

Effects of Excitation Duration in Transthoracic Cardiac M-Mode ARFI Imaging

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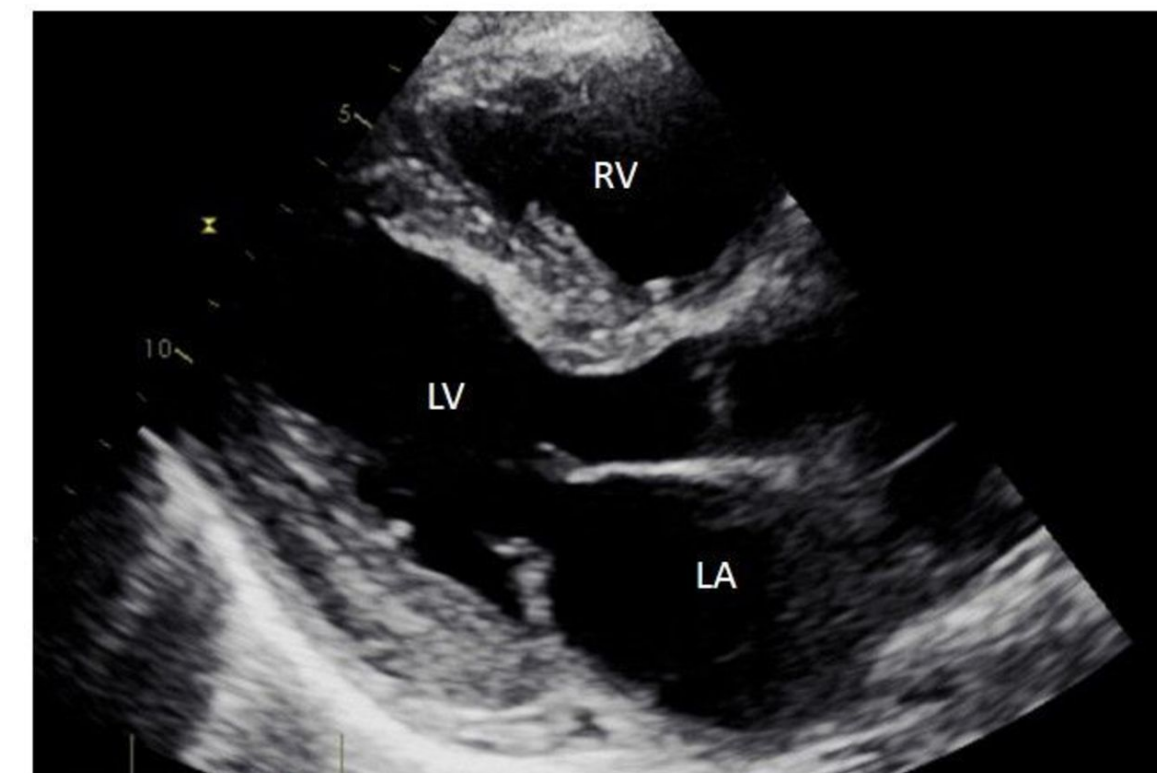
ARFI measures significant differences between amyloids' and controls' septal displacements, but diastolic/systolic ratio is different only with longest push.

DISCLOSURES

- Some authors hold intellectual property and have licensing agreements related to Acoustic Radiation Force Impulse (ARFI) and shear wave elasticity imaging.
- ARFI imaging is described in an implementation that is not FDA-cleared for clinical use.
- Some authors receive technical and in-kind support from Siemens Medical Solutions.

TRANSTHORACIC ECHOCARDIOGRAPHY

- Strain, Doppler, contrast, etc. are widely used to assess anatomical and physiological features.
- ARFI imaging may be a useful tool for cardiologists.
- We previously examined feasibility, safety, and robustness of transthoracic cardiac ARFI, but with limited tissue displacement and penetration depth.
- Address challenges using new Siemens Sequoia system and 5V1 phased-array cardiac probe.
- Examine the effects of the excitation pulse duration.
- Compare cardiac amyloid patients to age-matched controls.



Transthoracic echocardiogram of cardiac amyloidosis¹

AMYLOIDOSIS²

- Cardiac involvement is associated with symptoms of heart failure
- Causes thickening and stiffening of myocardial tissue.
- Diagnosed noninvasively by echocardiography, cardiac MRI, or nuclear scintigraphy.
- New drugs and treatments targeting the underlying amyloidogenic process underscore importance of early detection and screening.

