FIREFIGHTER PHYSIOLOGICAL MONITORING

TECHNOLOGY SUMMIT

March 28–30, 2018
Washington, DC

PRESENTED BY:

SCIENCE • MEDICINE • RESEARCH • TECHNOLOGY
EMERGENCY RESPONDERS
SMARTER

LINE-OF-DUTY DEATH
FIRE
EVERYONE GOES HOME
FIGHTER
LIFE SAFETY INITIATIVES

Potential use of EKG for Arrhythmias and Ischemia

Andrea Wilkinson

First Responder Health & Safety Laboratory

Skidmore College

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ECG & SMARTER Study

- Why ECG monitoring?
  - Prevention/ Early Detection
    - 85% of damage to the heart happens within two hours of blockage
  - Increase understanding of “trigger”
    - Potentially decreasing number of incidents

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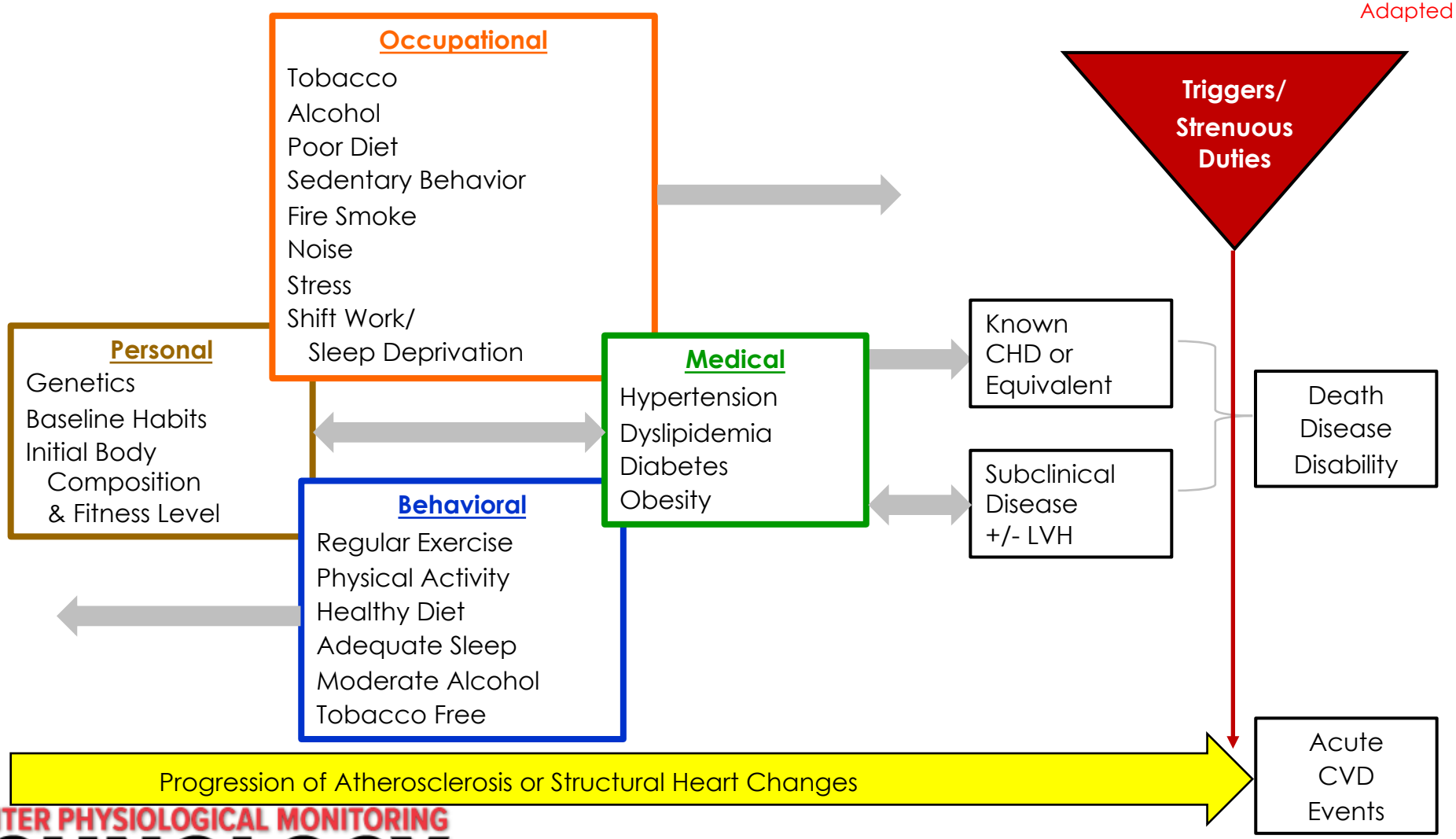
Model of CVE in the Fire Service

