Ann & Robert H. Lurie Children's Hospital of Chicago®

Stanley Manne Children's Research Institute™

Northwestern Medicine®
Feinberg School of Medicine

Pediatric 3D ECG with I

Ken Brady
Anesthesia, Critical Care
Lurie Children's Hospital

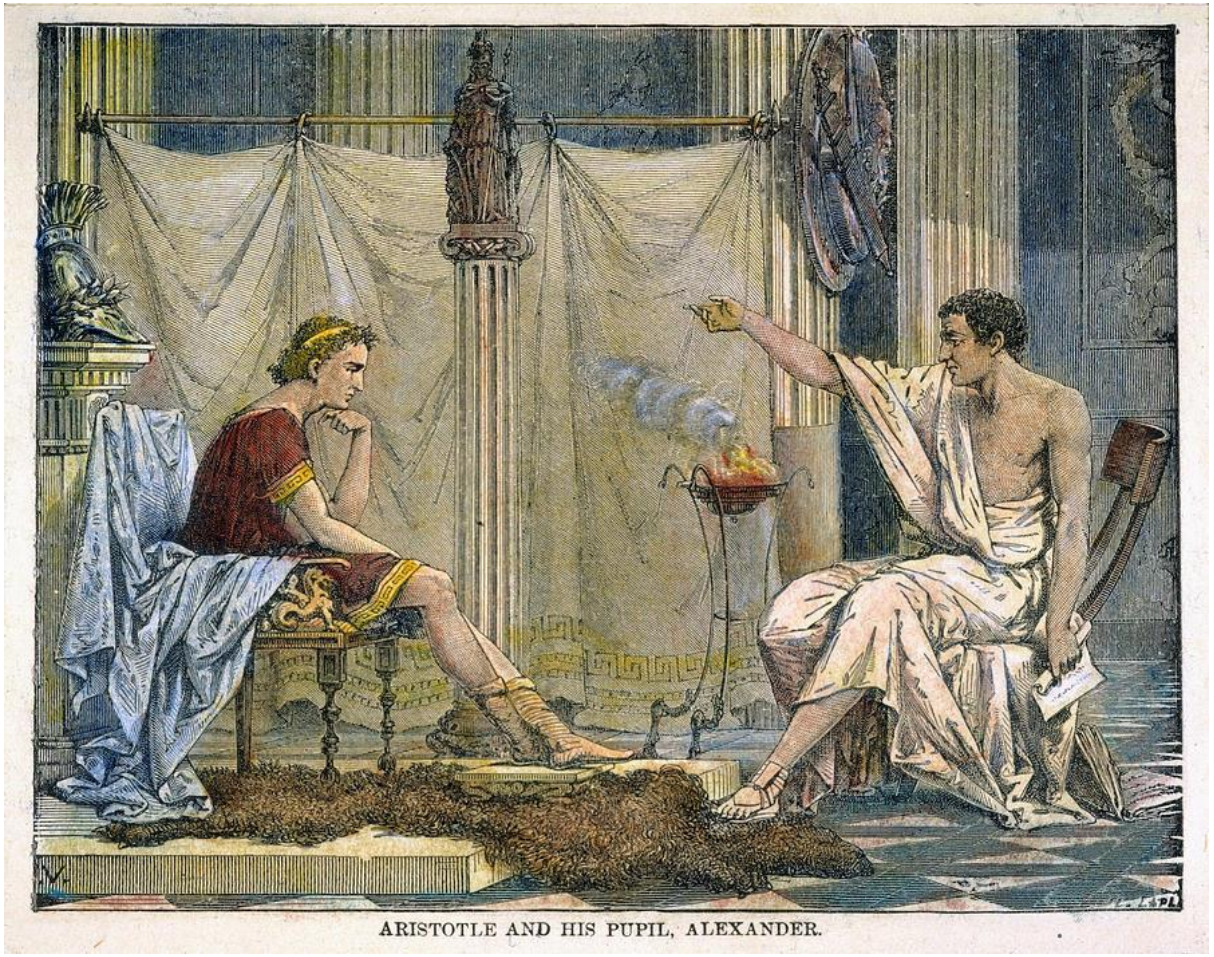
BEST CHILDREN'S HOSPITALS U.S. News & World Report HONOR ROLL

MAGNET RECOGNIZED AMERICAN NURSES CREDENTIALING CENTER

Disclosures

Patents filed by BCM

Our parents and teachers lied



ARISTOTLE AND HIS PUPIL, ALEXANDER.

You are special
You are smart
You will do great things
You will help people

Shakespeare told the truth

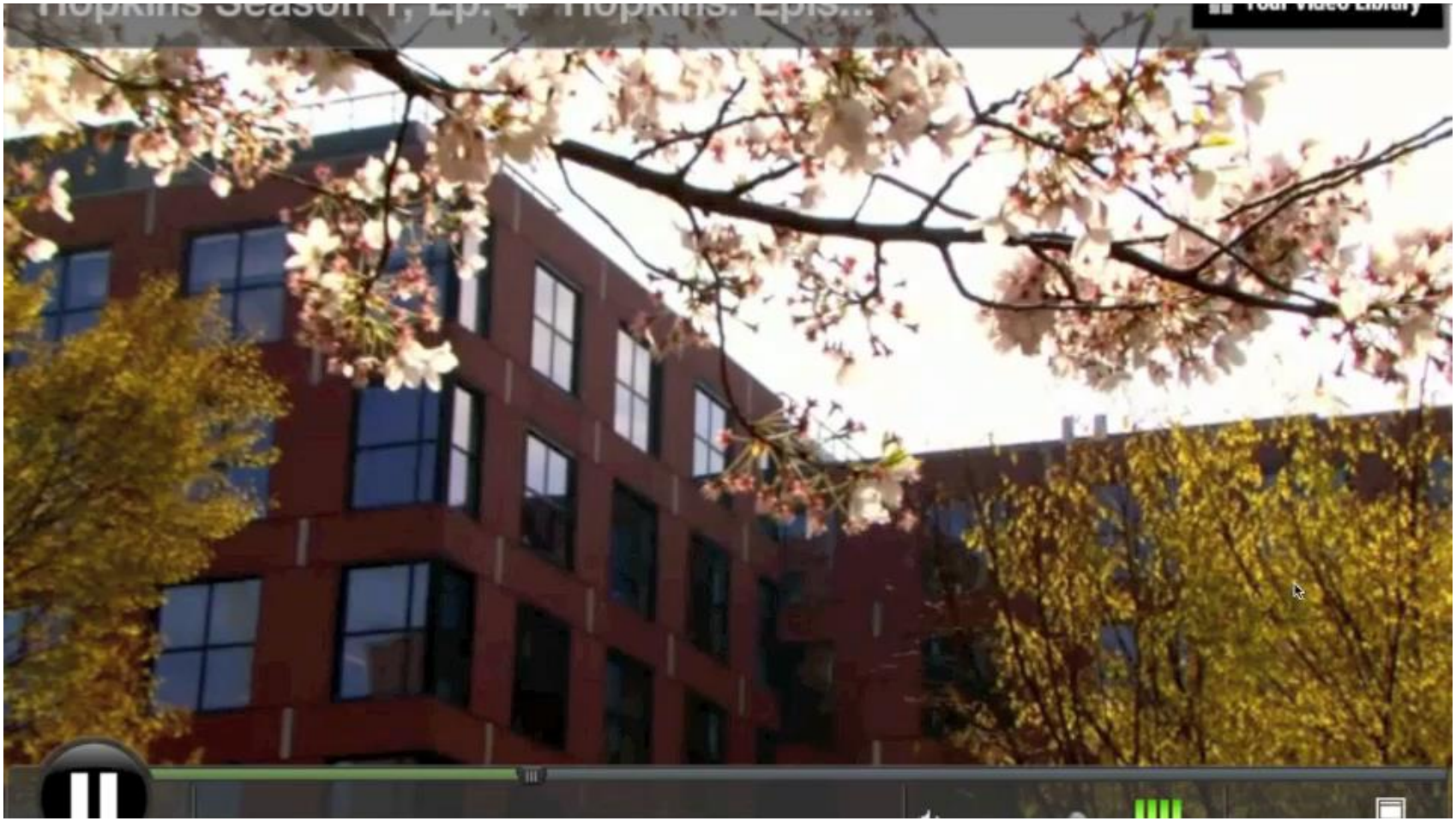
Friends, Romans, countrymen, lend me your ears…

