periodic testing in place we can:

1. Detect image quality degradation before it affects patient imaging
2. Determine the possible cause of a fault

QA Testing

Where to start?

NAS minimum periodic testing – six monthly

TABLE F.1: ULTRASOUND SYSTEM QUALITY CONTROL AND PERFORMANCE STANDARDS

Procedure [DDD]	Minimum Frequency	Required Procedure Elements	Control Limits/ Requirements
Physical and mechanical inspection	Six-monthly	Inspection of transducers, power cords, controls and system cleanliness	Satisfactory operation and condition
Display monitor setup and fidelity	Six-monthly	• Verification that contrast and brightness settings are in baseline positions • Evaluation of number of grey scale test pattern steps visible • Evaluation of clarity of displayed text	Number of grey scale test pattern steps visible should not decrease by more than 2 steps
Image uniformity	Six-monthly	Evaluation of a uniform region of tissue-mimicking phantom and identification of deviation from smooth tissue texture	No significant non-uniformities
Depth of penetration/visualisation	Six-monthly	Evaluation of maximum depth of either ultrasound speckle or object perception	< 6 mm change in depth of penetration/visualisation measurement from baseline value
Hard copy fidelity	Six-monthly	• Comparison of on-screen image and hard copy image • Verification that the weakest echoes visible on the display are visible in the hard copy image • Comparison with baseline image	Number of grey levels in the hard copy image should not change from the baseline value by more than 2.
Distance Accuracy	Six-monthly	• Measurement of known distances in vertical and horizontal directions	• Vertical measurement error less than 1.5 mm or 1.5% • Horizontal measurement error less than 2 mm or 2%

6 monthly minimum frequency

Performed by routine users or service engineer under supervision of medical physicist

NAS minimum periodic testing – Annual

Procedure [DDD]	Minimum Frequency	Required Procedure Elements	Control Limits/ Requirements
Anechoic object imaging [EEE]	Annually	• Evaluation of image quality • Comparison with baseline images	No major distortion or change from baseline performance
Axial resolution	Annually	• Evaluation of full-width-half-maximum (FWHM) from profile; OR • Evaluation of filament targets in an axial resolution grouping	• Resolution ≤ 1 mm for > 4 megahertz (MHz) transducer) • No significant change from baseline values
Lateral resolution or response width	Annually	• Measurement of filament image width OR • Evaluation of FWHM from image profile OR • Evaluation of filament targets in a lateral resolution grouping	• FWHM < 0.8 mm for > 4 megahertz (MHz) transducer) • Image width or spacing between targets < 1.5 mm • No major change from baseline values
Ring down or dead zone	Annually	• Imaging of filament targets near scanning window OR • Evaluation of image texture features	Dead zone < 3 mm (for >7 megahertz (MHz) transducer)

Annual minimum frequency

May require direct assistance of a medical physicist or ultrasound service engineer

Lessons from a New Zealand audit

Main findings:
Most faults were due to mechanical failures or non-uniformity of the image

Rating	Number (%)	Category of fault
1 – No flaws	415 (73)	NA
2 – Minor flaws Minor wear and tear/defect OK for clinical use	145 (25)	97 Weak or defective crystal elements 21 Damage to transducer surface 12 Loss of signal in large area 10 Cable damage 8 Deterioration in Dead Zone 8 Casing separation 3 Image processing artefacts
3 – Major flaws Clinically significant defect	12 (2)	10 Multiple dead crystal elements 5 Large signal voids 1 Casing separation
4 – Remove from service Machine unsafe to use	2 (0)	1 Major screen distortion (machine issue) 1 Image formation (machine issue)

Blair, A. EPSM2023 Conference Presentation: “Sounds Good? Findings from an Ultrasound Quality Assurance Program”, Medical Physics and Bioengineering, Christchurch Hospital, Riccarton Avenue, Christchurch.

