Quantitative Imaging Biomarkers Alliance Volume Flow and Contrast Enhanced Ultrasound Biomarker

AAPM 2022 Spring Clinical Meeting

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AAPM 2022 Spring Clinical Meeting
March 26, 2022 – New Orleans, LA

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Disclosures

- QIBA
  - Cochair, Ultrasound Coordinating Committee
  - Member, all four Biomarker Committees
- AAPM Ultrasound Subcommittee and working groups
- Member IEC WG9 & 6

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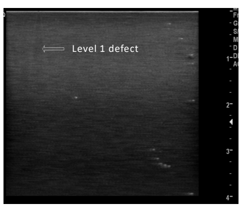
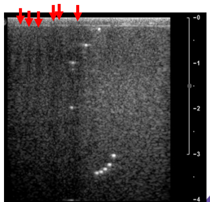
Before quantification, must assure proper functioning Transducer damage/defect is most common





Level 4 defects, replace

Image Uniformity Test

From 2020 draft of revised Routine Quality Assurance for Diagnostic Ultrasound Equipment; 2008 version available free to AIUM members

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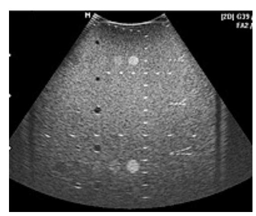
Also, should check 3D resolution, contrast resolution and depth of imaging for overall imaging performance



With traditional methods this can lead to a lot of numbers that are difficult to interpret, except in time series, and phantoms are around $3000

A bit harder for slice thickness with depth

These problems are probably resolved with what is expected to be a much simpler and less expensive phantom.

AIUM Quality Control Manual, 2014, free to AIUM members

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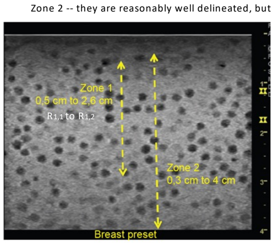
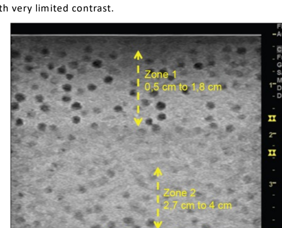
Visualization of randomly-distributed high-contrast, low-echo spheres

Visually estimate the depth range(s)
Zone 1 -- the spheres are clearly visible
Zone 2 -- they are reasonably well delineated, but with very limited contrast.





Modified from James Zagzebski, Univ. of Wisconsin

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In Automated analysis Find

- Lesion signal to noise ratio, *LSNR,* for each detected sphere.
  - *LSNR* = (mean pixel value in sphere - that of background)/σ_b
- Mean *LSNR*, $LSNR_{md}$, in overlapping small depth intervals, d
- Useable range, R_1 to R_2, in which $|LSNR_{md}| \geq$ n dB; n=-3 for Zone 1
- Mean useable contrast, $LSNR_{mZ}$, in zone Z
- Clarity Index, CI = log$|LSNR_{mZ}|$ x ($R_{z,2}$ - $R_{Z,1}$)
- Track all 4 relative to original reference values, or just the CI
- The CI for usually only one zone, carries more useable information, related directly to clinical performance than the hard-to-evaluate lateral, elevational and axial 3D plots of the beam profiles of filaments at each depth.

Questions?

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AIUM-QIBA **Volume Blood Flow (VBF)** Biomarker Committee Members	
J. Brian Fowlkes, PhD, FAIUM (Co-Chair)	University of Michigan
Oliver Daniel Kripfgans, PhD, FAIUM (Co-Chair)	University of Michigan
James Jago, PhD (Co-Chair)	Philips
Kazuya Akaki	Canon Medical Systems USA
Maryam Alsyedalhashem, PhD	King Fahad Specialist Hospital Dammam (Saudi Arabia)
Cristel Baiu, MS	Sun Nuclear Corp. / Gammex Inc.
Matthew Bruce, PhD	University of Washington
Elizabeth Carini, RDMS, RDCS, RVT, CCRC	Siemens Healthineers USA, Inc.
Paul L. Carson, PhD, FAIUM	University of Michigan
Shigao Chen, PhD, FAIUM	Mayo Clinc
Hyo-Min Cho, PhD	Korea Research Institute of Standards and Science
Yi-Hong Chou, MD, FAIUM	Taipei Veterans General Hospital
Vadivel Devaraju, PhD	University of Mississippi Medical Center
David Dubberstein, PhD	GE Healthcare
Todd Nicholas Erpelding, PhD	Canon Medical Systems USA
Jing Gao, MD, FAIUM	Cornell University / Rocky Vista University
Timothy J Hall, PhD, FAIUM	University of Wisconsin
Anne L. Hall, PhD	GE Healthcare
Mark R. Holland, PhD, FAIUM	Indiana University School of Medicine
Nicole Lafata, PhD	Duke Health
Safeer Hyder Laghari, PhD	Sukkur IBA University (Pakistan)
Chi-Yin Lee	Siemens

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Sibo Li	Philips
Adrian Lim, MD, FRCR	Imperial College London and Healthcare NHS Trust
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Ted Lynch, PhD	CIRS, Inc.
Ravi Managuli	Fujifilm Healthcare Americas Corporation
Andy Milkowski, BSME, MSIE	Siemens
Shigeto Ono	CIRS, Inc.
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Shriram Sethuraman	Philips
Randall Sung, MD	University of Michigan
Rimon Tadross, PhD	GE Healthcare
Iman Taghavi, MSc	Technical University of Denmark
Kai Erik Thomenius, PhD, FAIUM	Independent Consultant
Theresa A. Tuthill, PhD	Pfizer

