Strain Rate Imaging for Visualization of Mechanical Contraction

MV Andersen[1] (mvan@hst.aau.dk), S Schmidt[1], P Søgaard[2], J Struijk[1], B Atwater[3], D Friedman[3], K Arges[3], M LeFevre[3], C Moore[4], J Kisslo[3], O von Ramm[4]

[1]Aalborg University, [2]Aalborg University Hospital,

[3]Duke University Hospital, [4]Duke University

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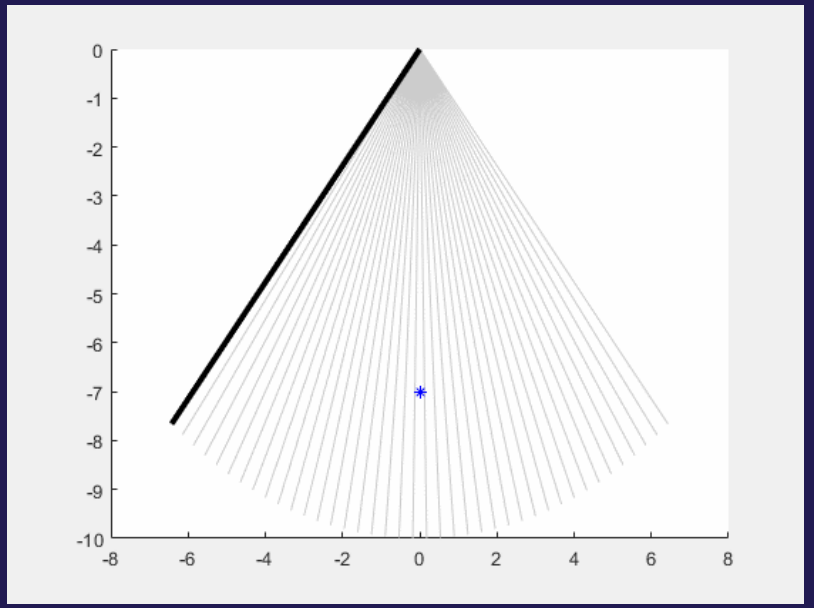
Background

- Sampling is a non linear process that creates new information not present in the real world. However, if the images is sampled adaquately the effect of aliasing can be mitigated.
- Kanai et al. were the first to describe the propagation of tissue motion in the heart during contraction using high frame rate ultrasound imaging.
- The study of propagating changes associated with electrical depolarization will require high temporal resolution comparable to electrocardiogaphy sampling rate (above 500Hz).
- Here we present strain rate images and their application for visualizing tissue shortening propagation in in left ventricle.



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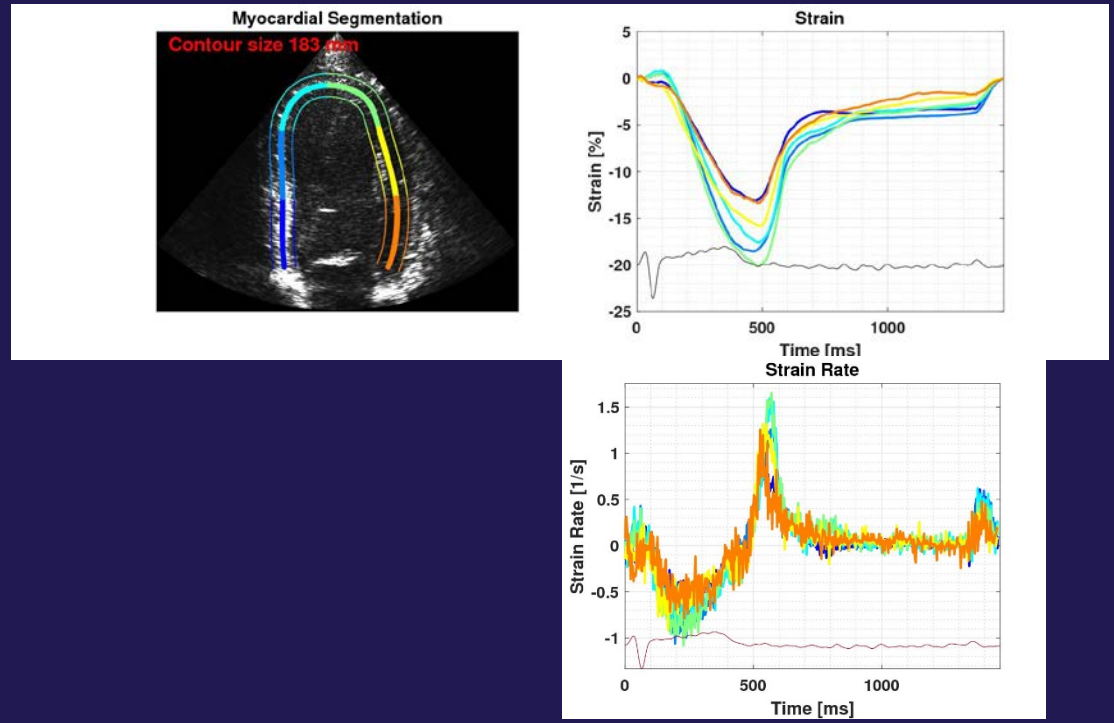
Methods