1. Visual Inspection

- Easy to perform
- No need for phantom
- Minimum 6-monthly frequency (NAS)
- Recommended it be performed regularly – in some cases daily (before clinical use), ACR recommends at least monthly

- BreastScreen Australia, National Accreditation Standards, 2022
- ACR–AAPM Technical Standard For Diagnostic Medical Physics Performance Monitoring Of Real Time Ultrasound Equipment, 2021

1. Visual Inspection

Includes visual inspection of :

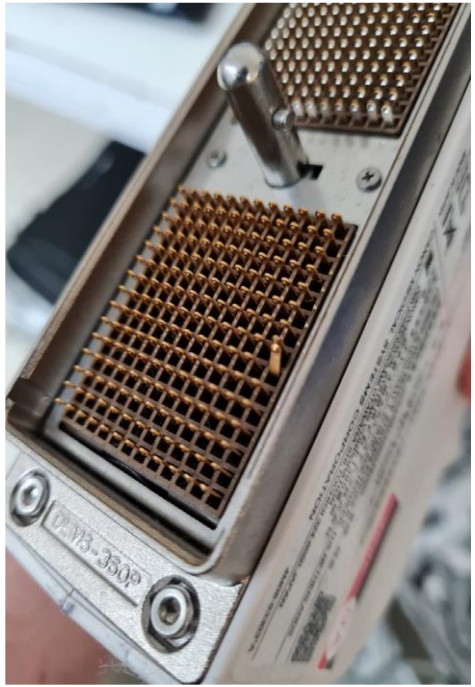
- Transducers
- Power cord and cables
- Controls – buttons/switches
- Monitor
- Housing
- Dust filters

Rating.	No. (%)	Category of fault
No flaws	415 (73)	NA
Minor flaws	145 (25)	97 Weak or defective crystal elements 21 Damage to transducer surface 12 Loss of signal in large area 10 Cable damage 8 Deterioration in Dead Zone 8 Casing separation 3 Image processing artefacts
Major flaws	12 (2)	10 Multiple dead crystal elements 5 Large signal voids 1 Casing separation
Remove unit	2 (0)	1 Major screen distortion (machine issue) 1 Image formation (machine issue)

Blair, A., 2023, EPSM2023: Sounds Good? Findings from an Ultrasound QA Program, Christchurch Hospital.

1. Visual Inspection – Transducers

Look for dirty or damaged contacts

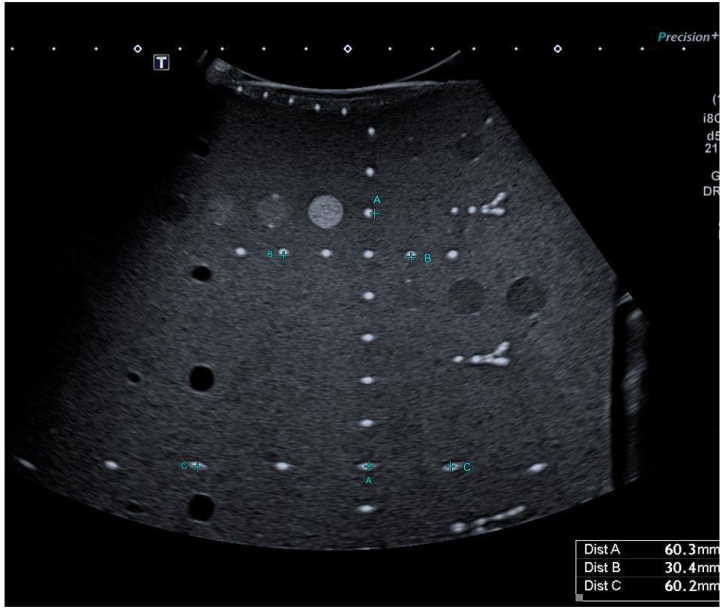


WHY?

