Automatic quality control processing for detection of element/channel dropout in ultrasound transducers

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Why Ultrasound Standards?

- Cost effective provision of medical physics services in ultrasound
  - Critical mass of data on system performance and value of such services
- More safe and effective ultrasound imaging (and therapy)

Dx Medical Ultrasound Standards

Steady
- AIUM
- IEC
- FDA
- NEMA/MITA
- AAPM
- DICOM

Peripheral to Rad'gy/Onc
- ASE, OB/Gyn

Early, dormant, revive
- NIST
- ASA/ANSI
- ACR

New
- QIBA

Early then dormant. Reviving?

- NIST – Power Measurement & Std. Source.
  - Possibly re-engaging
- Acoustical Society/ANSI
  - Dominates other areas of acoustics
- ACR
  - QC 96-present
  - Accreditation - Hangiandreou NJ
  - Real potential for new radiology/physics guides
- NCRP – Last ultras. publication in 2002

Steady Contributors

- AIUM – Main driver 1972 - 2012
- FDA -510k Guidance, strong contributions
- NEMA/MITA – Steady with AIUM since 1988 or so and independently
- AAPM- Since ~76 Report #8, QC document, Transrectal Therapy
  - Doppler eval. (Push Quantitative) & GS QC
- DICOM-Later than other modalities but steady solid additions, T. Nelson

Extant AIUM Performance Evaluation, Etc. Publications

- Performance Criteria and Measurements for Doppler Ultrasound Devices
- Recommended Ultrasound Terminology, Third Edition
- Routine Quality Assurance for Diagnostic Ultrasound Equipment
- Standard Methods for Calibration of 2D and 3D Spatial Measurement Capabilities of Pulse Echo Ultrasound Imaging Systems

AIUM Bioeffects and Safety

- Acoustic Output Labeling Standard for Diagnostic Ultrasound Equipment – to Sunset
- Acoustic Output Measurement Standard for Diagnostic Ultrasound Equipment- to Sunset:
- How to Interpret the Ultrasound Output Display Standard for Higher Acoustic Output Diagnostic Ultrasound Devices
- Medical Ultrasound Safety, Second Edition
- AIUM Consensus Report on Potential Bioeffects of Diagnostic Ultrasound
- Standard for Real-Time Display of Thermal and Mechanical Acoustic Output Indices on Diagnostic Ultrasound Equipment, Revision 2 (NEMA UD 2-2004)

Amer. Soc. Echocardiography

- Lang, R. M., et al. (2005). Recommendations for chamber quantification: A report from the ASE's guidelines and standards committee and the chamber quantification writing group, developed in conjunction with the european association of echocardiography. *J. ASE, 18*(12), 1440-1463.
- Earlier similar documents
- Similar OB/Gyn spatial measurements documents

IEC

- pulse echo US Perf. Eval. Series:
  - IEC 61319-1 spatial measurements
  - IEC 61319-2 depth of penetration* and local dynamic range
  - and one draft – (Madsen) and one quite different Technical Specification 62558 (Satrapa) on small void imaging

$$SNR(j) = \sqrt{\frac{A(j)^2}{A'(j)^2} - 1} \quad (2)$$

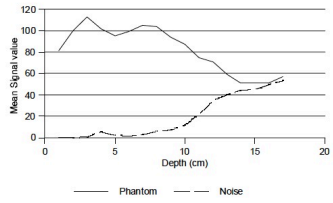


Figure 4 Average digitized image data value vs. depth for the phantom i data (A(j)) and for the noise image data (A'(j)).

- IEC 62127-1 and 2: Ultrasonics – Hydrophones
  - Part 1: Measurement and characterization of medical; ultrasonic fields up to 40 MHz
  - Part 2: Calibration for ultrasonic fields …40 MHz
- **IEC/TR 60854** Edition 1.0 (1986-10-30) Methods of measuring the performance of ultrasonic pulse-echo diagnostic equipment
- **IEC 61157** Edition 2.0 (2007-08-09) Standard means for the reporting of the acoustic output of medical diagnostic ultrasonic equipment
- **IEC 61161** Edition 2.0 (2006-12-13) Ultrasonics - Power measurement - Radiation force balances and performance requirements

- **IEC 61161** (2006-12-13) Ultrasonics - Power measurement - Radiation force balances and performance requirements
- **IEC 61266** (1994-12-15) Ultrasonics - Hand-held probe Doppler foetal heartbeat detectors - Performance requirements and methods of measurement and reporting
- **IEC/TS 61390** (1996-07-25) Ultrasonics - Real-time pulse-echo systems - Test procedures to determine performance specifications
- **IEC 61685** (2001-07-18) Ultrasonics - Flow measurement systems - Flow test object