Adapted from Soteriades et al., *CIR*, 2011.



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Specific Concerns

- What/how many arrhythmias could be seen with wearable ECG devices?
- Time points of interest- when should/could devices be worn?
- Visualization of rhythms
- How would data be evaluated?
  - Medical Professional?
  - Automated Interpretation?
    - Accuracy
      - False positives
      - False negatives
    - Ambulatory effects

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- Team sought to explore existing technologies to:
  - Better understand usability
  - Explore use models within the Fire Service
  - Develop recommendations for the use of ECG in firefighting for detection of life-threatening arrhythmias and ischemic changes

Previous Research

- 1975- Barnard & Duncan:
  - 15-30 seconds after alarm, HR's increased an average of 47bpm
  - S-T segment changes were observed in ECG shortly after tones dropped
- 2013- Smith et al:
  - Combination of sympathetic nervous system activation, strenuous physical work, heat stress/dehydration, and environmental conditions leads to significant CV strain, mediated by individual characteristics
- 2017- Hunter, et al:
  - 20 minutes of fire simulation training results in EKG-detected ischemia in "healthy fire fighters"

Cardiovascular Strain of Firefighting

A)

- Increased Cardiac Work/Shear Stress
- Altered Vascular Function
- Enhanced Coagulatory Potential

Underlying CHD

Cardiomegaly/LVH, and/or Underlying CHD

B)

- Plaque Rupture and Thrombus Formation
- Arrhythmia

SCD or Other CVD Event

Extreme Physiology & Medicine

Smith, Barr, and Kales, *Extrem Physiol Med*, 2013.