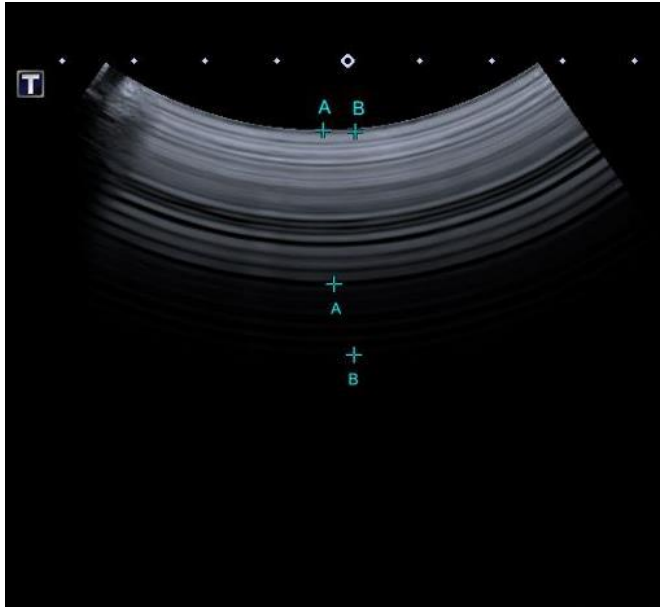
They can result in signal loss or void

1. Visual Inspection – Transducers

Signal loss/void in phantom



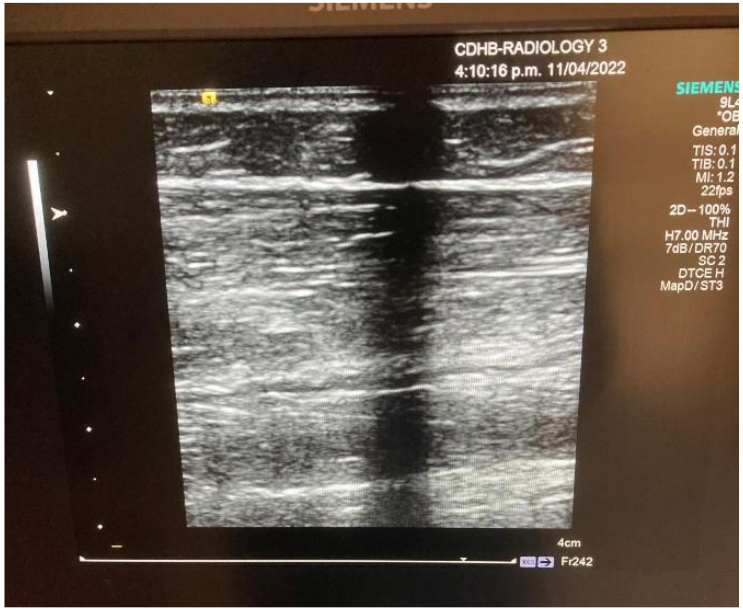
Signal loss/void in air



Blair, A., 2023, EPSM2023: Sounds Good? Findings from an Ultrasound QA Program, Christchurch Hospital.

1. Visual Inspection – Transducers

Signal loss or void clinical



Blair, A., 2023, EPSM2023: Sounds Good? Findings from an Ultrasound QA Program, Christchurch Hospital.

1. Visual Inspection – Transducers

Housing damage

Matching layer damage

- Infection control issue
- May cause damage to transducer:
  - delamination of matching layer or backing layer
  - damage to transducer elements

Blair, A., 2023, EPSM2023: Sounds Good? Findings from an Ultrasound QA Program, Christchurch Hospital.

1. Visual Inspection – Power cord and cables

Look for damaged or missing cable insulation

Blair, A., 2023, EPSM2023: Sounds Good? Findings from an Ultrasound QA Program, Christchurch Hospital.

1. Visual Inspection – Controls and housing

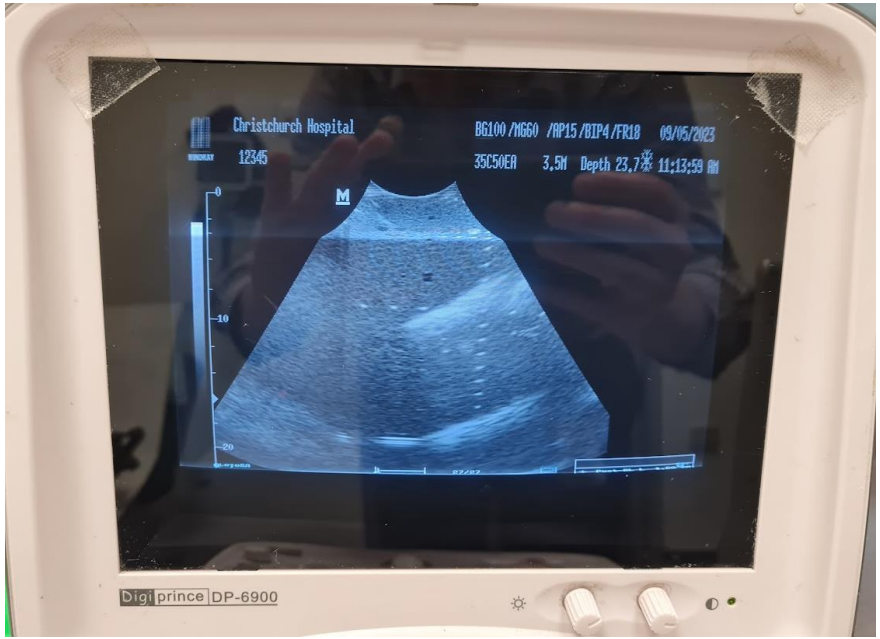
Item	Checklist	Problem
Housing	• Are all movable parts of housing, including wheels, functioning? • General cleanliness of housing	• Limit to ergonomics • Infection control
Controls & buttons	Are all knobs and buttons clean and working?	• Infection control • Limit to functionality of device