- B-mode images were acquired using Duke University's phased array ultrasound system, T5 (Duke University, Durham, NC, USA).
- Images had an 80° field of view and angular sampled with respect to the theoretical diffraction-limited azimuth resolution. To acquire images at a high frame rates we use exploso scan with 32:1, 16:1 or 8:1 parallel receive operations for every transmit in order to sample images at 1 ms to 4 ms intervals.
- Due to the way strain and strain rate curves are normally visualized, it can be exceedingly difficult to detect propagating waves along the myocardial contour.



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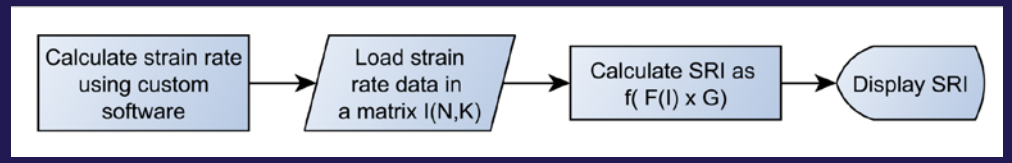
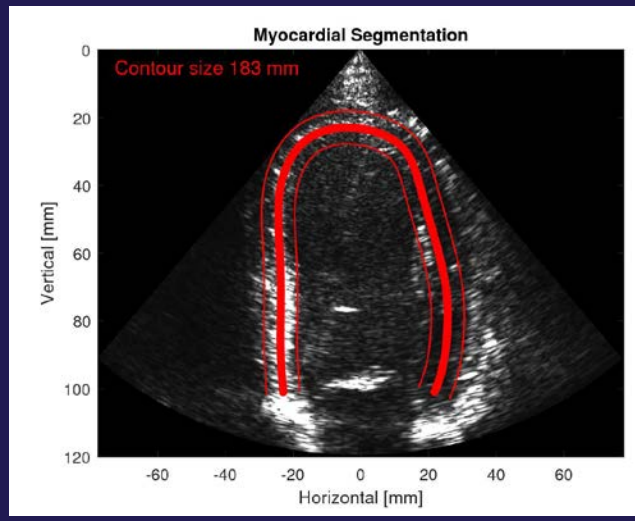
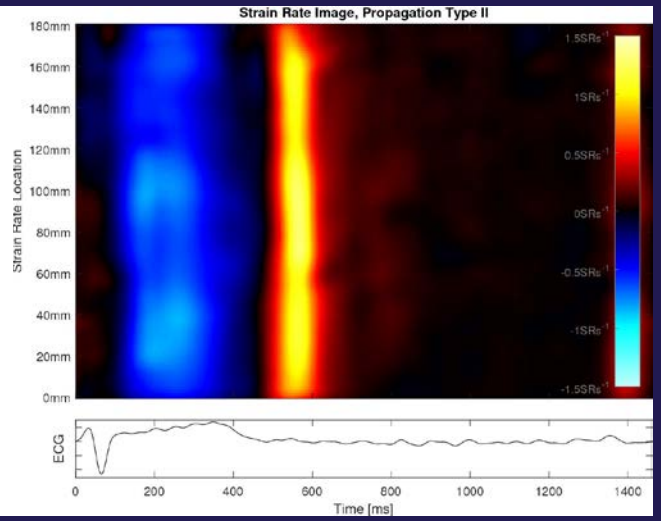
Strain Rate Image



In the strain rate image, the horizontal direction is time, and vertical direction is relative location along the myocardial contour.