The evil that men do lives after them;

The good is oft interred with their bones

Act III, Scene II *Julius Ceasar* by William Shakespeare

The evil that men do



Current state of decision support in the ICU

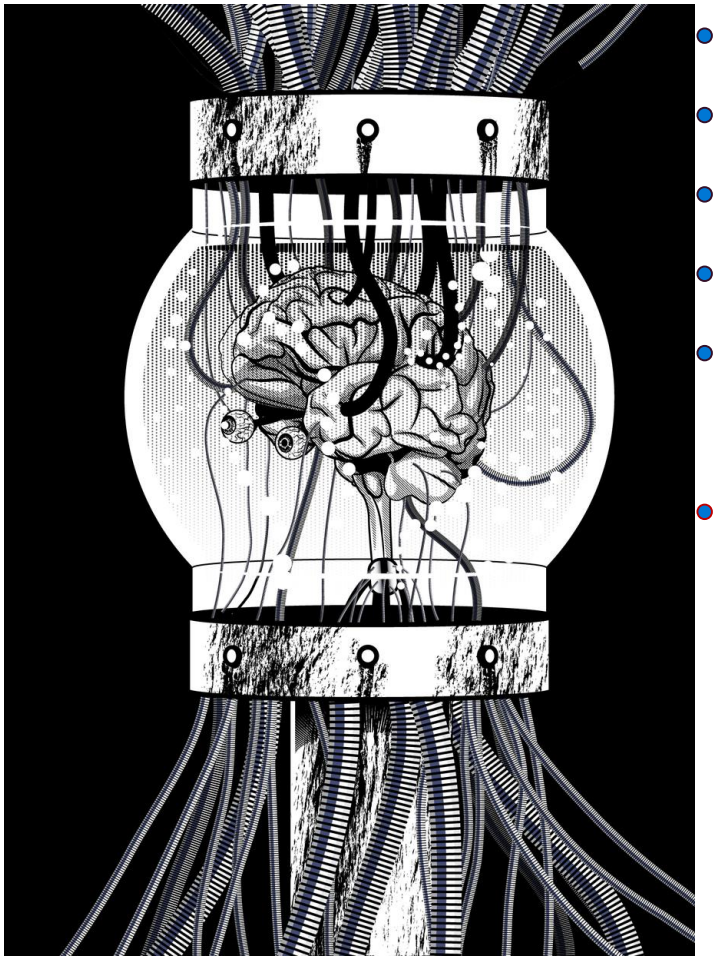
- Univariate monitors that work in isolation to measure narrowly-focused physiologic parameters.
  - No cross-talk protocols to measure interactions.
  - No vision for multivariate forecasting.
  - No visualization across optimizable parameters.
  - No disease-specific platforms.

Not a univariate problem

The flawed univariate monitor

Monitoring a physiologic parameter in isolation drives optimization of that parameter *at the expense of other physiologic parameters*

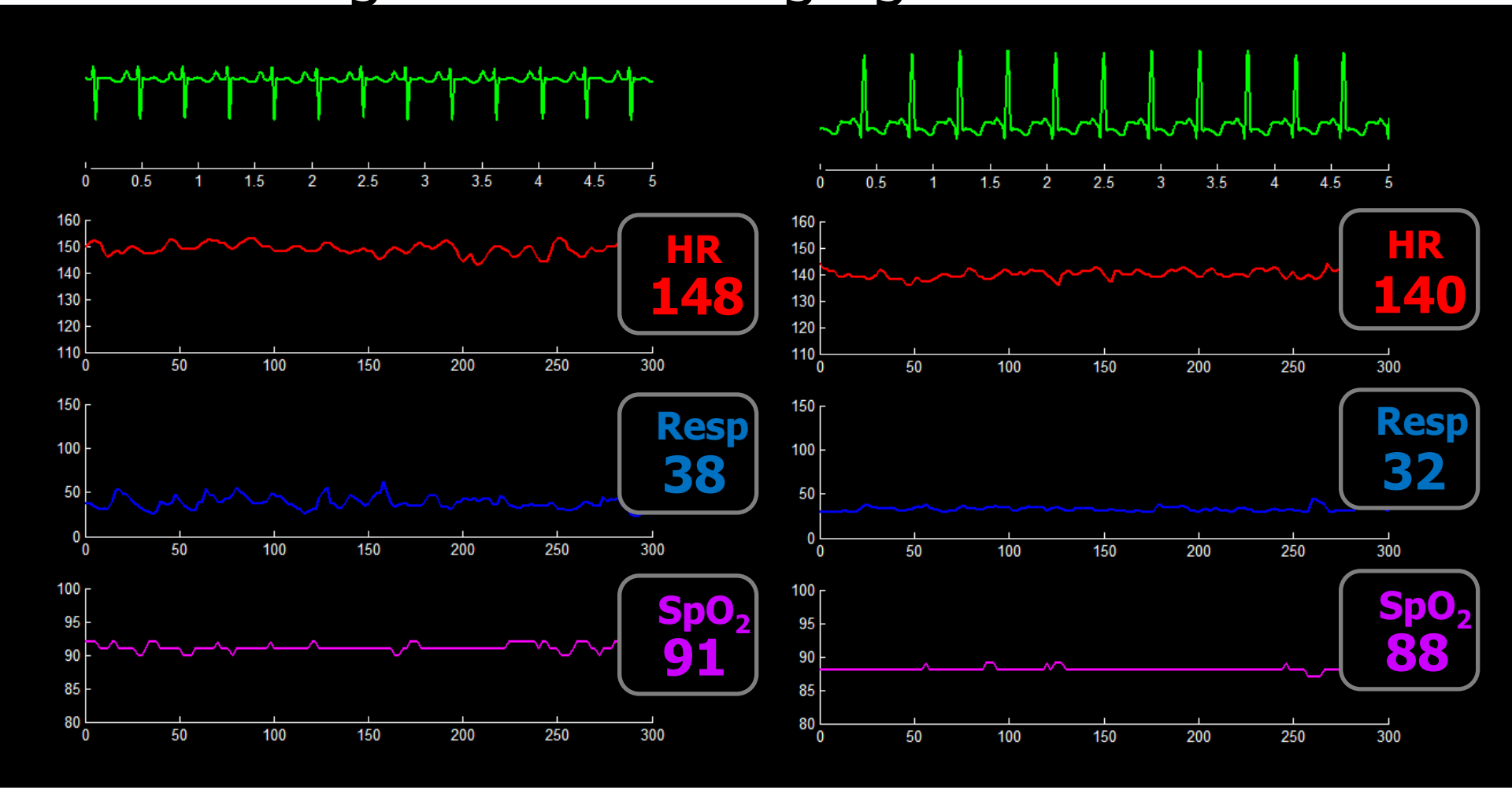
Is machine learning the panacea?