Dust filter	Does the dust filter need to be cleaned?	• US unit could overheat
		  • Processing time will slow
		  • Electronics will be damaged

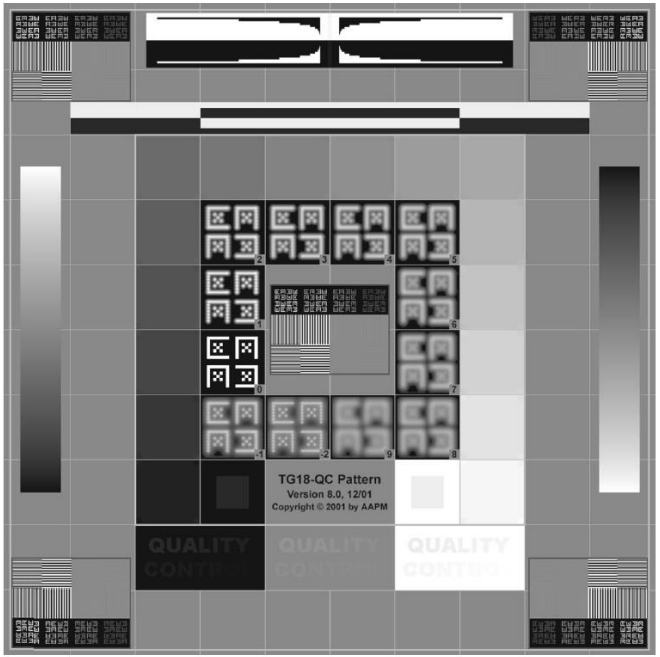
GAMMEX RMI, The QA Cookbook for Ultrasound, 1994

1. Visual Inspection – Display monitor

Some monitor issues are obvious on visual inspection



Other issues may be found using a test pattern (TG18-QC, as in mammography)

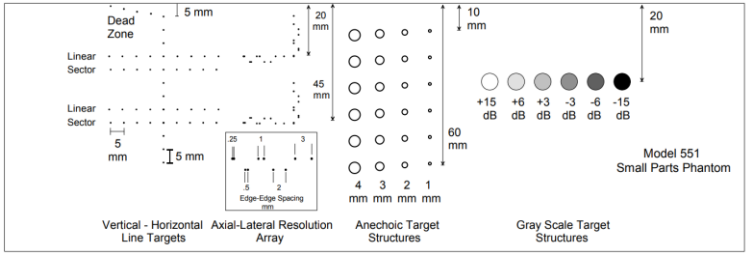


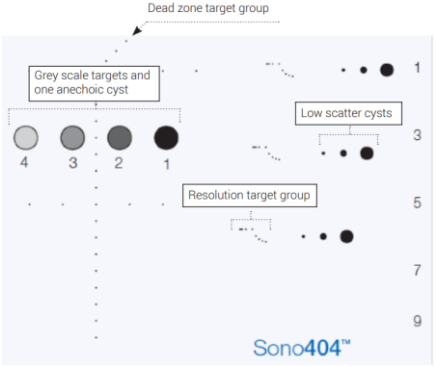
- Blair, A., 2023, EPSM2023: Sounds Good? Findings from an Ultrasound QA Program, Christchurch Hospital.
- Samei et al., 2005, Performance assessment of medical displays, Med. Phys. 32