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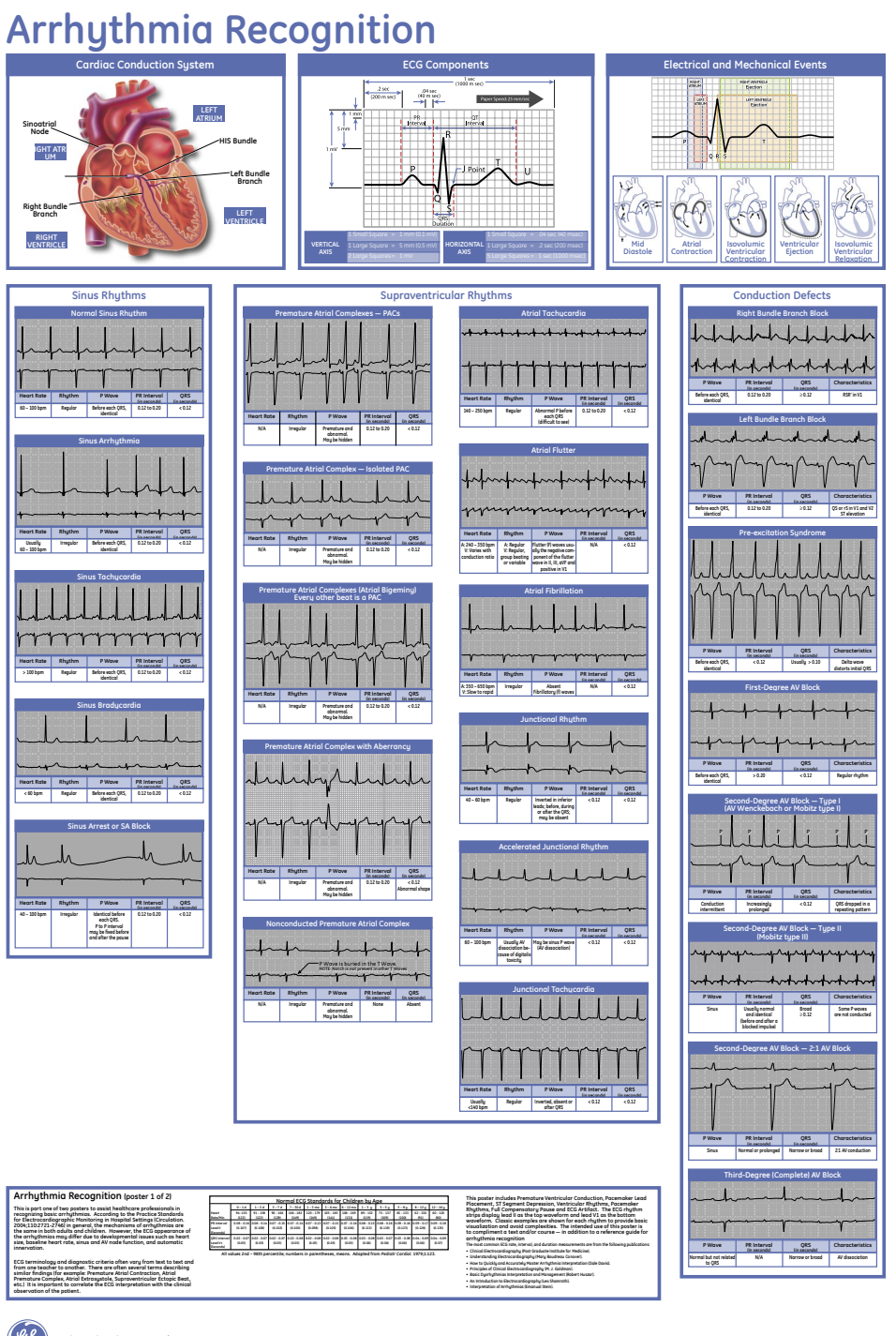
Understanding Arrhythmias

- What is it?
  - Abnormal heart rhythm
  - Often reported as feeling like a fluttering or a brief pause
- Pathology that alters the flow of electrical current in the body

