RSNA QIBA Ultrasound Shear Wave Speed Phase II Phantom Study in Viscoelastic Media

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Objective

Perform a comparison of shear wave speed (SWS) measurements between commercially-available systems using calibrated phantoms that have viscoelastic behavior similar to that observed in normal and fibrotic liver.

Introduction

- Significant inter-system variability in liver shear wave speed (SWS) measurements can preclude meaningful comparison of measurements performed with different systems [1, 2, 3].
- The RSNA Quantitative Imaging Biomarker Alliance (QIBA) ultrasound SWS committee has been developing elastic and viscoelastic (VE) phantoms to evaluate system dependencies of SWS estimates used to non-invasively characterize liver fibrosis.
- Previous elastic phantom studies demonstrated inter-system variability ranging from 6–12% in elastic phantoms with nominal SWS of 1.0 and 2.0 m/s [1]. A source of inter-system variability not characterized in that study was the impact of viscosity and dispersion that may lead to differences between group SWS measurements.

Methods

- CIRS, Inc. (Norfolk, VA) fabricated 3 phantoms (E2297-A1, -B3, -C1) using a proprietary oil-water emulsion infused in a Zerdine® hydrogel.
- The phantoms were characterized by phase velocity at 200 Hz and linear dispersion slope ($\frac{dc}{df}$) from 100–400 Hz to provide a metric of their dispersion [4].
- These metrics were compared to *in vivo* human SWS measurements with different degrees of fibrosis acquired at Duke [4] and the Mayo Clinic/Philips Research [5], and the phantoms represent: **healthy liver (A1)**, **mildly fibrotic (B3)** and **significantly fibrotic (C1)** tissue.
- The phantoms were shipped to and measured at academic, clinical, government and vendor sites using different systems with curvilinear arrays at multiple focal depths (3.0, 4.5 & 7.0 cm).

Vendor	System Model	# of Sites
General Electric (phantom mode)	LOGIQ E9	3
Philips	Epiq	3
	IU22	2
Samsung Medison	RS80A	3
Siemens	S2000	1
	S3000	3
Supersonic Imagine	Aixplorer	5
Toshiba	Aplio 500	3
Zonare	ZS3	1