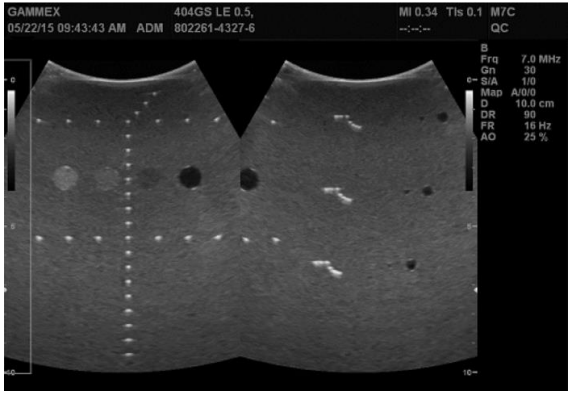
Phantoms for breast ultrasound image quality testing

Things to consider:

- Test objects included
- Speed of sound in material
- Longevity/stability
- Cost



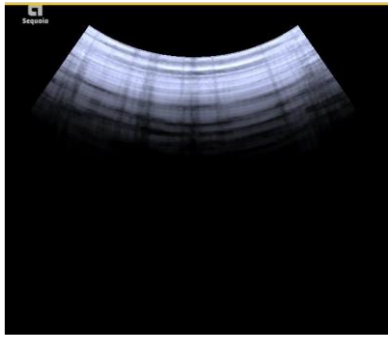




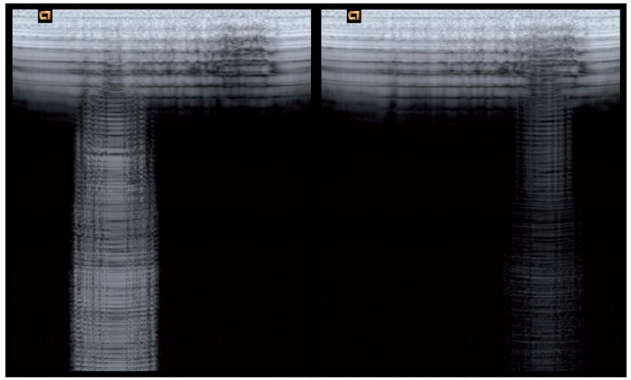
- Blair, A., 2023, EPSM2023: Sounds Good? Findings from an Ultrasound QA Program, Christchurch Hospital.
- ATS551Phantom_101623.pdf (sunnuclear.com)
- Sono404-Ultrasound_092121.pdf (sunnuclear.com)

2. Transducer testing

- B-mode testing for weak or dead transducer elements
- Applies to linear and curvilinear transducers where a subset of elements are active at a time
- Elements can be tested by applying a thin layer of using gel to transducer surface and slowly sliding a paper clip over the surface



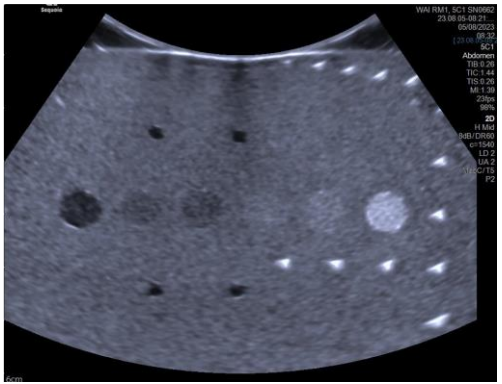
Weak transducer elements (no phantom)



Paper clip test.

Left = working elements

Right = weak elements



Weak transducer elements (in phantom)

- Blair, A., 2023, EPSM2023: Sounds Good? Findings from an Ultrasound QA Program, Christchurch Hospital.
- Dudley, 2021, An adaptation of the ultrasound transducer element test for multi-row arrays, Physica Medica, 84

3. Image quality testing - Baselines

- Ultrasound image quality baselines must be set (similar to mammography)
- They are an important step in a QA program as they allow for assessment of system stability over its lifetime
- Record the system settings used for each transducer and for each test when setting baselines. This allows each test to be more faithfully repeated during periodic testing.