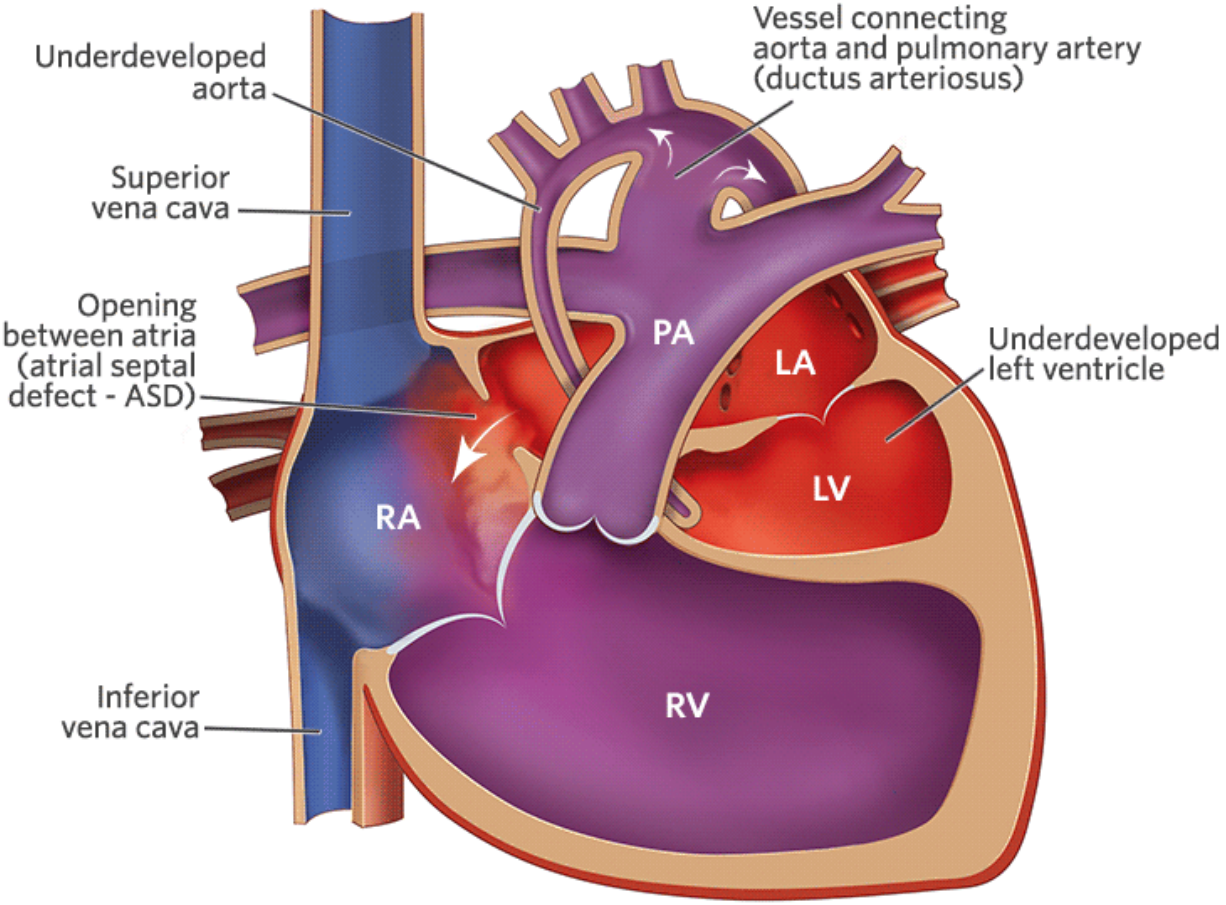
- Processing Power
- Limits of human perception
- Tireless, Vigilant, Consistent
- Forecasting
- Individual optimization

- Prone to type I statistical error

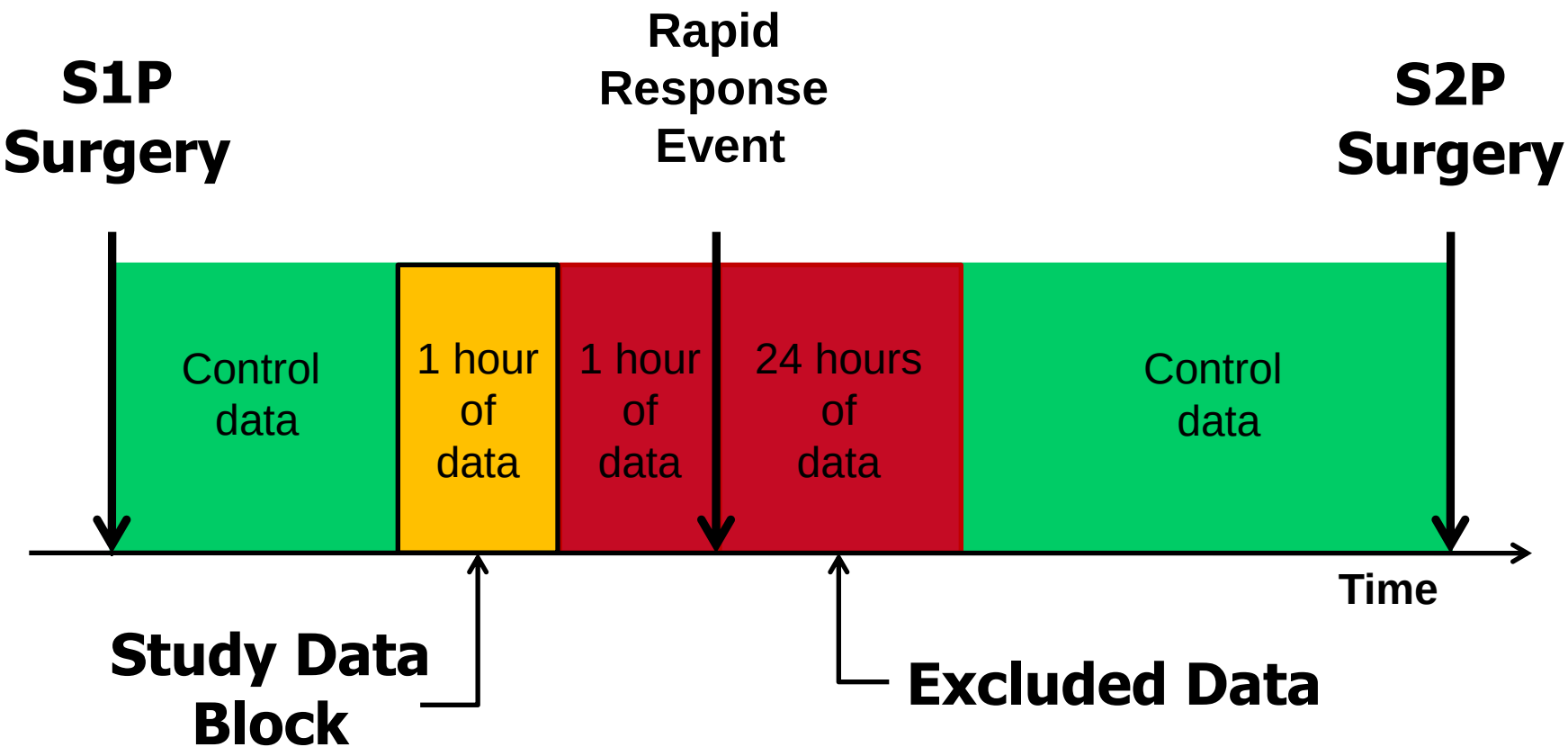
Forecasting: the low-hanging fruit



What is HLHS?