Due to:
Dan Sullivan, MD
Duke U. Radiology

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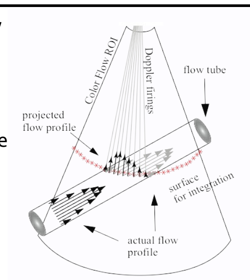
3D/4D Volume Flow

Integration of Color Flow Velocity Vector Function Normal to the C-plane Surface Yields Blood Volume Flow

$$Q = \oint_S \vec{v} \cdot d\vec{A}$$



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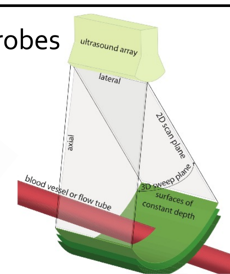
Mechanically Swept Probes



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Fully Electronic (2D array) Probes

Philips xMatrix

GE Voluson e4D

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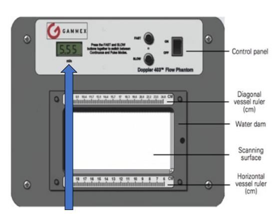
Complex Flow Phantom



Calibrated Volumetric Flow

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Ultrasound Systems in this Study*

- Canon (formerly Toshiba) Aplio 500 with a mechanically swept 9CV2 probe
- GE Logiq LE9 with a mechanically swept RSP6-16 probe
- Philips Epiq 7 with an X6-1 2Dmatrix array

* Other participating companies have systems in development.

Kripfgans et al. Radiology, 2020

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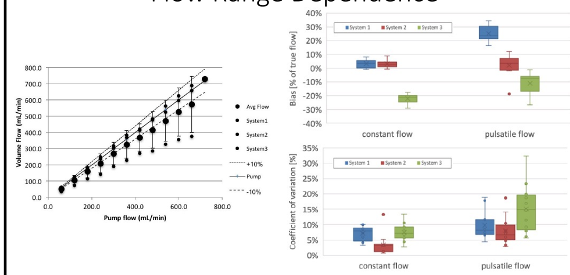
Flow Range Dependence



Kripfgans et al. Radiology, 2020

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Ultrasound Volume Blood Flow

- Current status is stage 0 – draft stage, ready for full committee
- A checklist of each actor's responsibilities is drafted.
- Finalizing section 4 for assurance of conformance and determining the necessary tests for bias and variance.
- Two publications under review:
  - Measurement variation using 2D vs. 3D methodologies for blood flow for improvement / reduction in intra-observer variability
  - Beam spacing and beam width paper
- A currently funded NIH project on umbilical venous flow may provide additional groundwork data.

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QIBA CEUS Committee Leadership

- Co-chairs
  - Mike Averkiou, PhD — University of Washington
  - Richard Barr, MD — Northeastern Ohio Medical University
  - Todd Erpelding, PhD — Canon Medical Systems USA

72 members

https://qibawiki.rsna.org/index.php/Ultrasound_CEUS_BC

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Participating Institutions and Companies (sample)

University of Washington	Cannon	Philips	GE	Mayo Clinic
Northeastern Ohio Medical University	Bracco	Siemens	University of Alabama at Birmingham	University of Michigan
Children's Mercy Hospital	FDA	UCSD	St. Jude Children's Research Hospital	Foothills Medical Centre, University of Calgary

And more

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Why we need CEUS quantification

Extract important physiologic information, related to perfusion, from the time evolution of the tumor image intensity during the bolus transit (wash-in/washout)

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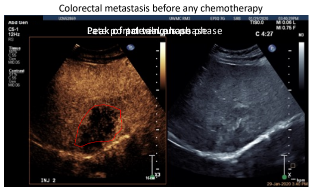
Why we need CEUS quantification

Colorectal metastasis before any chemotherapy



Quantification objective: Extract important physiologic information, related to perfusion, from the time evolution of the tumor image intensity during the bolus transit (wash-in/washout)

*Outlined lesion is colorectal metastasis in the liver

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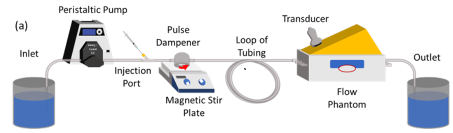
Groundwork—the QIBA CEUS phantom

Use similar for training techs to perform reproducible studies



- Sonovue/Lumason: 0.2 ml in 19.8 ml saline, inject 2 ml of diluted solution into flow phantom (effort to mimic clinical dose and to be in middle of intensity-concentration linearity range)
- Collect 5 TICs per scanner on a single day (4 scanners used)
- Repeat above procedure on 3 different days (total of N=15 per scanner)
- Keep system parameters constant between trials. Image tube in same orientation and depth every time

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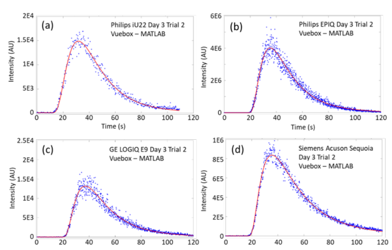
Groundwork Results (sample TIC's)



- Substantially similar curves are produced from all scanners
- Arbitrary amplitude calibration among vendors produces different intensity values—current challenge
- Lognormal distribution produces curves well fitted to the data
- We use fitted curves to extract the important perfusion-related parameters

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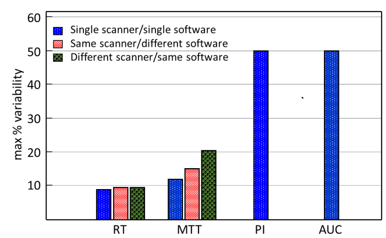
Results (overall summary)

Averkiou, et al., *Invest. Radiol.* 55, 10 (2020



RT and MTT: 10-20% variability

PI and AUC: 50% variability

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