- Goodsitt et al.: Real-time B-mode ultrasound, Medical Physics, Vol. 25, No. 8, August 1998
- BreastScreen Australia, National Accreditation Standards, 2022

3. Image quality testing - Baselines

- Test conditions to record:
  - US frequency (for transducers with adjustable frequencies)
  - Maximum depth
  - Focal zone position
  - Time gain control knob positions – it can be helpful to create a template for positioning
  - Gain
  - Dynamic range
  - Image processing used
    - It is best to perform testing with the least amount of image processing applied
    - Image processing includes harmonic imaging, spatial compounding, etc which affect visibility of defects and artifacts

- Goodsitt et al.: Real-time B-mode ultrasound, Medical Physics, Vol. 25, No. 8, August 1998
- BreastScreen Australia, National Accreditation Standards, 2022

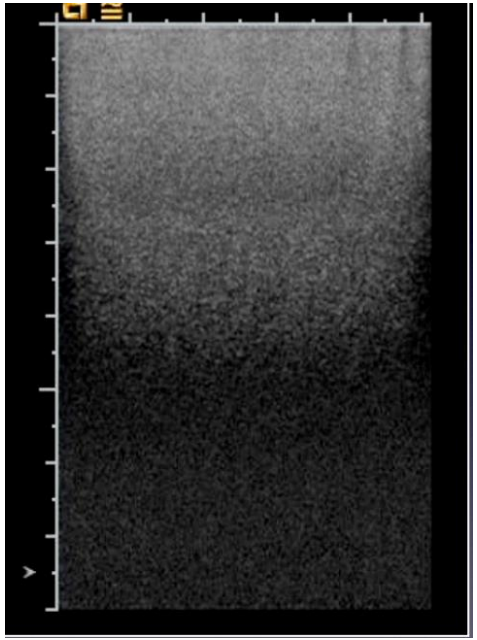
3. Image quality testing – Uniformity

Why?

- Non-uniformities may mask subtle changes in tissue texture
- Test which results in most failures

What causes non-uniformity?

- Horizontal usually defects in hardware (transducer elements or layers, electrical contacts, circuitry)
- Vertical usually TGC or multiple focal depth issue so usually adjustable, if not service required

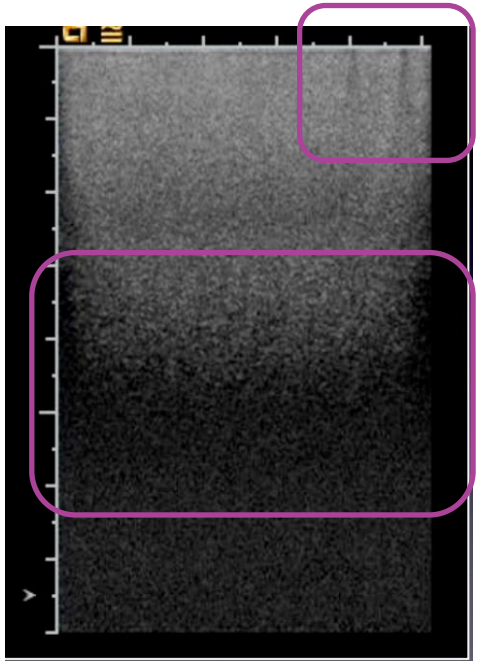


- Boote, E.J., Current Ultrasound Quality Control Recommendations and Techniques, University of Missouri-Columbia, 49-14425-36368-705.pdf (aapm.org)
- Blair, A., 2023, EPSM2023: Sounds Good? Findings from an Ultrasound QA Program, Christchurch Hospital.

3. Image quality testing – Uniformity

How?

- Find uniform region on phantom (no test objects)
- Adjust max depth to visualise to bottom of phantom
- Identify deviations from smooth tissue texture
- Look for any non-uniformities or artifacts



Horizontal non-uniformities

Signal loss implies weak or dead elements

Vertical non-uniformity

May be resolved by adjusting TGC

- Boote, E.J., Current Ultrasound Quality Control Recommendations and Techniques, University of Missouri-Columbia, 49-14425-36368-705.pdf (aapm.org)
- Blair, A., 2023, EPSM2023: Sounds Good? Findings from an Ultrasound QA Program, Christchurch Hospital.