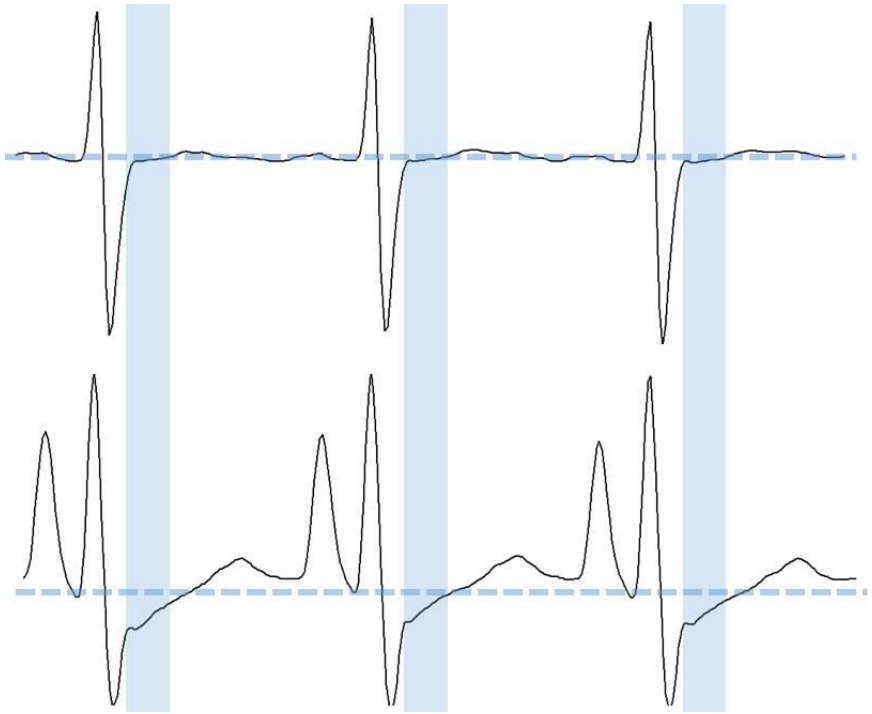

Underdeveloped aorta
Vessel connecting aorta and pulmonary artery (ductus arteriosus)
Superior vena cava
Opening between atria (atrial septal defect - ASD)
PA
LA
Underdeveloped left ventricle
LV
RA
RV
Inferior vena cava

Forecasting arrest in HLHS: study data

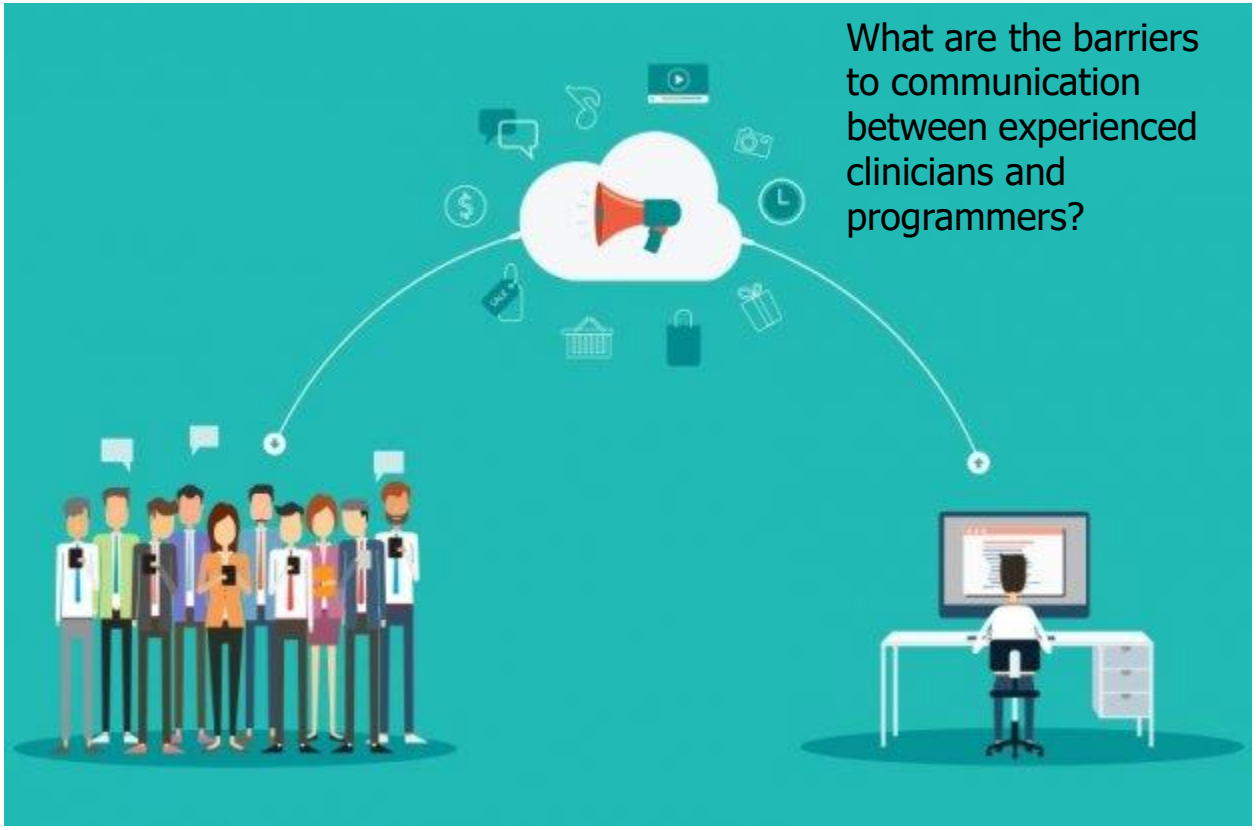


What are the features of pre-arrest?

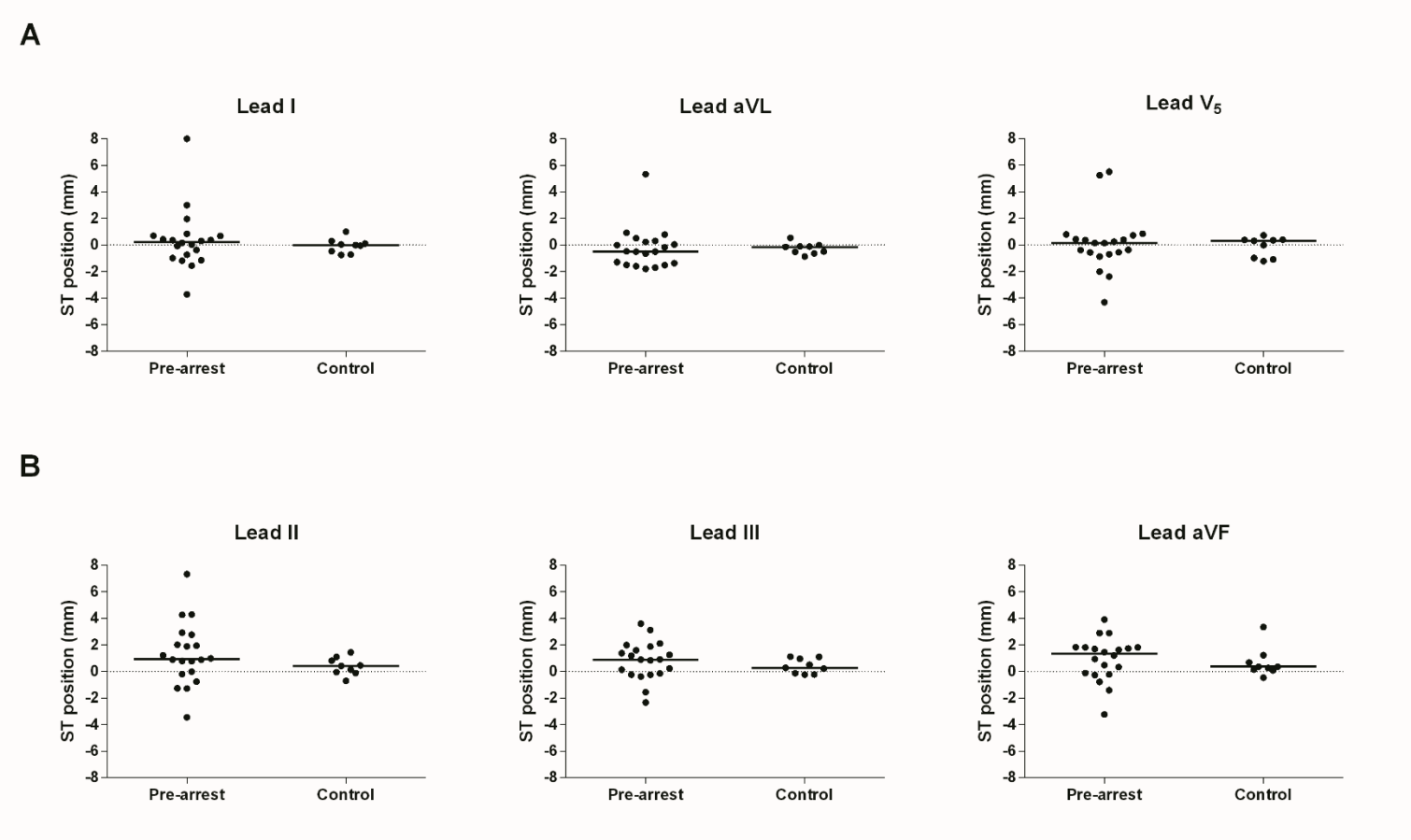
- ECG: ST-segments are a marker of strain/ischemia
- Confounded by conduction abnormalities related to the underlying heart condition.