- **IEC 61828** (2001-05-29) Ultrasonics - Focusing transducers - Definitions and measurement methods for the transmitted fields
- **IEC 61846** (1998-04-06) Ultrasonics - Pressure pulse lithotripters - Characteristics of fields
- **IEC/TS 61895** (1999-10-08) Ultrasonics - Pulsed Doppler diagnostic systems - Test procedures to determine performance
- **IEC/TS 61949** (2007-11-27) Ultrasonics - Field characterization - In situ exposure estimation in finite-amplitude ultrasonic beams
- **IEC/TS 62306** (2006-03-20) Ultrasonics - Field characterisation - Test objects for determining temperature elevation in diagnostic ultrasound fields

- **IEC 62359** - 2.0 (2010-10-27) Ultrasonics - Field characterization - Test methods for the determination of thermal and mechanical indices related to medical diagnostic ultrasonic fields
- **IEC/TR 62649** Edition 1.0 (2010-04-28)
- Requirements for measurement standards for high intensity therapeutic ultrasound (HITU) devices

IEC, (AAPM, AIUM) Draft QC Standard

- Need simple, reliable method of detecting reduced element/channel sensitivity in Dx arrays.
- Uniformity test in phantoms plus mechanical integrity and technologist observations detected 98.4 % of detected system failures.*
  - Depth of penetration and distance measurement accuracy not effective at detecting equipment failures*

Element/Channel Damage

- Satrapa - Averaging a cineloop to test for image nonuniformity*

  * Satrapa J, Preliminary Ultrasound Imager Quality Test, IEC TC87, WG9 meeting, Sestri Levante, Italy, Feb., 2010.

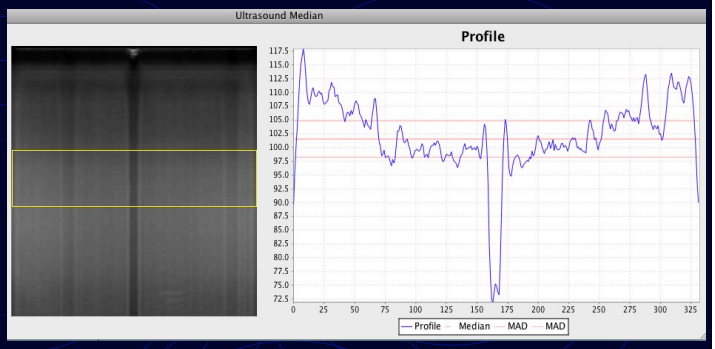
- Channel loss is dominant QC detection*
  - *Hangiandreou NJ, et al., Ultras. Med. Biol., 37, 1350-57, 2011

- Uniformity and Mulitipurpose Phantoms
  - Madsen multicurvature coupling with penetration and spatial measurements.

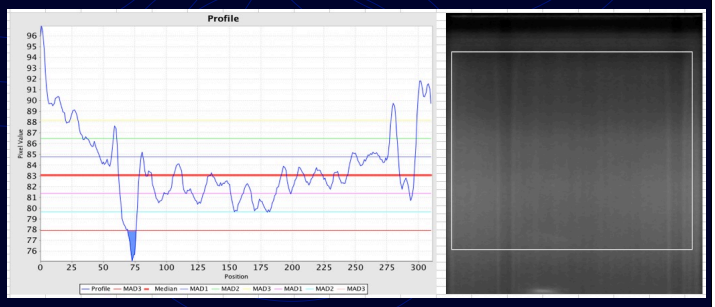
Readily available software for Uniformity Tests

- Plugin to multiplatform freeware ImageJ developed to:
  - Read uncompressed DICOM images
  - Segment & obtain temporal median of rectangular and curved linear array images in cine loop
  - Display profile of the mean over depth in near field of each column to aid detection of weak channels
  - Test initial automated detection algorithm
- Soon available after testing by Ultrasound Subcommittee

Filament blocking central elements Noticeable defect in unaveraged image. Probably an unacceptable defect



Profile and average image with unblocked array

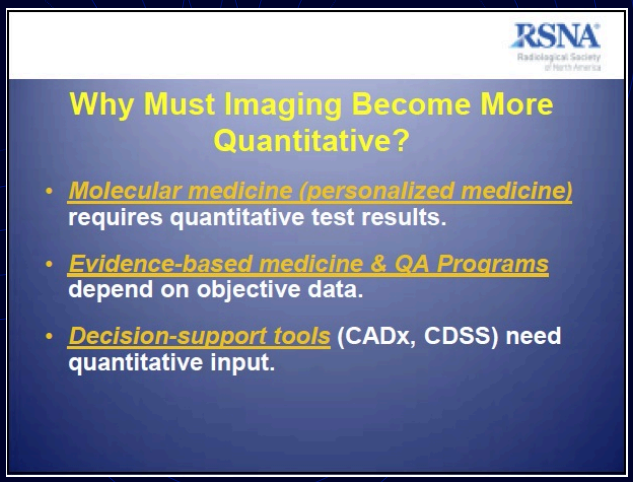


Conclusions

- Sensitivity visually is fairly simple to achieve
- Use professional judgments for relevant defects
- An initial criterion might be – what defects are visible on image of phantom with processing usually seen by physicians
- Worked on cylindrical void detectability as a criterion.