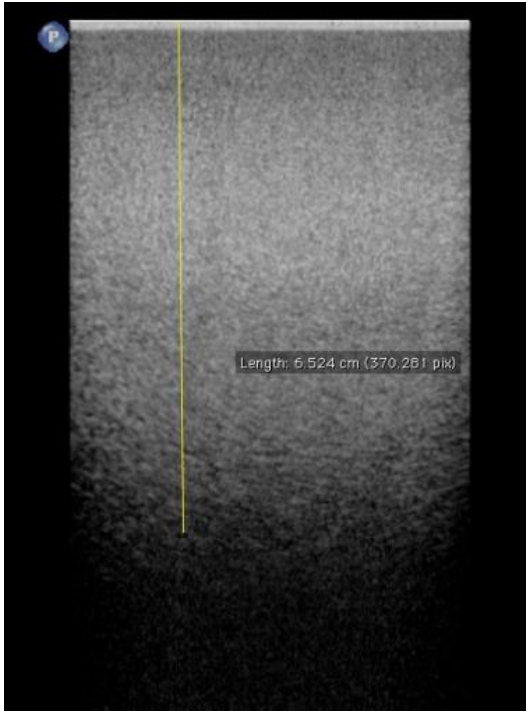
3. Image quality testing – Penetration depth

Why?

To ensure sensitivity of system is maintained (sensitivity = weakest signals that are detected)

How?

- Adjust maximum depth to visualise bottom of phantom
- Adjust image for full visualisation if necessary (TGC)
- Assess by looking for change in ultrasound speckle, object perception or change in brightness



Boote, E.J., Current Ultrasound Quality Control Recommendations and Techniques, University of Missouri-Columbia, 49-14425-36368-705.pdf (aapm.org)

3. Image quality testing – Spatial resolution

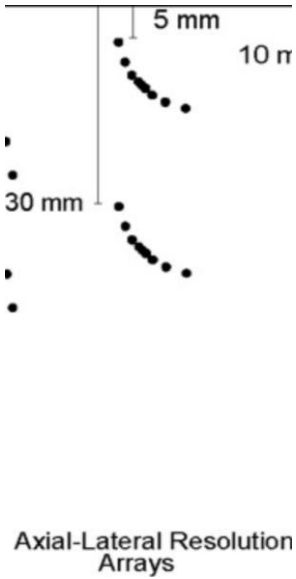
Why?

To ensure system adequately detects small, closely spaced objects along the beam axis (axial resolution) and perpendicular to the beam axis (lateral resolution)

How?

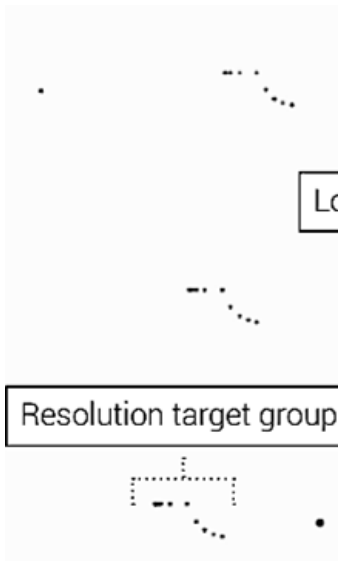
Easiest method is to determine the smallest known gap in the axial-lateral resolution arrays if available

ATS Model 550 Breast & Small Parts Phantom

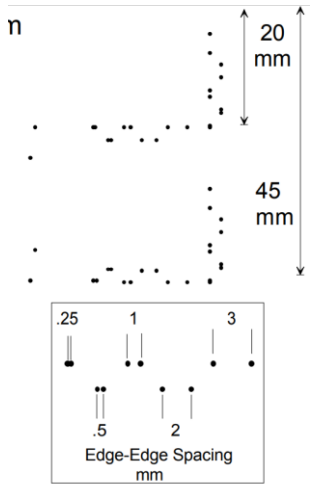


Axial-Lateral Resolution Arrays

Sun Nuclear Sono404™ Small Parts Phantoms



CIRS Model ATS 551 Small Parts Phantom



Axial-Lateral Resolution Array

- ATS, Model 550 Breast & Small Parts Phantom Instructions Manual, Revised January 2015
- https://www.sunnuclear.com/uploads/documents/datasheets/ATS551Phantom_101623.pdf
- https://www.sunnuclear.com/uploads/documents/datasheets/Diagnostic/Sono404-Ultrasound_092121.pdf

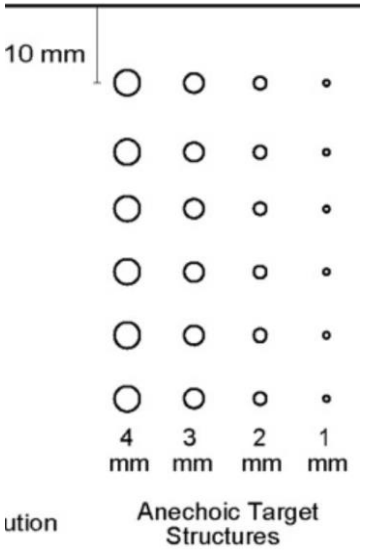
3. Image quality testing – Contrast resolution

Why?