The A.I. team in medicine

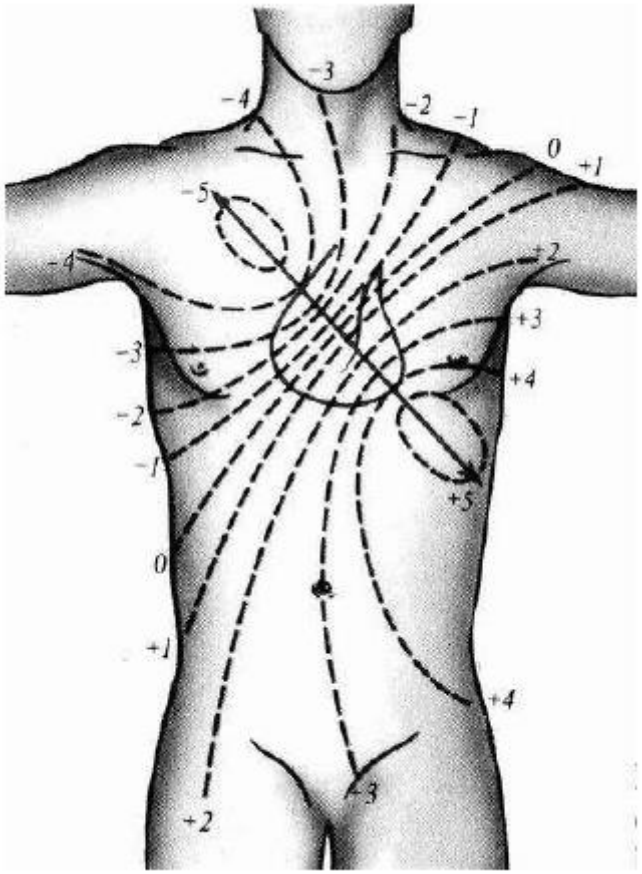


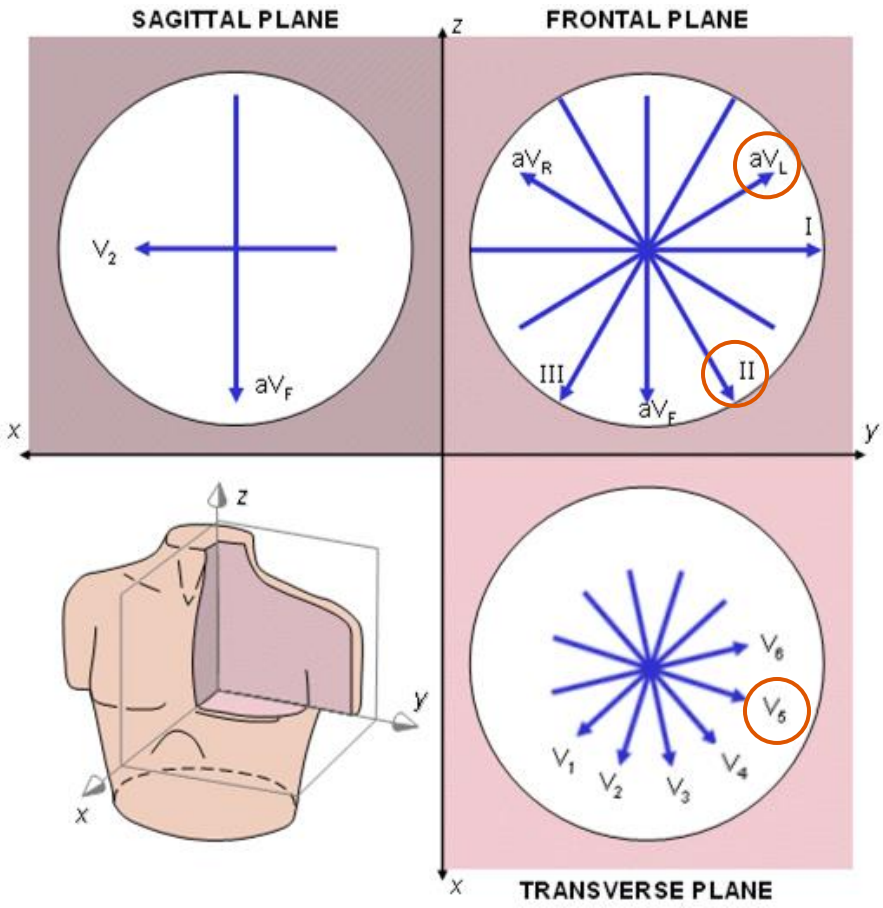
Pre-arrest and control ST segments



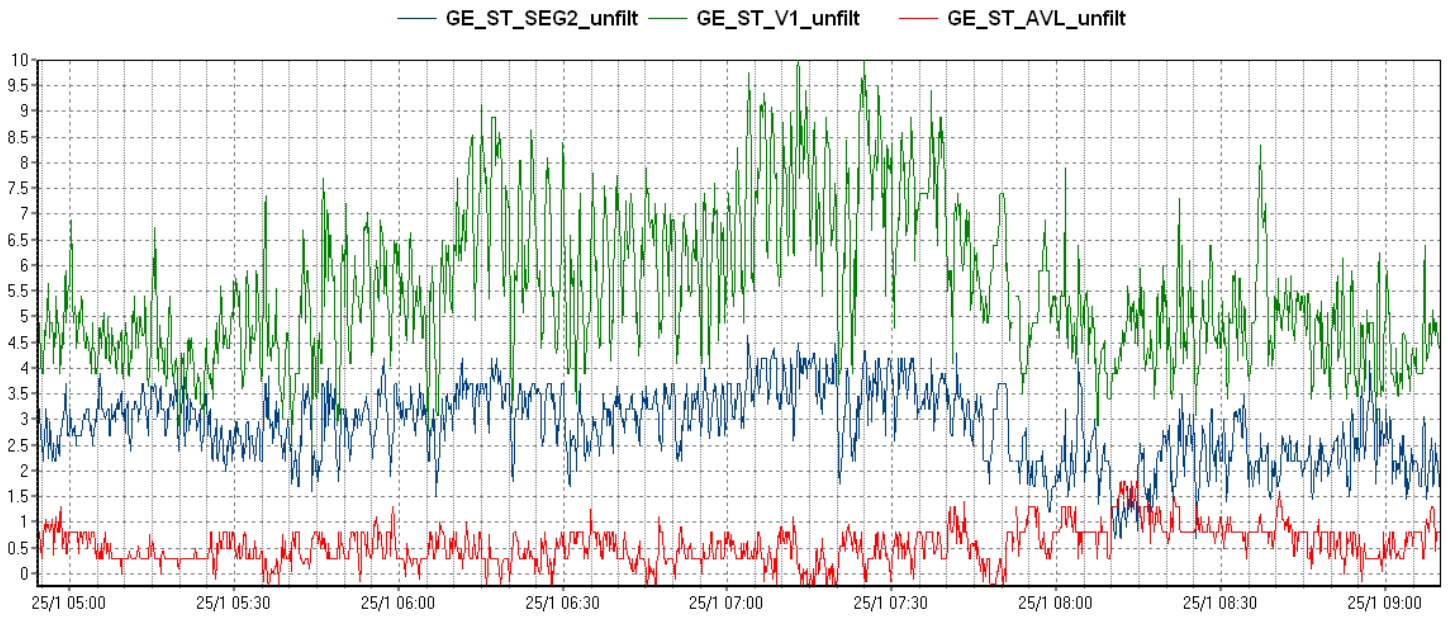
Vu EL, Rusin CG, Penny DJ, Kibler KK, Easley RB, Smith B, Andropoulos D, Brady K: Pediatr Crit Care Med 2017; 18:44–53.

