Imaging performance of Quantitative Transmission ultrasound tomography: preliminary results towards establishing industry consensus standards

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QT Ultrasound

INTRODUCTION

Abstract: Quantitative Transmission (QT) Ultrasound is an FDA approved breast imaging modality, but no industry standard exists for evaluating its imaging performance. As a model for future standards and regulatory guidance, we have comprehensively characterized the performance of our latest 3D QT Ultrasound scanner — including spatial resolution, contrast to noise ratio (CNR), linear measurement accuracy, and image uniformity — for both transmission and reflection imaging.

METHODS

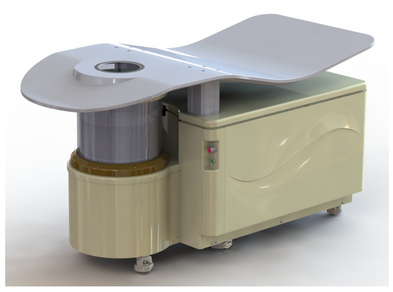

Fig. 1: 3D CAD rendering of the QT Scanner 2000

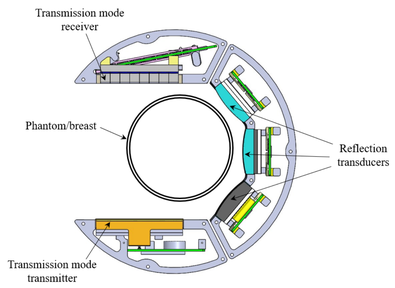

Fig. 2: Schematic of the QT Scanner 2000 scan head

System [1]:

- Transmitter and 2048-element receiver array (8 rows x 256 columns of 2.5 mm x 0.5 mm-sized elements) for transmission imaging
- 3 transducers (short, medium, and long-range foci) for reflection imaging
- Housing rotates 360° within water bath, automatically stepping to scan full imaging volume
- Fully 3D data acquisition and image reconstruction

Phantom Measurements [2]:

- Imaged custom phantoms to quantify performance
- Spatial resolution: cylindrical agar phantoms with embedded urethane cylinder or glass beads
- CNR & linear measurement accuracy:
  Transmission: cylindrical urethane phantoms with three 1.4, 5, 10, or 20-mm-diameter rods
  Reflection: 2-layer agar phantom with glass beads
- Uniformity: stack of cylinders with different speeds

Fully 3D speed, attenuation, and reflection maps

RESULTS

Spatial Resolution

Transmission

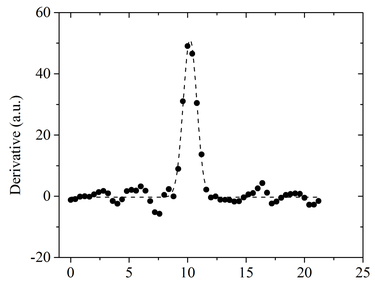

Fig. 3: Point spread function across urethane-agar interface

Spatial Resolution (FWHM)
X & Y: 1.49 ± 0.07 mm
Z: 2.35 ± 0.11 mm

Reflection

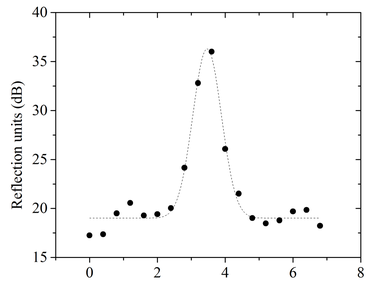

Fig. 4: Point spread function across 100-µm-diameter glass beads

Spatial Resolution (FWHM)
X & Y: 0.96 ± 0.11 mm
Z: 3.19 ± 0.32 mm

Contrast to Noise Ratio

CNR (Transmission)
20 mm: 17.4 ± 0.06 dB
10 mm: 17.3 ± 0.10 dB
5 mm: 17.4 ± 0.04 dB
1.4 mm: 15.6 ± 0.26 dB

CNR (Reflectance)
2 mm: 33.5 ± 0.6 dB
0.8 mm: 32.6 ± 0.9 dB
0.55 mm: 32.5 ± 0.5 dB
0.3 mm: 31.5 ± 0.5 dB
0.2 mm: 25.1 ± 0.4 dB
0.1 mm: 23.1 ± 0.2 dB

Reflection

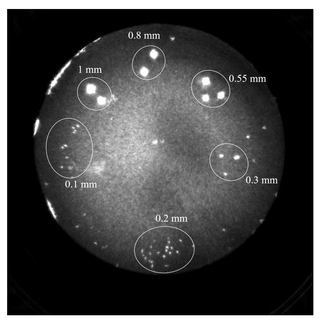

Fig. 5: QT reflection image of CNR phantom with glass beads of various sizes marked as groups