Quantitative Imaging Biomarkers Alliance (QIBA)

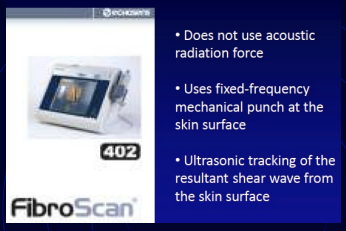
D Sullivan, QIBA Ultrasound Biomarkers Meeting, 03.29.2012, Phoenix,



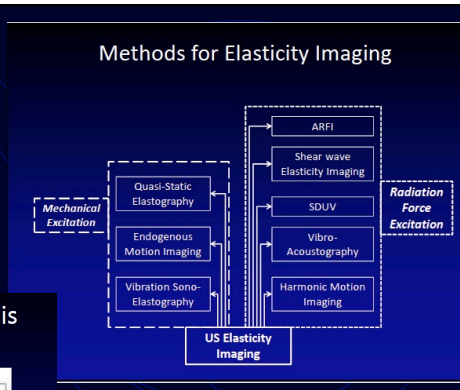
RSNA Radiological Society of North America

Examples of Imaging Biomarkers

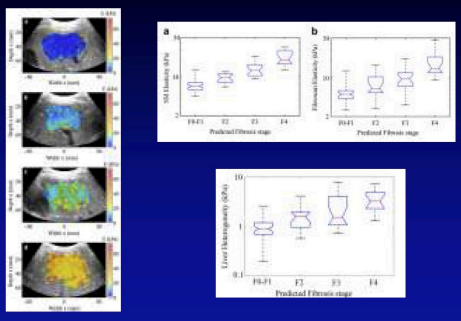
Biomarker	Test	Metric
COPD: Air-tissue ratio	CT scan densitometry	MLD (mean lung density)
Cancer: Tumor burden	CT scan volumetry; MR scan volumetry	Volume
Cancer: Glucose avidity	FDG-PET scan	SUV (standardized uptake value)
Cancer: Vascular permeability	DCE-MRI scan	K_{trans}; IAUC
Brain surgery risk: Proximity to eloquent cortex	fMRI scan brain-mapping	Center and magnitude of cortical activation



- Does not use acoustic radiation force
- Uses fixed-frequency mechanical punch at the skin surface
- Ultrasonic tracking of the resultant shear wave from the skin surface



Supersonic Shear Imaging: Liver Fibrosis



Bavu et al. "Noninvasive In Vivo Liver Fibrosis Evaluation Using Supersonic Shear Imaging: A Clinical Study on 113 Hepatitis C Virus Patients," UMB, 37(9), 2011.

- TJ Hall, QIBA Ultrasound Biomarkers Meeting, 03.29.2012, Phoenix

Meetings/Call Summaries

- 06.22.2012 QIBA US SWS Tech Ctte Call Summary -
- 06.01.2012 QIBA US SWS Tech Ctte Call Summary
- 05.14.2012 QIBA US SWS Tech Ctte Call Summary
- 05.04.2012 QIBA US SWS Tech Ctte Call Summary
- 04.18.2012 QIBA US SWS Tech Ctte Call Summary

http://
qibawiki.rsna.org

Presentations and Reports:

- 2012 QIBA Annual Meeting Presentation: QIBA US SHEAR WAVE SPEED Clinical Applications Committee Report
- 2012 QIBA Annual Meeting Presentation: US Modality Committee Report
- 2012 AIUM Presentation:QIBA-Blood Flow Measurement in the Hemodialysis Patient *M.L. Robbin, MD*
- 2012 AIUM Presentation: Novel Pushes Make Complex Shear Waves for Elasticity Imaging *J. Greenleaf, PhD*
- QIBA Ultrasound Biomarkers Meeting, 03.29.2012-Agenda
- QIBA Ultrasound Biomarkers Meeting, 03.29.2012-Dr. Sullivan Presentation
- QIBA Ultrasound Biomarkers Meeting, 03.29.2012-Dr. Carson Presentation
- QIBA Ultrasound Biomarkers Meeting, 03.29.2012-Dr. Cosgrove Presentation
- QIBA Ultrasound Biomarkers Meeting, 03.29.2012-Dr. Garra Presentation
- QIBA Ultrasound Biomarkers Meeting, 03.29.2012-Dr. Hall Presentation
- QIBA Ultrasound Biomarkers Meeting, 03.29.2012-Dr. Hoyt Presentation
- QIBA Ultrasound Biomarkers Meeting, 03.29.2012-Dr. Nelson Presentation
- QIBA Ultrasound Biomarkers Meeting, 03.29.2012-Dr. Rognin Presentation
- QIBA Ultrasound Biomarkers Meeting, 03.29.2012-Dr. Rubin Presentation