DATA ACQUISITION

- Duke Medical Center IRB-approved clinical study of patients with confirmed cardiac amyloidosis (N=11) and age-matched controls without cardiac disease (N=12)
- ARFI “push” pulses lengths of 200, 400, or 800 μ s, up to three times greater energy than achieved previously
- 20-Hz “push” PRF over 2.5 seconds with pulse-inversion harmonic tracking pulses
- Sequences below FDA mechanical index and probe heating limits
- Live ECG was acquired and retrospectively aligned
- Parasternal Long Axis and Short Axis views of the Intraventricular Septum (PLAX / PSAX of IVS)
- Full echo workups and ARFI acquisitions were done by a single experienced cardiac sonographer, and DICOM data were stored



ARFI-DERIVED INDICES OF STIFFNESS

Estimation of cardiac windows:

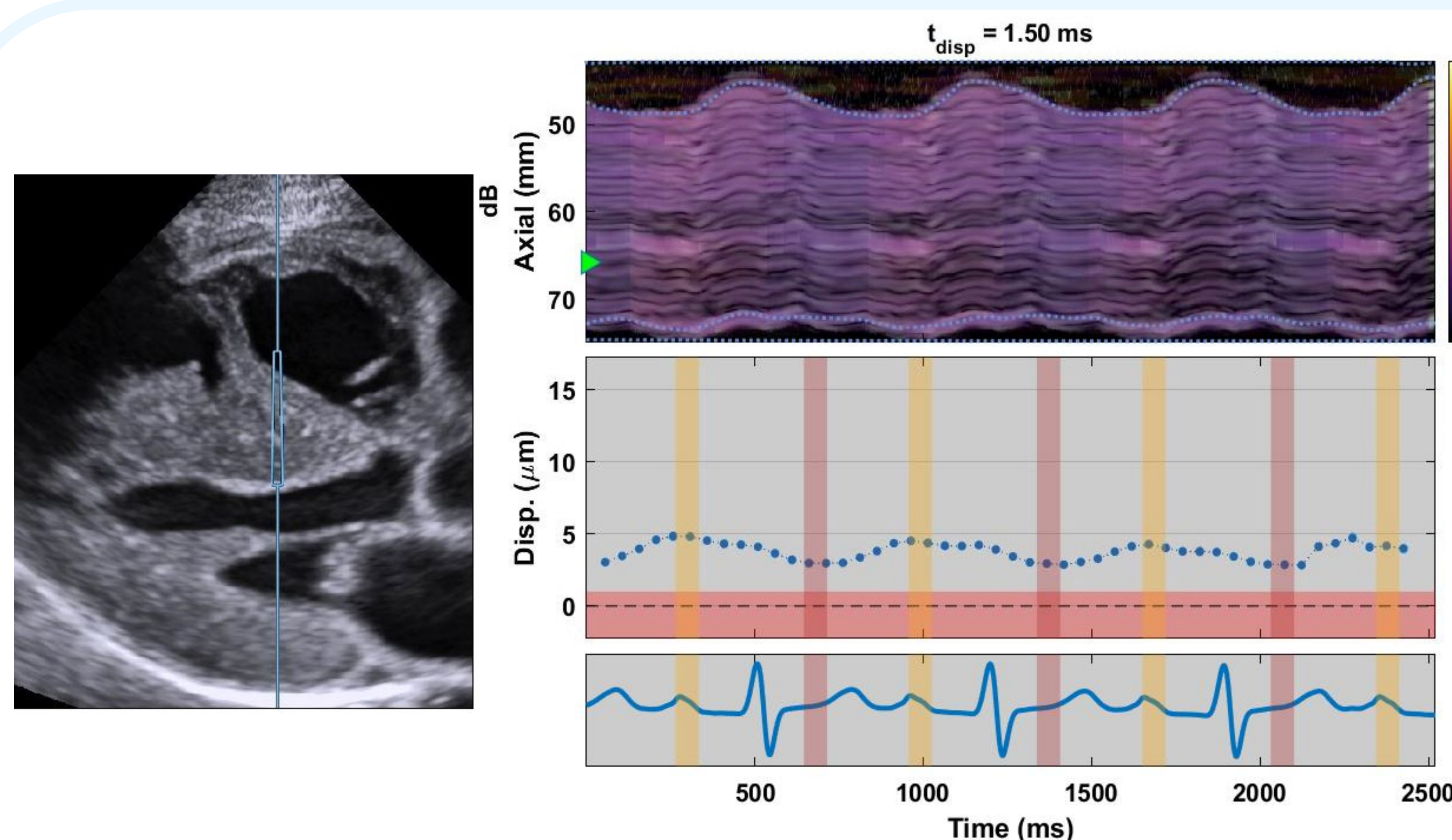
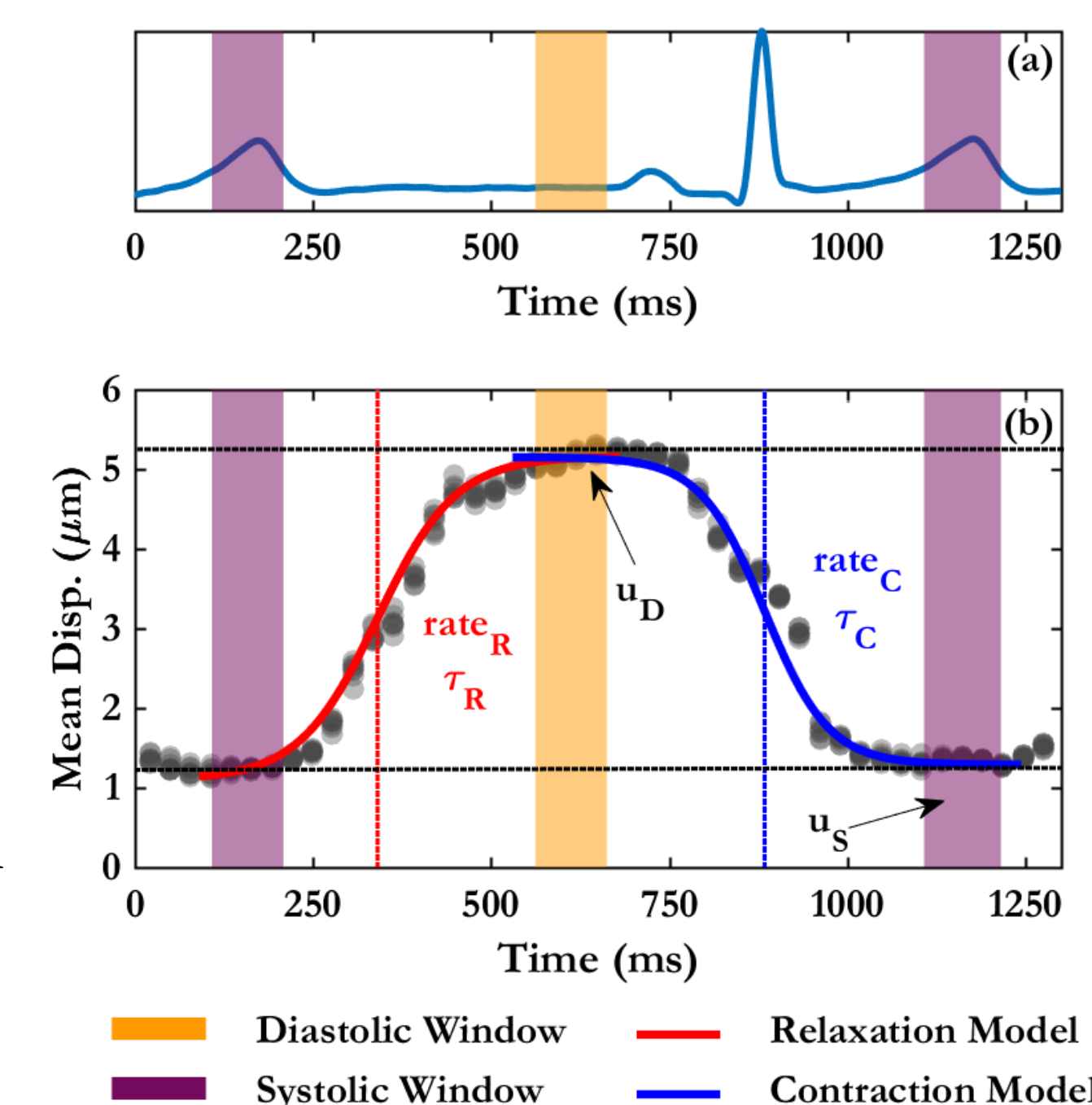
- Diastole at 70% of R-R interval
- Systole at 25% of the R-R interval
- Window length: 10% of R-R interval