Results

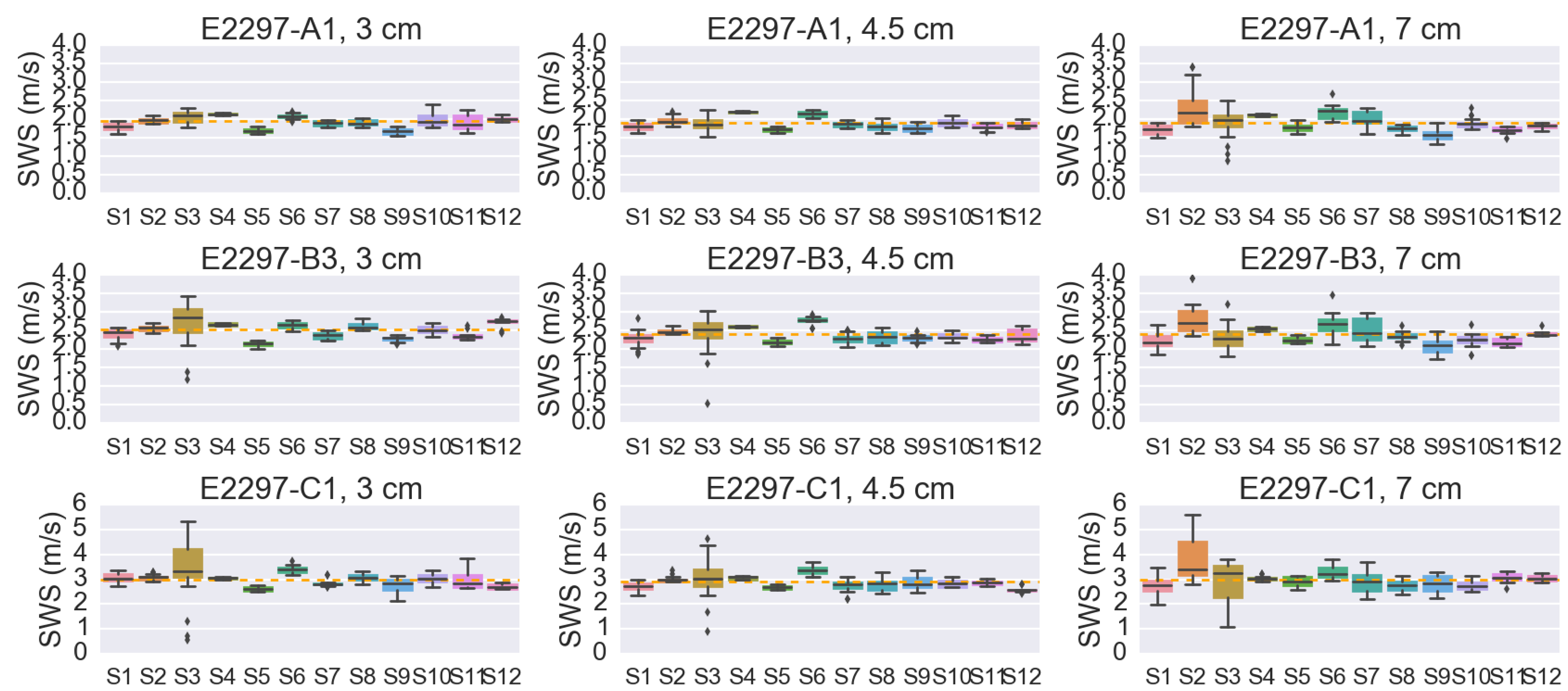

Figure 1: SWS measurements for each system (randomized order) in each phantom for each focal depth. Each box plot represents the 25th–75th percentile range of all measurements made with that system (potentially at multiple sites), with the black horizontal line in each box representing the 50th percentile. The whiskers extend to include 1.5× the standard deviation (σ) of the measurement data, with outliers represented as individual points beyond that range. The dashed orange line in each plot represents the grand median across all of the systems for that specific phantom and focal depth. Notice that the range of SWS for each row of plots is held constant, but varies as a function of each phantom.

Table 1: Grand median (GM) SWS values across all systems (dashed orange lines in Figure 1), interquartile range (percentage of grand median) and the maximum single system median deviation (Max Diff) from the grand median for each phantom and focal depth.

Focal Depth (cm)	E2297-A1 GM (m/s)	E2297-A1 IQR (m/s)	E2297-A1 Max Diff (%)	E2297-B3 GM (m/s)	E2297-B3 IQR (m/s)	E2297-B3 Max Diff (%)	E2291-C1 GM (m/s)	E2291-C1 IQR (m/s)	E2291-C1 Max Diff (%)
3.0	1.94	0.24(12.4%)	13.7	2.52	0.24(9.6%)	14.5	3.00	0.31(10.3%)	13.5
4.5	1.90	0.21(11.1%)	15.3	2.40	0.28(11.5%)	16.0	2.90	0.31(10.7%)	15.5
7.0	1.90	0.34(17.7%)	17.6	2.40	0.36(15.1%)	12.7	2.99	0.47(15.7%)	13.7