Why all these leads?



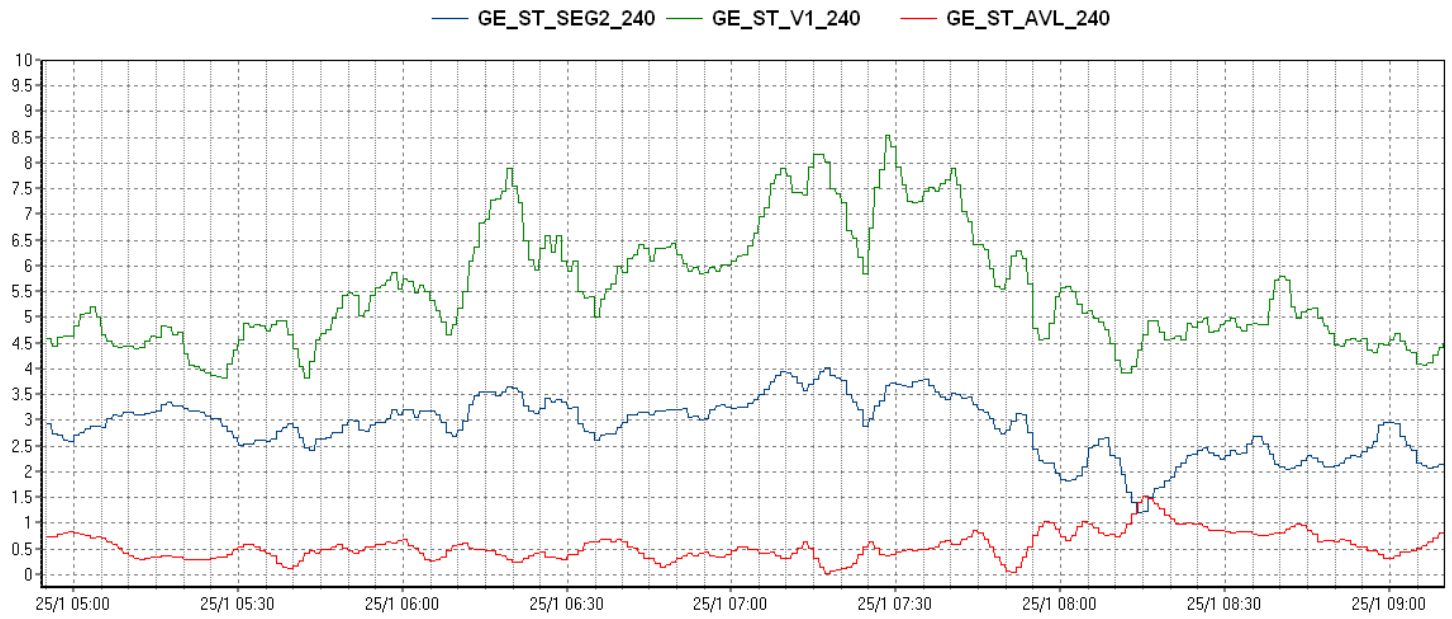


Creating the ST vector



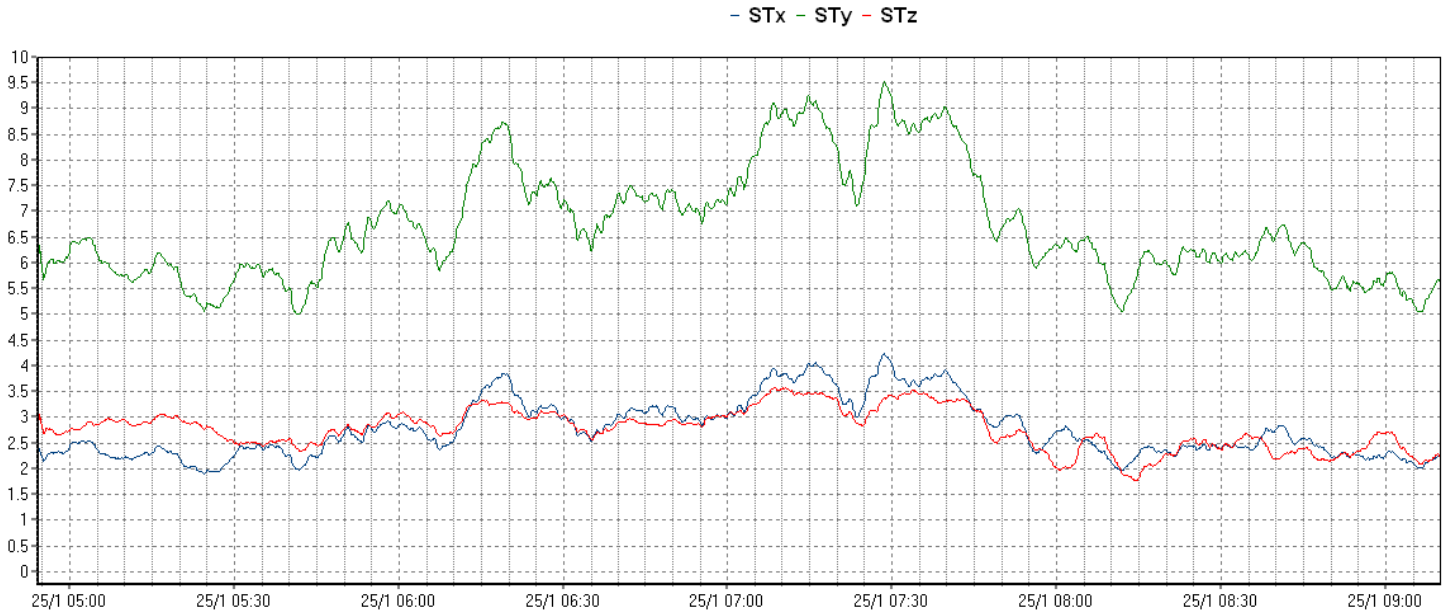
- Raw signals collected at 0.5 Hz in each lead (II, V5, and, aVL)