Opportunities -Other standards needs

- QIBA-like efforts in:
  - Volumetric/ other morphometry
    - QIBA CT volumetry example
  - Spectral and color flow Doppler-
    - correction tables or company changes
  - Quantitative and/or safe & uniform 3D CA imaging
- Simple, cheap guides for common applications
  - Standards often serve multiple audiences
  - Most IEC standards are expensive

The surface area of the ellipsoids is given by:

$$A = 2\pi\left(\frac{b}{2}\right)^2 + \pi a_1\left(\frac{b}{2\varepsilon_1}\right)\arcsin\varepsilon_1 + \pi a_2\left(\frac{b}{2\varepsilon_2}\right)\arcsin\varepsilon_2$$

where

ε_1 is the eccentricity $(1 - (b/(2a_1))^2$;

ε_2 is the eccentricity $(1 - (b/(2a_2))^2$.

See Table 1 for expected values for the two objects in Figure B.1.

Need Practical Procedures for Use of IEC Spatial Measurements & Other Standards

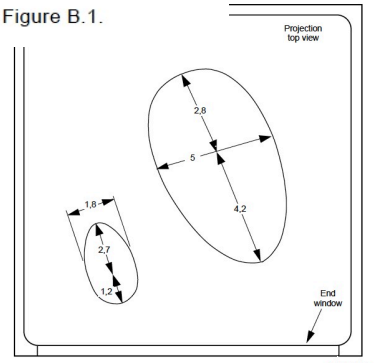
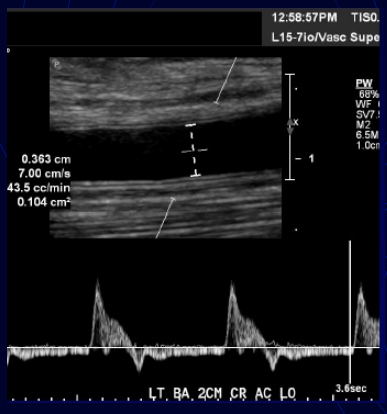
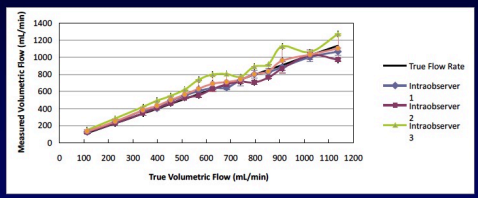


Figure B.3 – Projection view from top of test object shown in Figure B.1

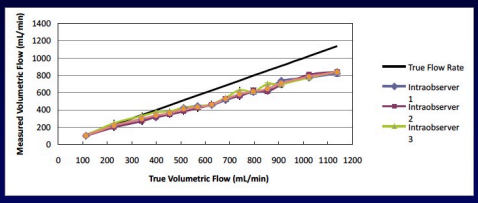
Large, unnecessary variations in volume flow measurements



Philips iU22



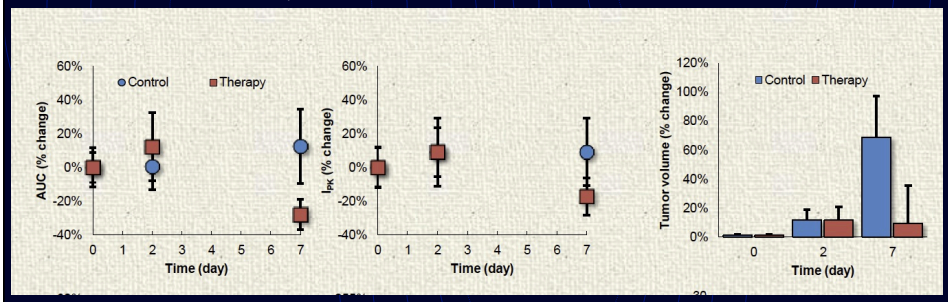
Zonare



Hoyt K; Accuracy of Volumetric Flow Rate Measurements: An In Vitro Study Using Modern Ultrasound Scanners. *J Ultrasound Med* 2009;28:1511-1518.

Quantitative volumetric mapping of tumor vascularity using contrast enhanced US

- **Hoyt K, Sorace A, Saini R. Investigative Radiology, 47:167-174, 2012.**



- **Automated acoustic output based on bubble disruption rate**
- **Refill rate Imaging**

Conclusions

- There are many opportunities to create or improve ultrasound standards and practical use guidelines.
- A more complete listing than presented here might be a useful public page on an individual's or the ultrasound subcommittee's web site. Its hard to find the various types of standards on an organization's site.