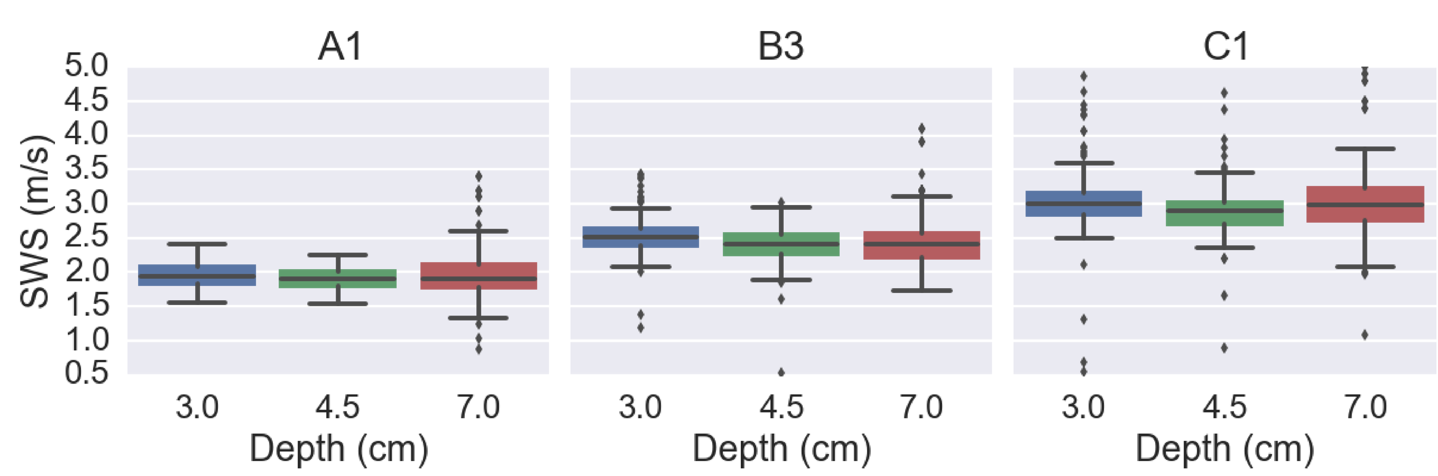

Figure 2: Aggregate SWS measurements across all sites and systems as a function of phantom and focal depth. SWS measurement variance increases as a function of higher stiffness (A1 → C1) and focal depth (3 → 7 cm), which is consistent with the limitations of finite shear wave spatial and temporal sampling, and decreased signal-to-noise ratio with increasing stiffness and depth [6].

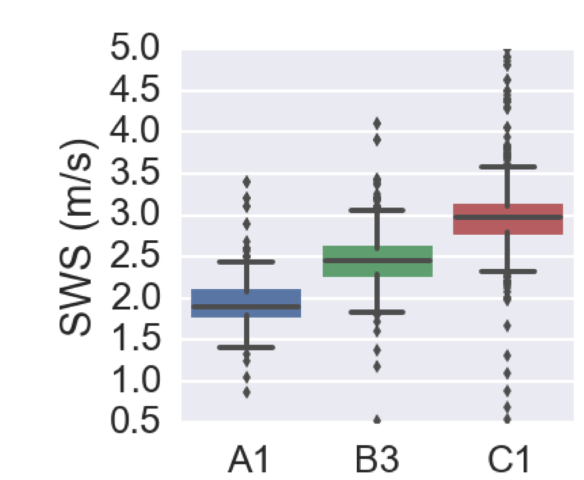

Figure 3: Aggregate SWS measurements for all focal depths, sites and systems in each phantom. Despite some inter-system variability, current generation ultrasound SWS imaging systems are able to differentiate viscoelastic material properties ($p < 0.01$, one-way ANOVA) that span healthy to fibrotic liver.

Conclusions

- All of the current-generation ultrasound SWS measurement systems were able to report SWS that differentiated each of the viscoelastic materials tested in this study.
- The deepest focal depth yielded the greatest inter-system variability for each phantom (maximum of 17.7%) as evaluated by IQR.
- Inter-system variability was consistent across all 3 phantoms and was not a function of stiffness.
- Median SWS estimates for the greatest outlier system in each phantom/focal depth combination ranged from 12.7–17.6%.

Acknowledgements & Disclaimers

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References

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