To determine the smallest anechoic, cyst-like object that can be visualised.

How?

- Adjust image to visualise as many objects as possible, limiting image processing
- Record smallest object at each row/depth
- Assess objects for shape/distortion
- Assess for fill-in. If gain adjustment does not remove fill-in, further investigation is required



Goodsitt et al.: Real-time B-mode ultrasound, Medical Physics, Vol. 25, No. 8, August 1998

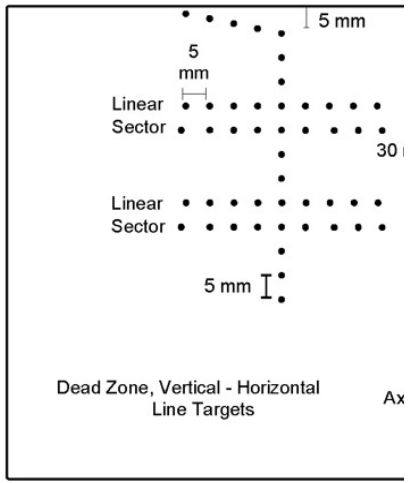
3. Image quality testing – Distance accuracy

Why?

- Vertical distance – deviations may indicate drift or failure in timing circuits
- Horizontal distance – deviations may indicate flaw or damage in transducer geometry

How?

- Adjust maximum depth to visualise all distance accuracy objects
- Place focal zone at region relevant to transducer use (same as baseline)
- Adjust image for full visualisation if necessary (TGC)
- Assess by measuring known horizontal and vertical distances



- GAMMEX RMI, The QA Cookbook for Ultrasound, 1994
- Goodsitt et al.: Real-time B-mode ultrasound, Medical Physics, Vol. 25, No. 8, August 1998

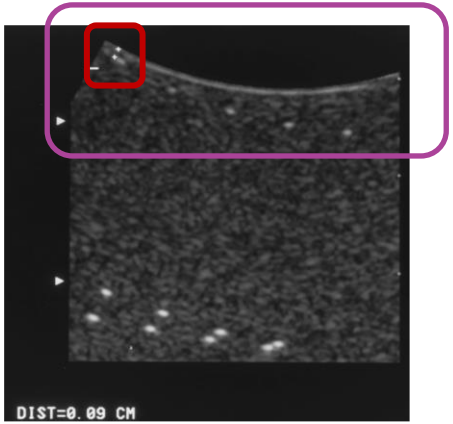
3. Image quality testing – Dead zone/ring down

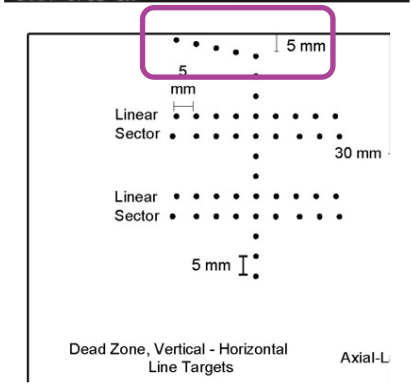
Why?

- Superficial visualisation important for breast imaging – lesions and changes close to skin
- Increased dead zone reduces visibility of these structures
- Cause – transducer damage, poor acoustic coupling

How?

- Set focal zone close to surface
- Scan dead zone test object
- Measure depth of pin closest to transducer





• GAMMEX RMI, The QA Cookbook for Ultrasound, 1994
• Boote, E.J., Current US QC Recommendations and Techniques, University of Missouri-Columbia, 49-14425-36368-705.pdf (aapm.org)

Summary

- Periodic testing ensures degradation of image quality may be found before it affect patient imaging
- Establishment of baseline values *and* baseline conditions is essential
- More frequent visual/physical inspection and uniformity testing can assist in finding the most common faults in breast ultrasound systems

Questions?