Indices:

- Displacement ratio (displacement in diastole / in systole)
- Rates and time constants of relaxation and contraction

Methods:

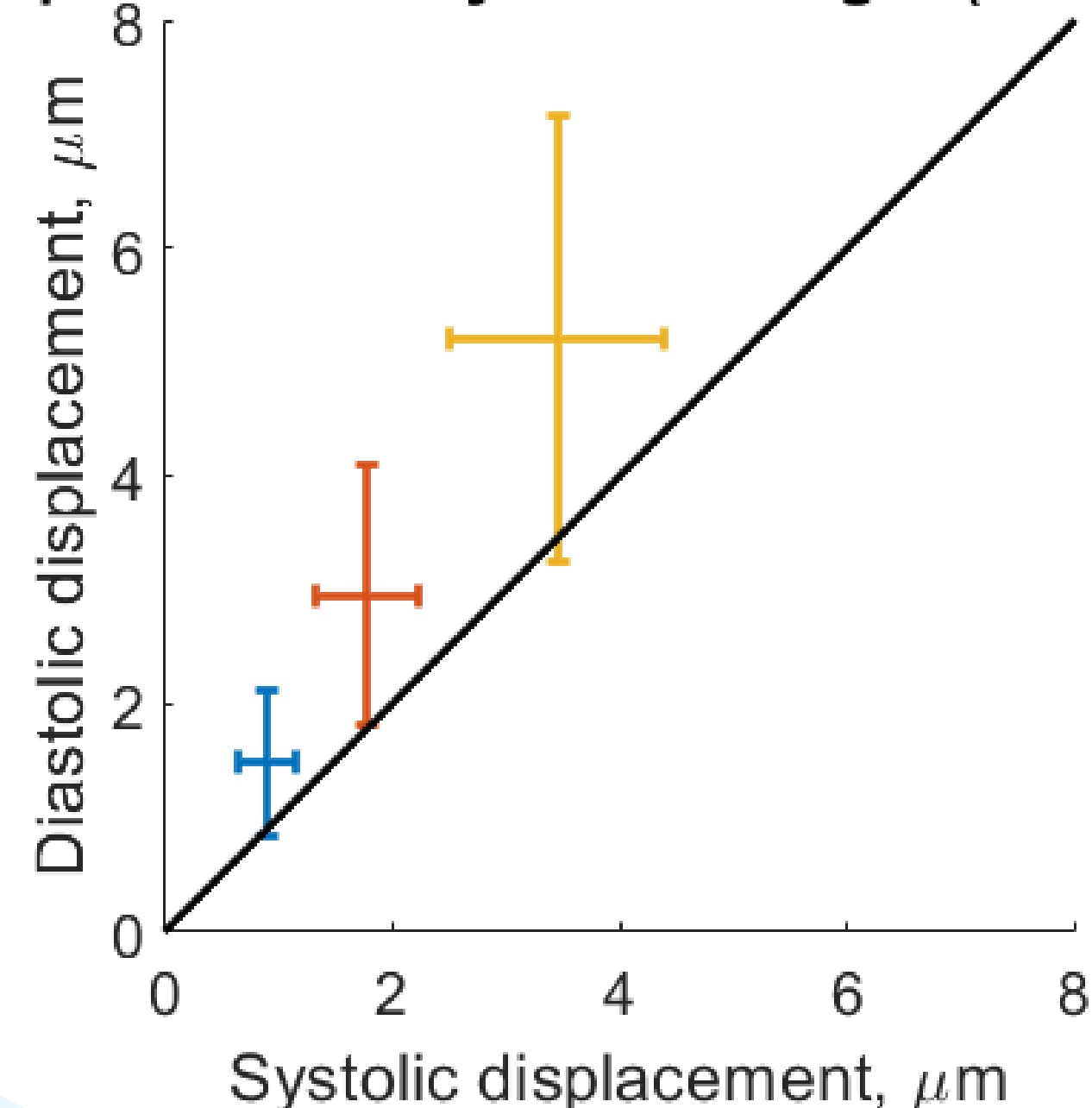
- Compare diastolic and systolic displacements across push lengths
- Compare amyloid's septal displacements and ratios to those of controls