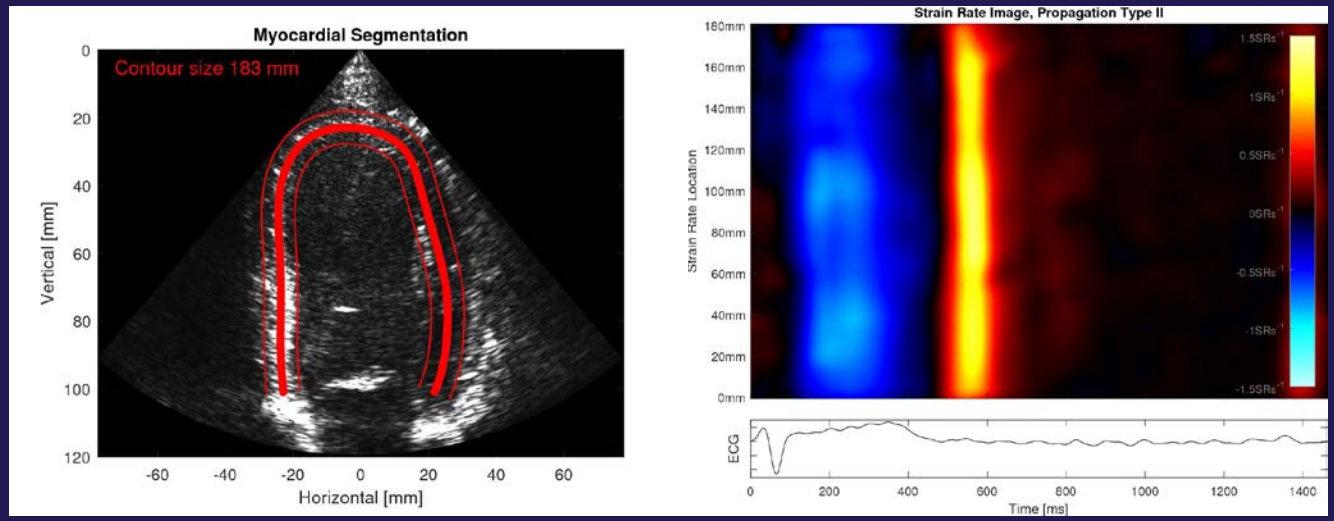
- It is easier for the human eye to find patterns in an image.
- Therefore we can use a large number of strain rate curves (100+ curves), where horizontal image axis is time and vertical is the location along the myocardial contour.

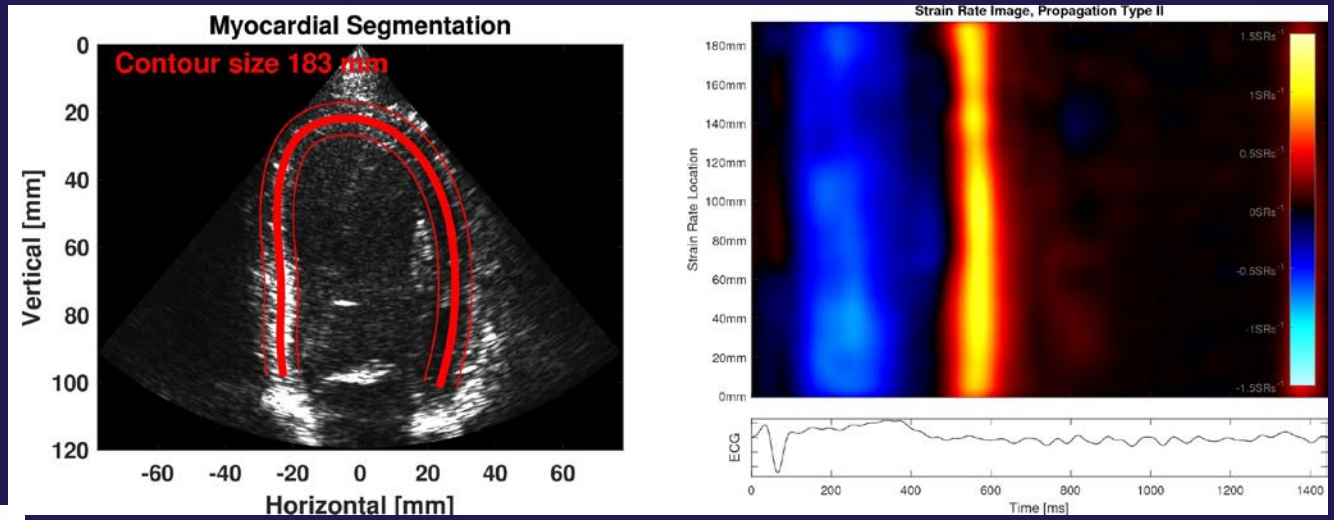




Strain Rate Image

- Two consecutive heart beats show that the patterns observed in strain rate images are consistent from beat to beat in the same patient.