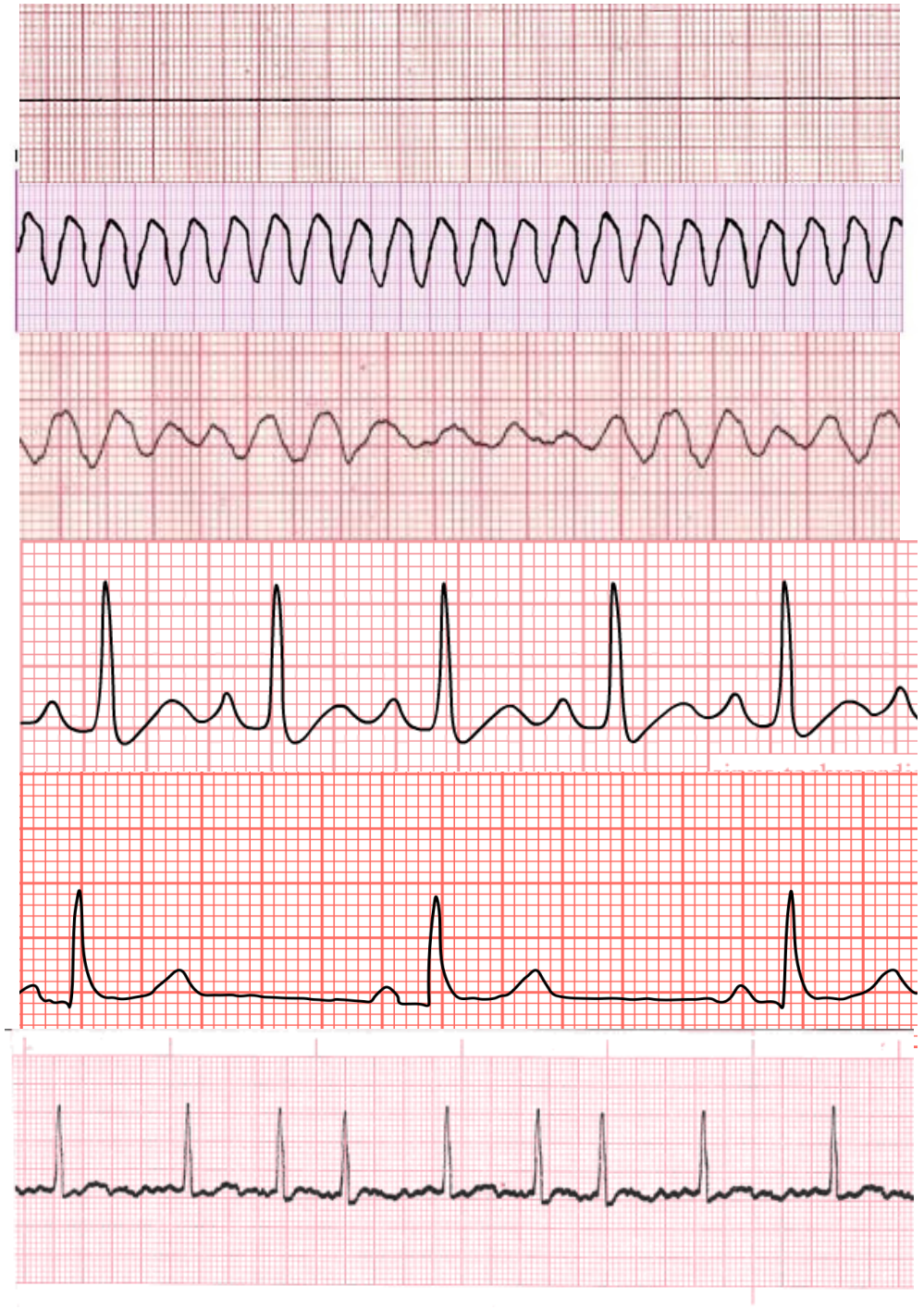
MANY

types and classifications of arrhythmias!



Life threatening arrhythmias (LTA)

- Asystole
- Ventricular tachycardia
- Ventricular flutter/fibrillation
- Extreme tachycardia
- Extreme Bradycardia
- Atrial fibrillation
  - Not typically LTA, but has risks