Creating the ST vector



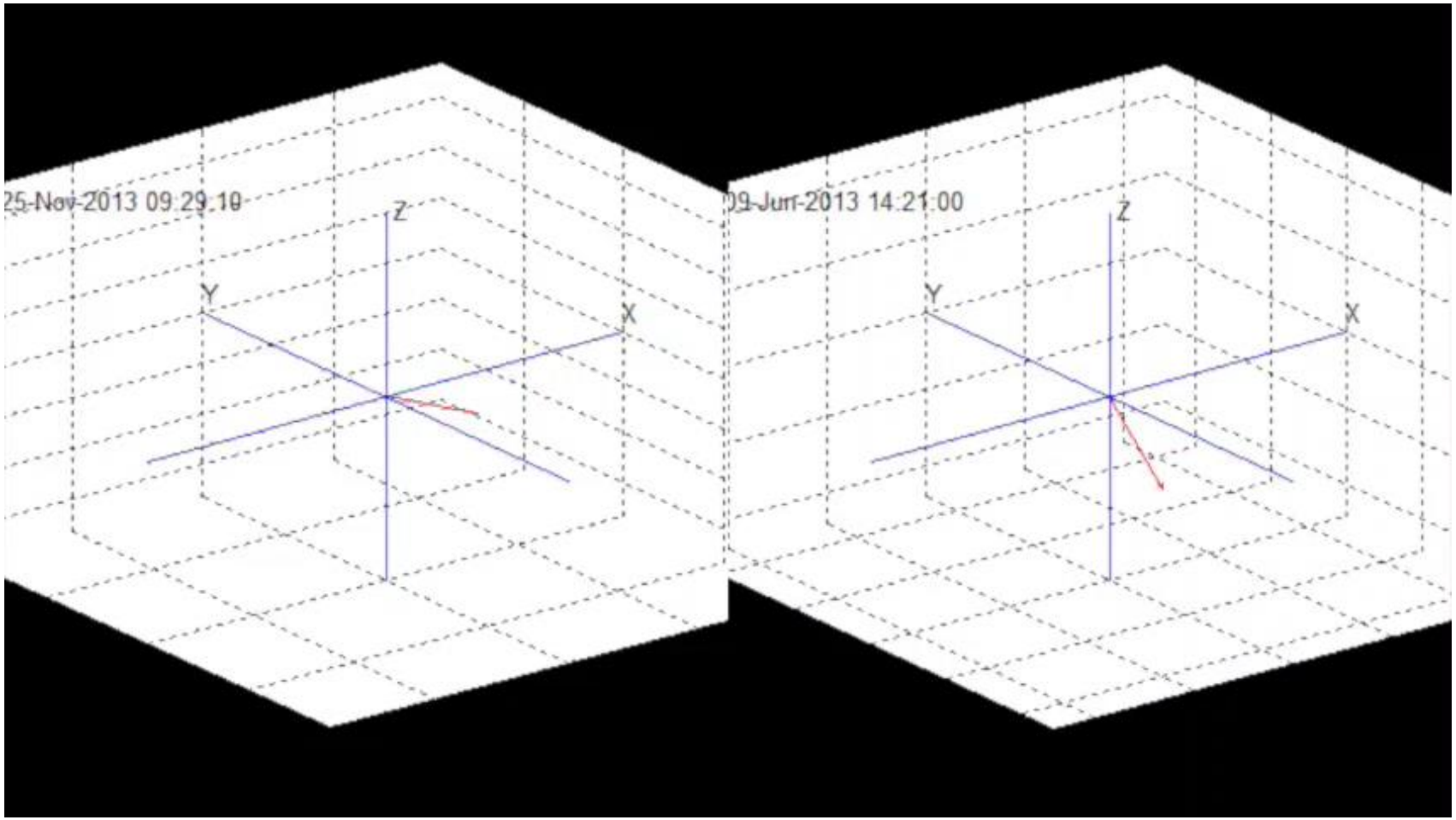
- Raw signals collected at 0.5 Hz in each lead (II, V5, and, aVL)
- Signals filtered with a four minute moving average filter

Creating the ST vector



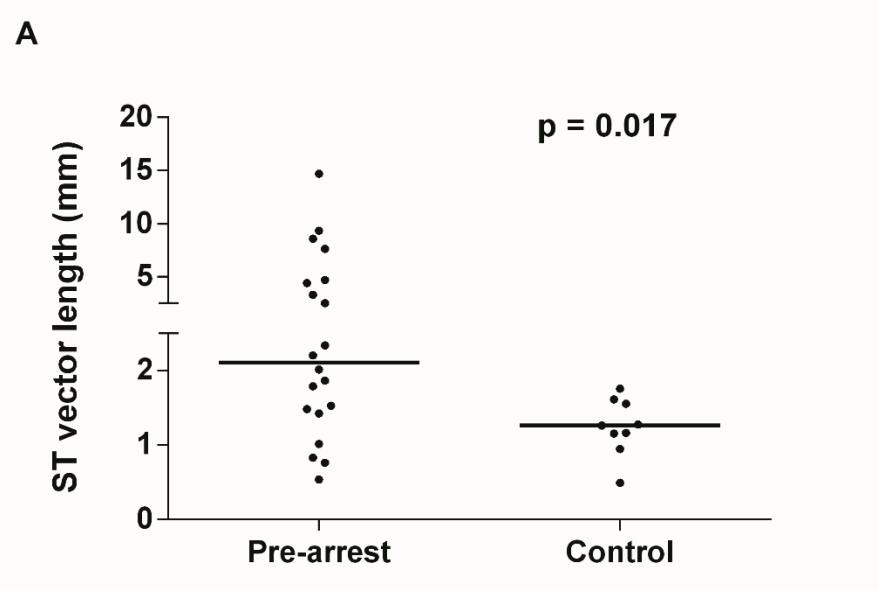
- Raw signals collected at 0.5 Hz in each lead (II, V5, and, aVL)
- Signals filtered with a four minute moving average filter
- Leads resolved into X, Y, and Z components

3D ECG in time



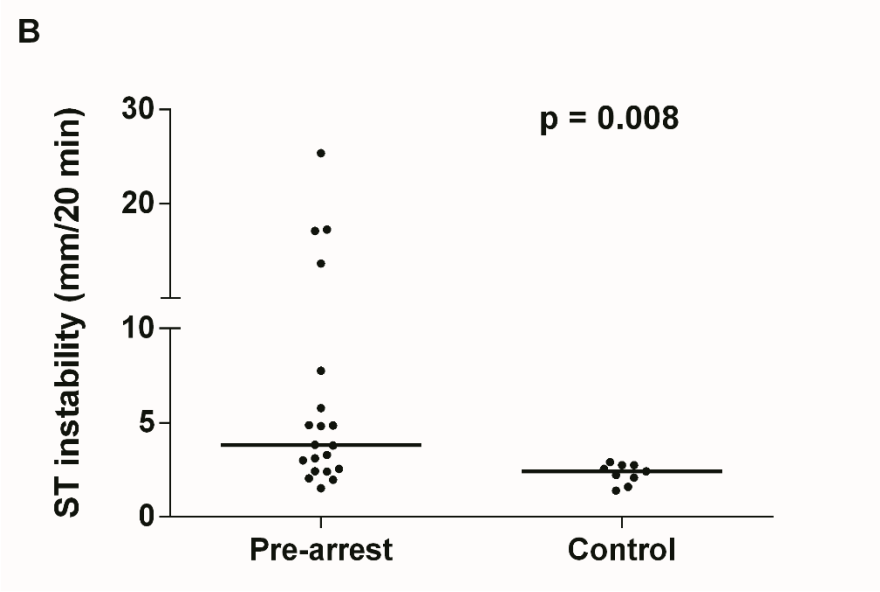
Results

ST Vector Magnitude



- Control: Median 1.3 mm
  [IQR: 1.1 – 1.6]
- Deterioration: Median 2.1 mm
  [IQR: 1.4 – 4.6]
- ROC area under curve: 0.78