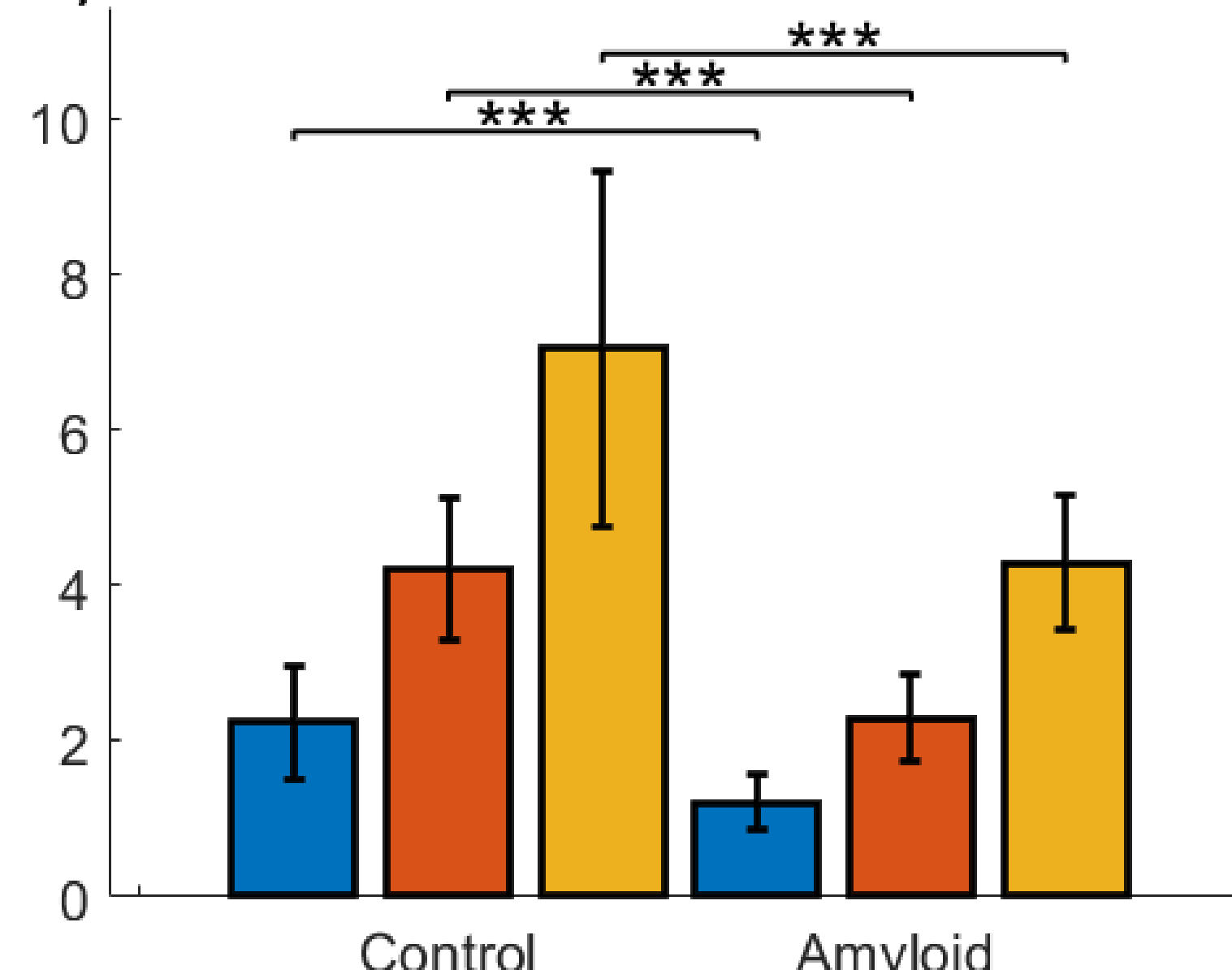
RESULTS

- Good temporal repeatability was observed across beats within acquisitions.
- Diastolic and systolic displacements increased with pulse length.
- Amyloid patients exhibited lower significantly lower diastolic and systolic displacements compared to controls, within each pulse length ($p < 0.001$).
- Only when using the 800 μ s pulse was the displacement ratio significantly lower in amyloid patients than controls ($p < 0.05$).
- For low and medium push lengths, displacements were regularly obscured in the noise floor, contributing to variability of displacement ratio metric.
- Rates, time constants, and shear wave speeds were too noisy to analyze.
- Control subjects have widely varying levels of cardiac function and image quality, which will be examined in future work. Cardiac functional metrics will be calculated from the standard echo exams that were acquired.