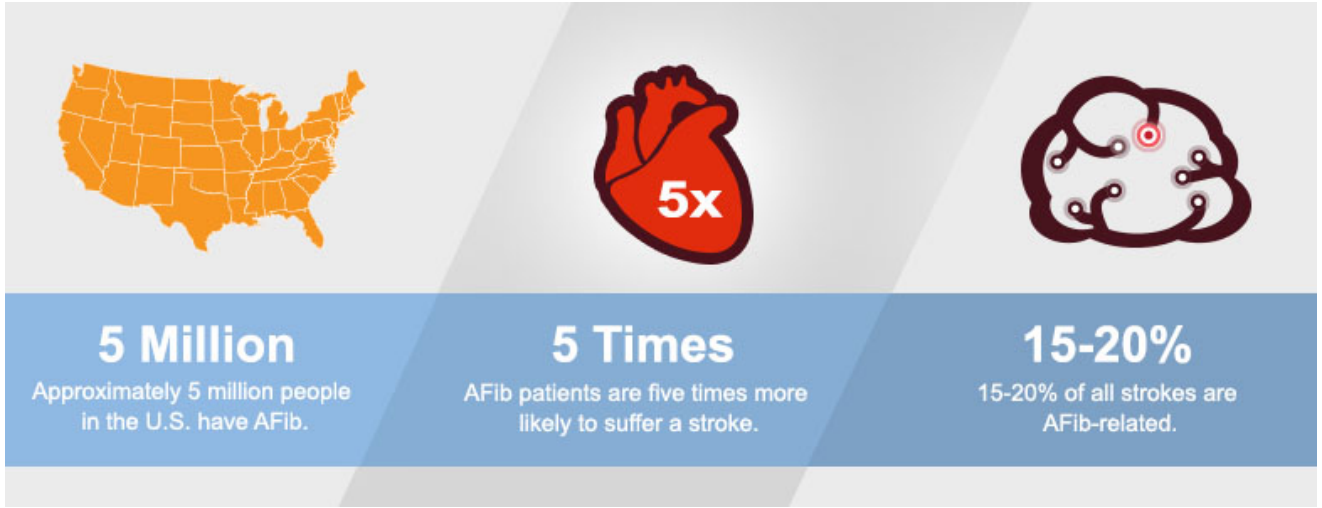


Atrial Fibrillation

- Atrial Fibrillation is the most commonly sustained heart rhythm disorder
  - Electrical signals are fast and erratic
  - Common causes include CAD, valvular heart disease, hypertension, and thyroid disorders
  - In some patients no cause can be found- 'lone' atrial fibrillation

