Pediatric 3D ECG with I

Ken Brady
Anesthesia, Critical Care
Lurie Children’s Hospital
Disclosures

Patents filed by BCM
Our parents and teachers lied

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 Caesar* 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
- Superior vena cava
- Opening between atria (atrial septal defect - ASD)
- Inferior vena cava
- Vessel connecting aorta and pulmonary artery (ductus arteriosus)
- Underdeveloped left ventricle

RA: Right Atrium, PA: Pulmonary Artery, LA: Left Atrium, LV: Left Ventricle, RV: Right Ventricle
Forecasting arrest in HLHS: study data

- **S1P Surgery**
  - Control data
  - 1 hour of data
  - 1 hour of data
  - 24 hours of data

- **Rapid Response Event**

- **S2P Surgery**
  - Control data

- **Study Data Block**

- **Excluded Data**

- **Time**
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

What are the barriers to communication between experienced clinicians and programmers?
Pre-arrest and control ST segments

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

- 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

Multivariate Logistic regression model

- 25 arrest events in 13 subjects
- Heart rate, Heart rate variability, respiratory variability, ST magnitude, ST instability, $\text{SpO}_2$,
- 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