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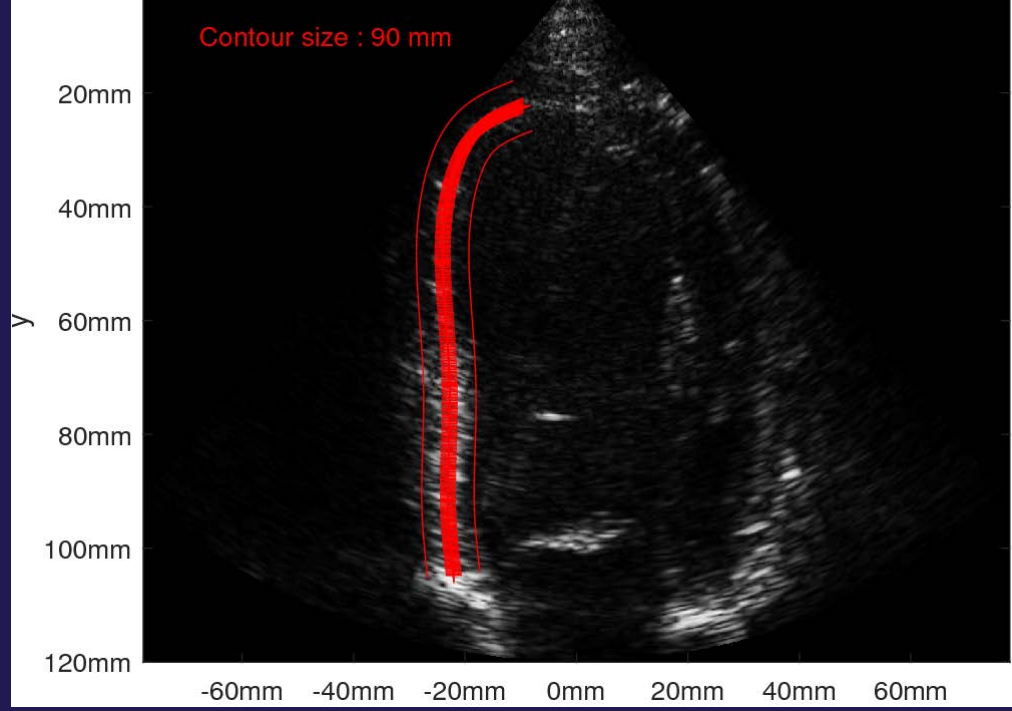
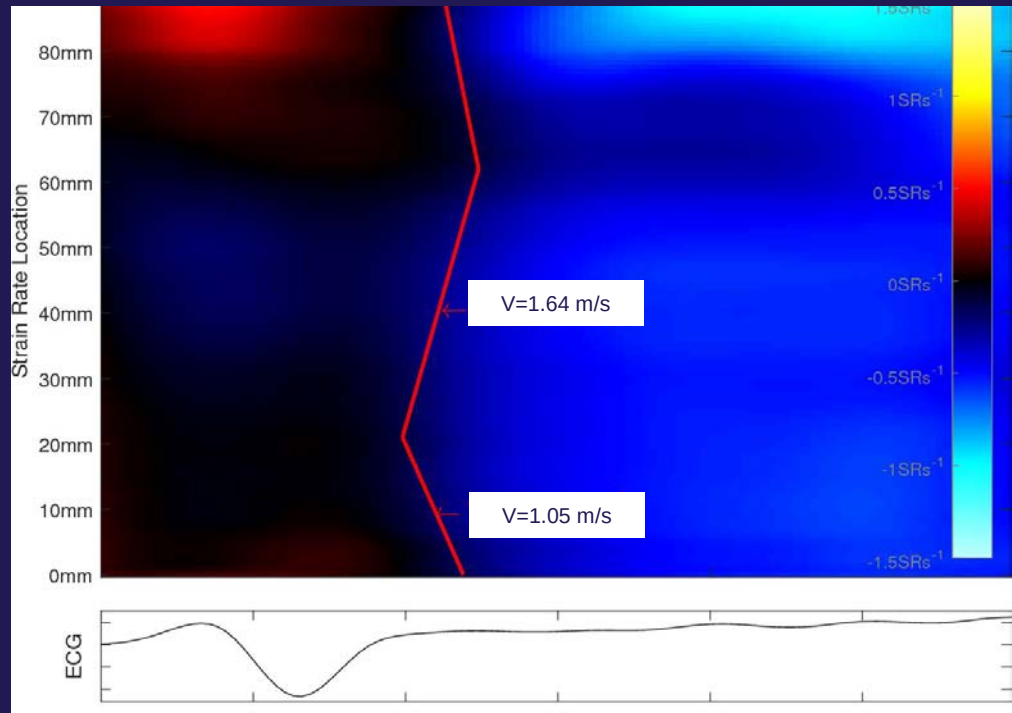
Results