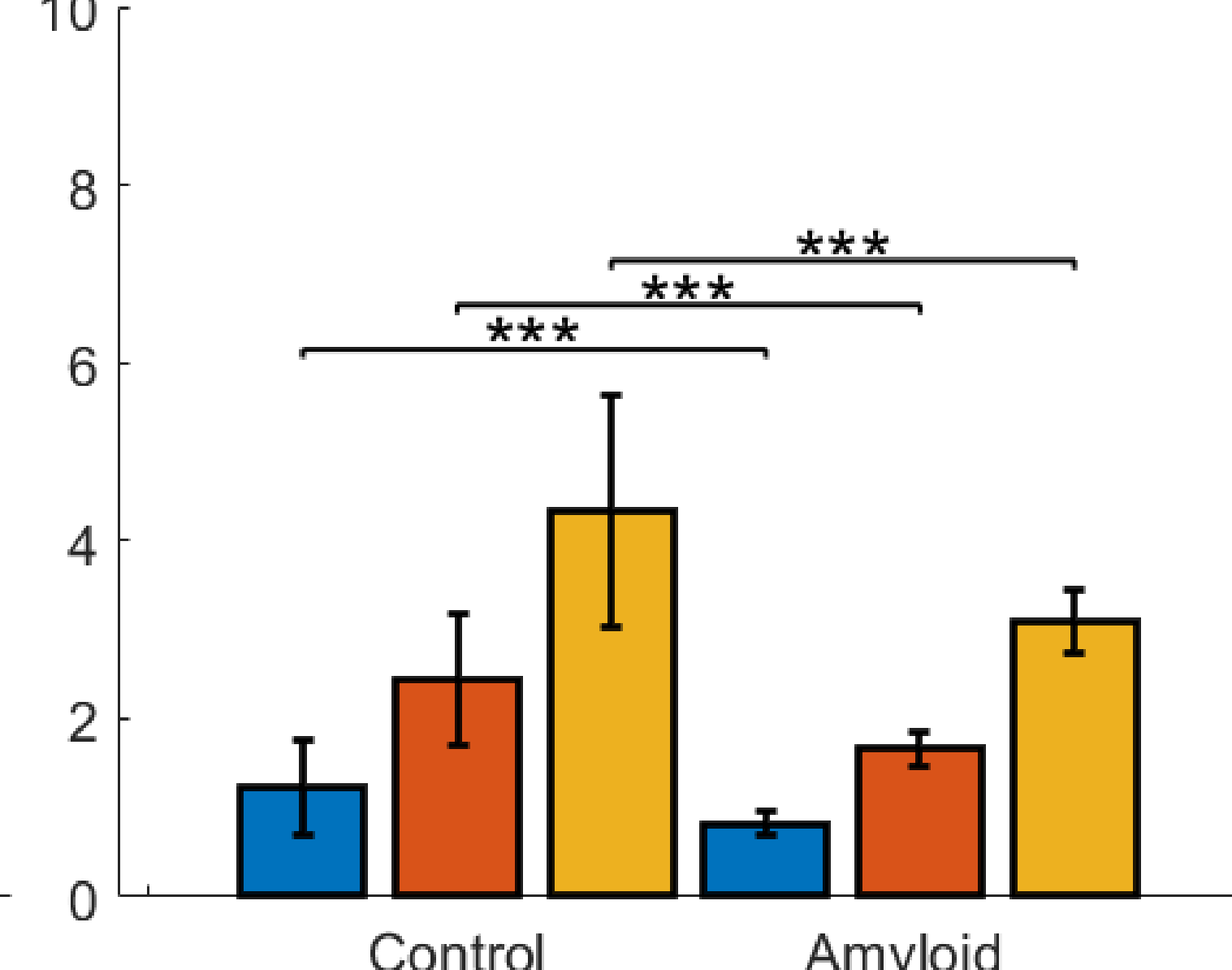
Displacements by Pulse Length (Med&IQR)