Linear Measurement

Transmission

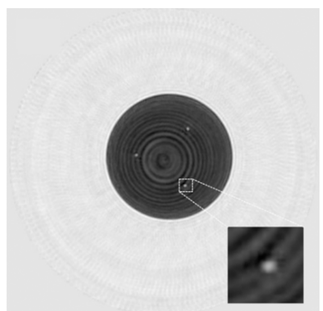

Fig. 6: Coronal speed of sound image of cylindrical phantom with three 1.4-mm-diameter rods

Linear Measurement Accuracy
Coronal: 0.96%
Axial: 1.18%
Sagittal: 1.20%

Reflection

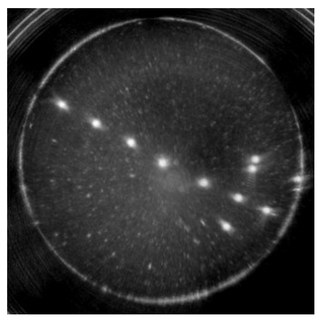

Fig. 7: Coronal reflectance image of linear accuracy phantom with 0.7-mm-diameter glass beads

Linear Measurement Accuracy
Coronal: 0.55%
Axial: 0.59%
Sagittal: 1.07%

The QT Scanner 2000 provides high-resolution, high-fidelity, multimodality breast imaging that can identify breast anatomy

RESULTS

Uniformity

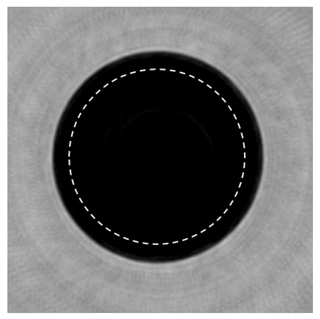

Fig. 8: Coronal speed of sound image of uniform phantom

Speed of Sound Uniformity
Overall uniformity mean > 99%

Overall Speed Measurement
Accuracy: 0.17%
Precision: 0.16%

Clinical Images

Transmission

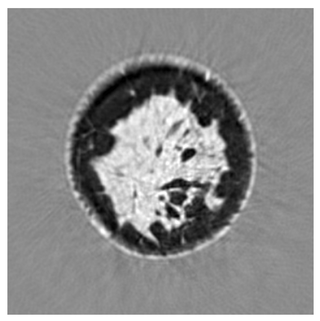

Fig. 9: Coronal speed of sound image of a whole breast, showing brighter fibroglandular tissue embedded in darker fat tissue

Reflection

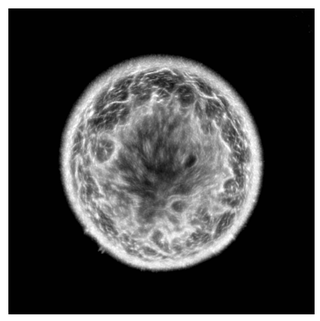

Fig. 10: Corresponding coronal reflection image

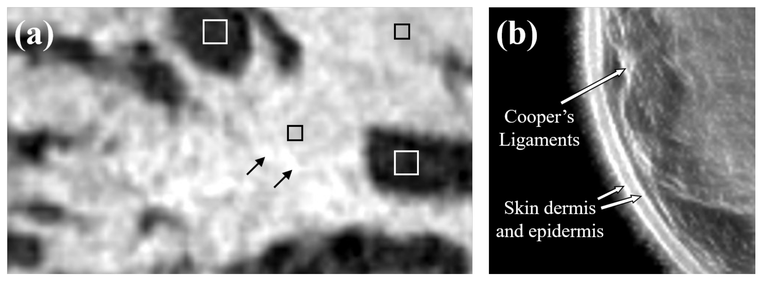

Fig. 12: (a) Zoom-in-view of speed of sound image of breast tissue, where white squares mark fat, black squares mark glandular tissue, and black arrows mark ducts. (b) Reflection image showing delineation of interfaces, including multiple skin layers and Cooper's ligaments.

CONCLUSIONS

- **We have characterized the imaging performance of the QT Scanner 2000.**
- **Our comprehensive evaluation provides an excellent basis for future regulatory guidance and industry consensus standards.**
- **Our clinical images demonstrate the utility of the scanner for research and clinical breast imaging applications.**

REFERENCES

1. M.W. Lenox, et al., *Int J Biomed Imaging*, 2015, pp. 454028
2. J.W. Wiskin, et al., *IEEE Trans Ultrason Ferroelectr Freq Control* , 2017, pp. 1161