- When focussing on the interventricular septum only, we see that there is a propagating wave of the tissue shortening onset.
- This tissue shortening onset propagation along the myocardial contour can be visualized using high frame rate strain rate images.
- The superimposed red line indicates tissue shortening onset along the interventricular septum. This line was defined by visual inspection of strain rate images.





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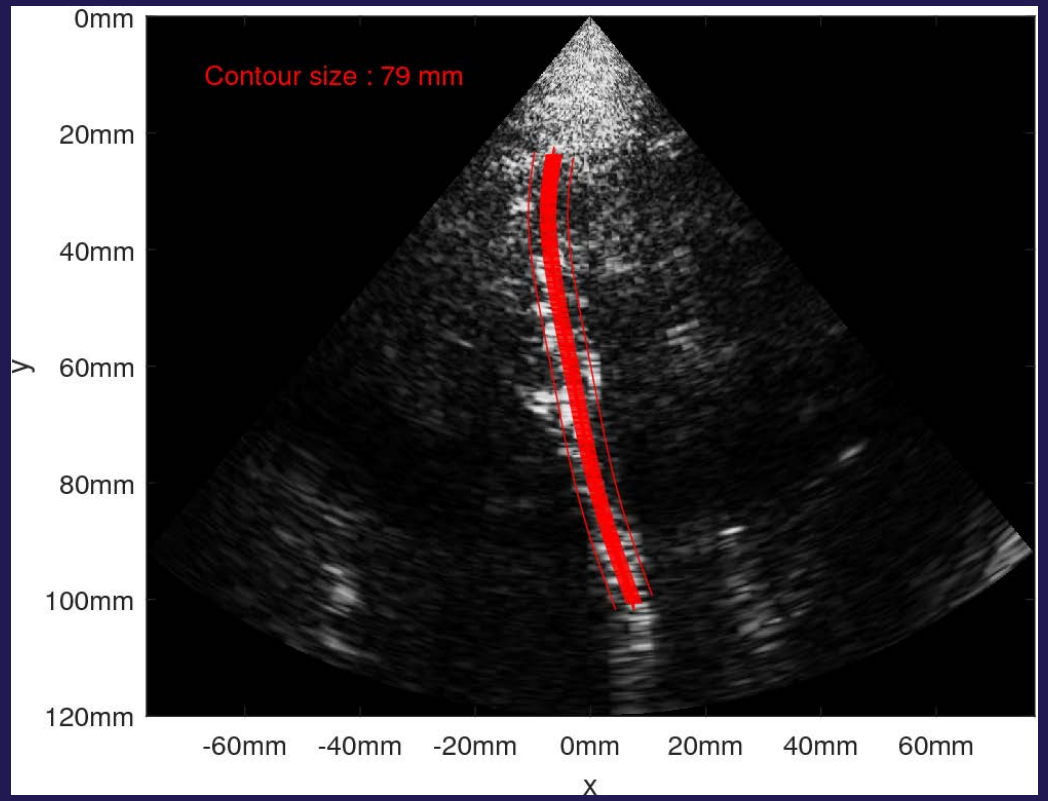
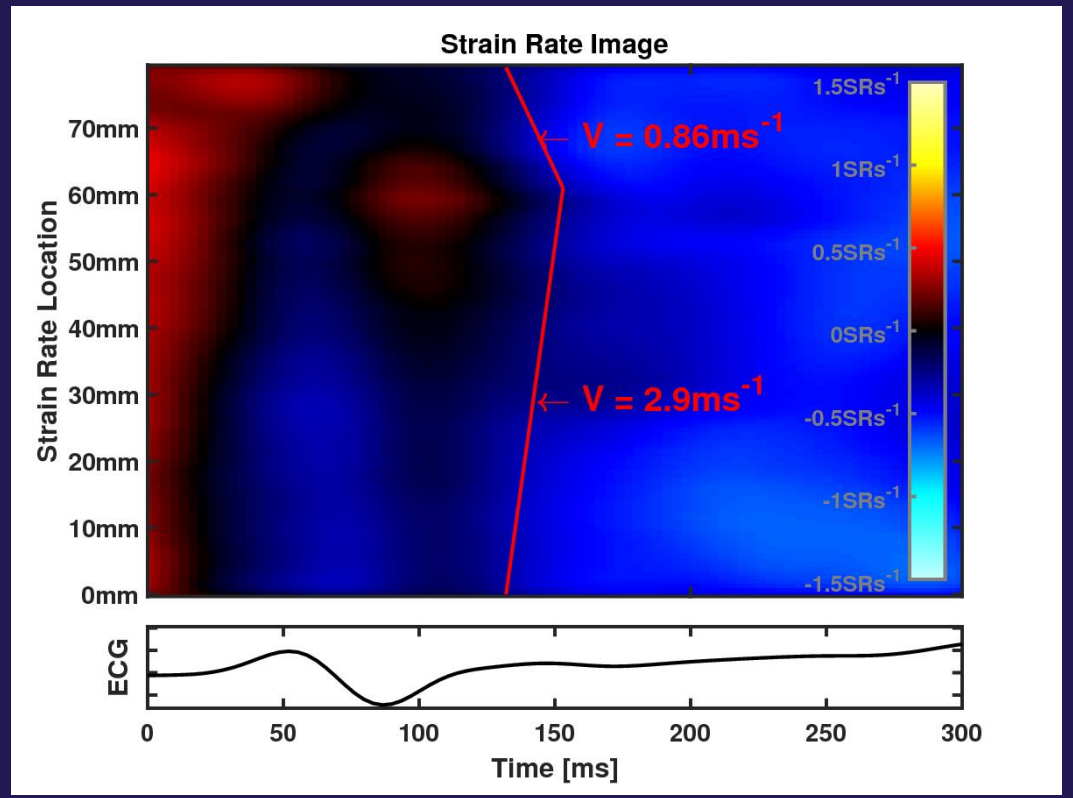
Results