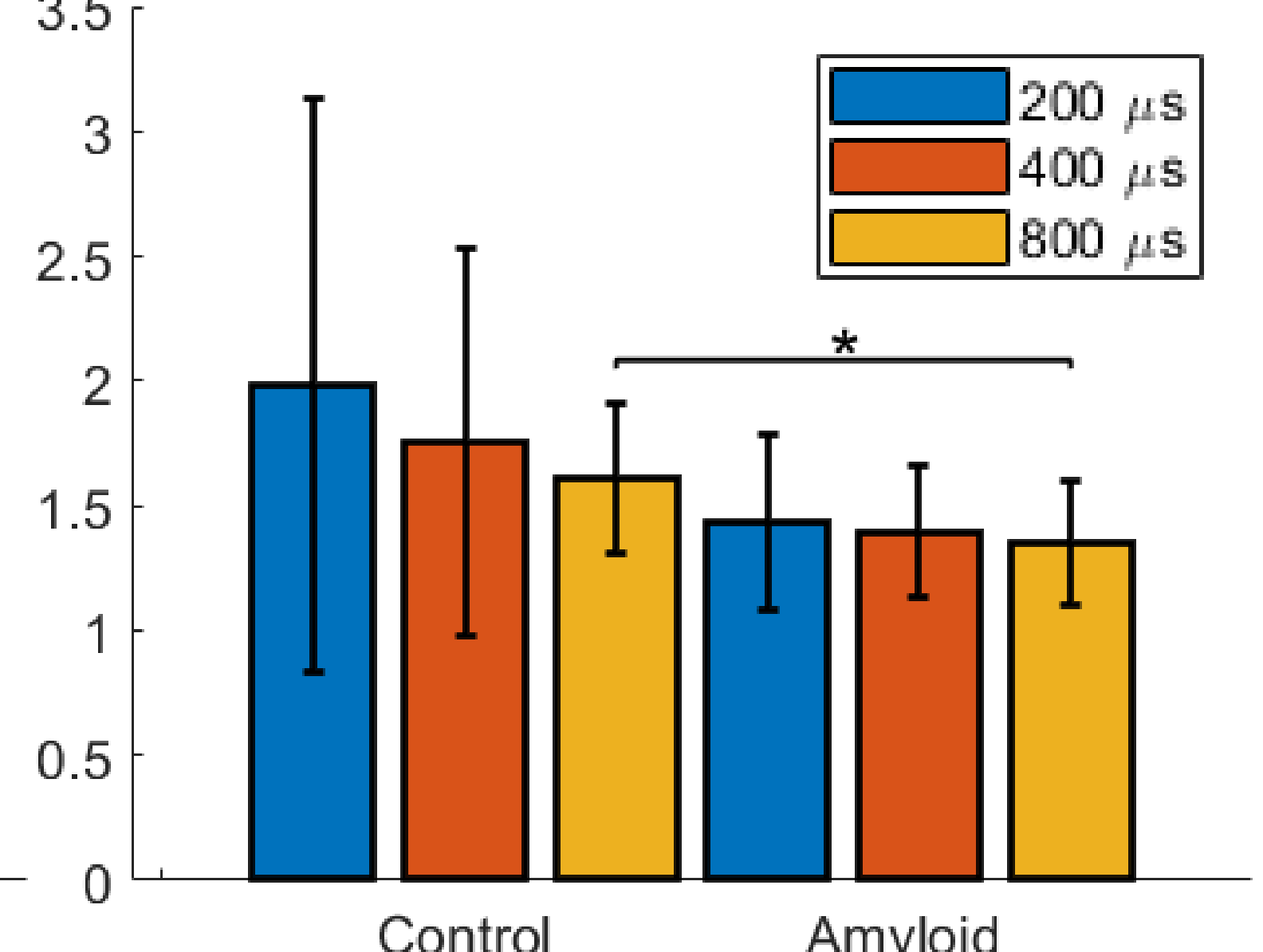
Diastolic displacement, μ m



Systolic displacement, μ m



Displacement ratio (unitless)



¹Ali M Agha et al. Open Heart 2018;5:e000881, ²S. Dorbala, et al. Journal of Cardiac Failure 10.1016/j.cardfail.2019.08.001, ³Cardenas-Garcia et al., Critical Care Ultrasonography 2013