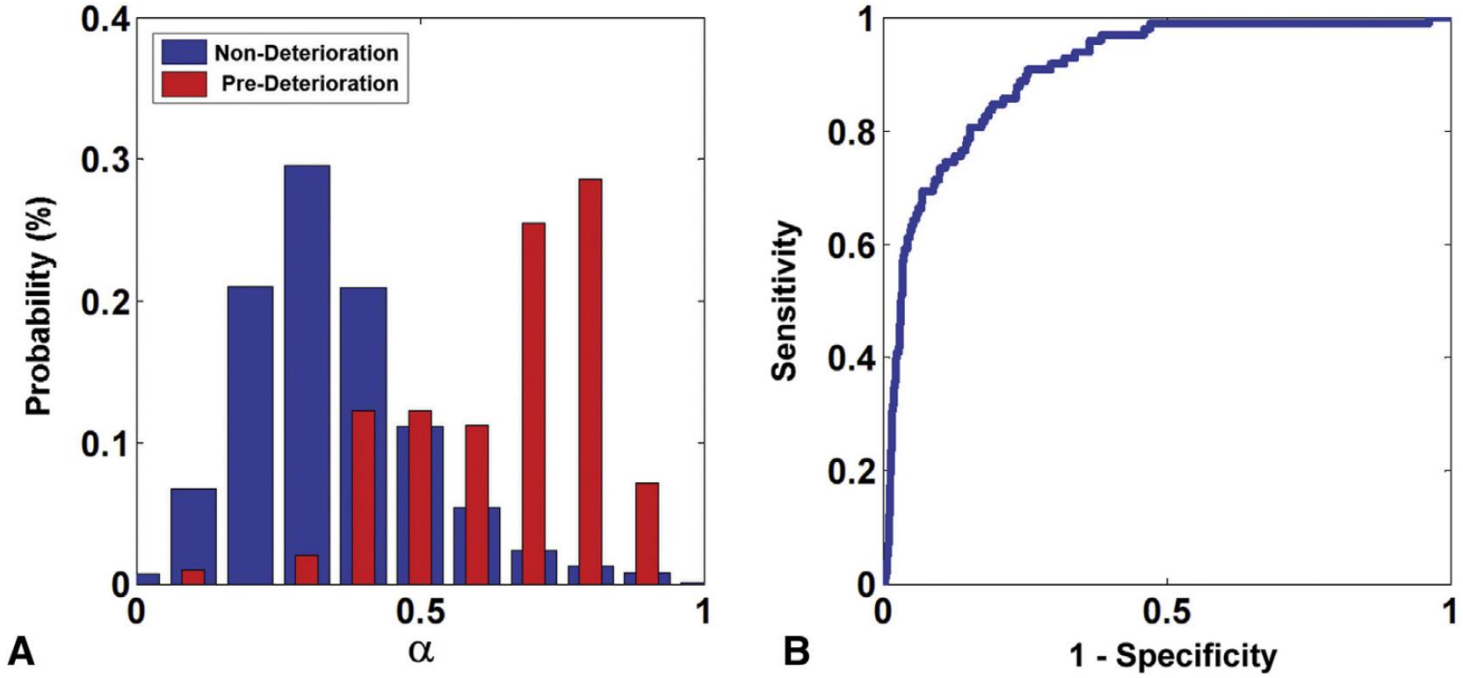
ST Vector Instability



- Control: Median 2.4 mm / 20 min
  [IQR: 1.8 – 2.7]
- Deterioration: Median 3.8 mm / 20 min
  [IQR: 2.4 – 25.4]
- ROC area under curve: 0.81

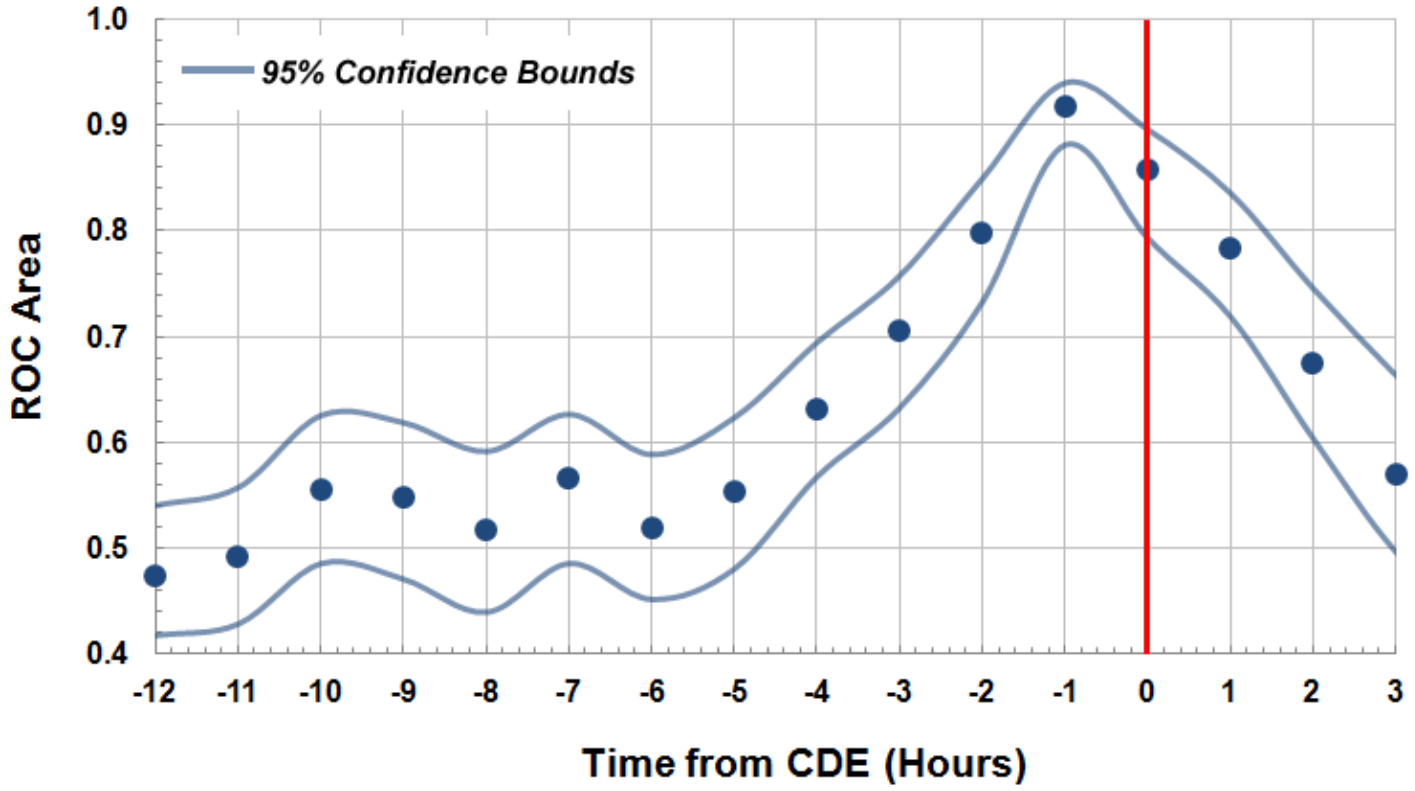
Vu EL, Rusin CG, Penny DJ, Kibler KK, Easley RB, Smith B, Andropoulos D, Brady K: Pediatr Crit Care Med 2017; 18:44–53.

Multivariate Logistic regression model



- 25 arrest events in 13 subjects
- Heart rate, Heart rate variability, respiratory variability, ST magnitude, ST instability, SpO_2,
- AUC: 0.91

Time course of HLHS decompensation



What did we learn?

Thank You

Blaine Easley
Kathy Kibler
Craig Rusin
Chris Rhee
Jen Mytar
Charles Fraser III
Charles Hogue
Charlie Brown
Marek Czosnyka
Peter Smielewski
Ray Koehler
Dean Andropoulos