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Results

In a cohort of 22 patients with no diagnosed abnormalities, 5 different propagating patterns were identified, where the most common type was a propagation from somewhere inside the middle of the interventricular septum.

Type	I	II	III	IV	V
#	2	9	6	3	2
V1 $[ms^{-1}]$	V>20	1.29 ± 0.87	0.71 ± 0.16	1.86 ± 0.42	1.06 ± 0.24
V2 $[ms^{-1}]$		1.38 ± 0.39	1.74 ± 1.23		

IVS contraction propagation velocity in a normal cohort

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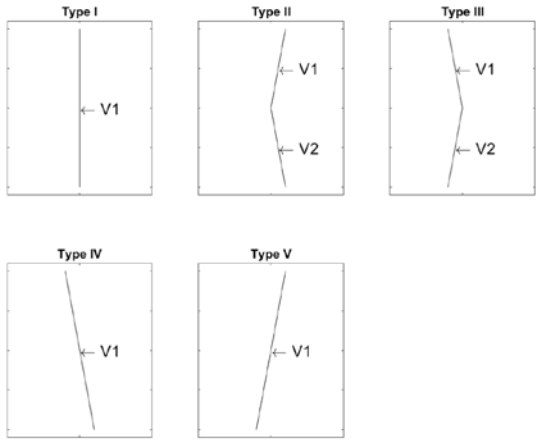
Patterns



Summary

- With high frame rate ultrasound we are able to identify the origin of mechanical shortening of the ventricle.
- High frame rate imaging combined with the strain rate images allow for the observation of propagation patterns of shortening onset.
- Though multiple patterns arise in normal patients, the contractile pattern is consistent from beat to beat in each patient.

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