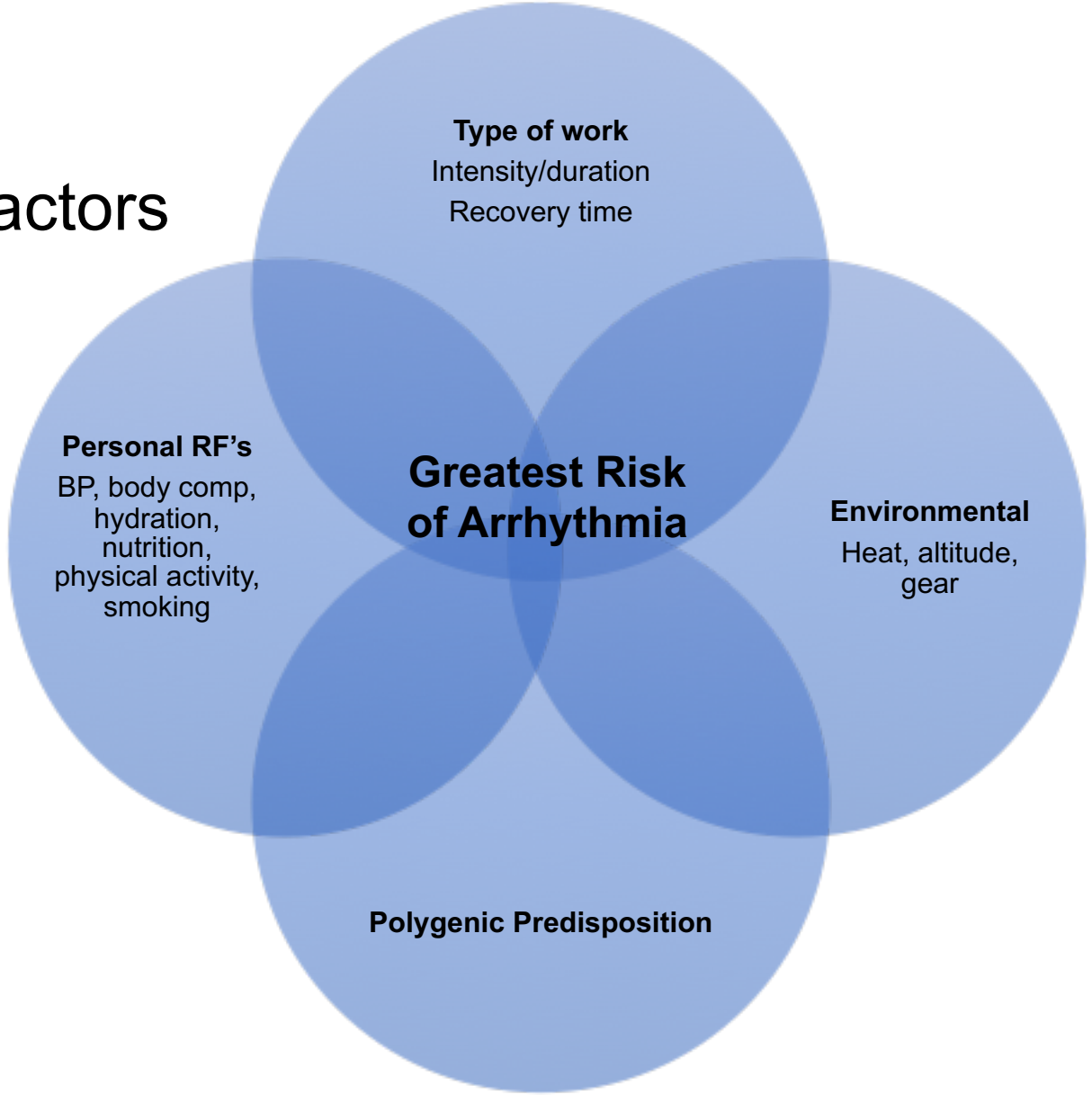
Atrial Fibrillation

- AFib itself is not typically life threatening, but complications can lead to life threatening conditions
- Risks:
  - 5X increase risk for stroke (AHA)
  - Heart Failure
  - Chronic fatigue
  - Further arrhythmias
  - Inconsistent blood supply



Risk of Arrhythmia affected by many factors

- SCBA & tool load
- CV fitness
- Underlying CV disease
- Dehydration
- Other systemic health risks



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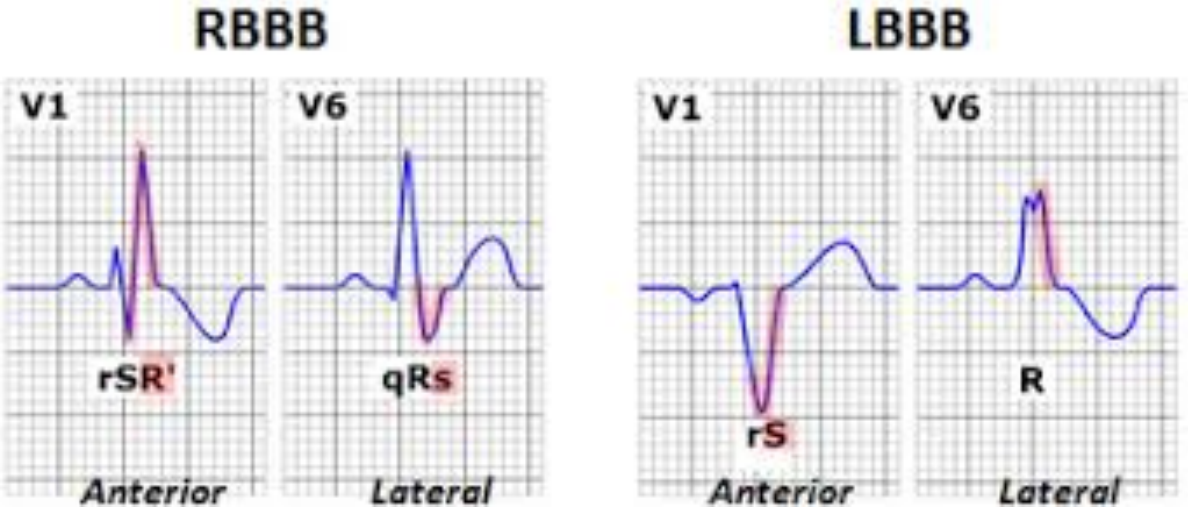
Arrhythmia monitoring

Conduction defects

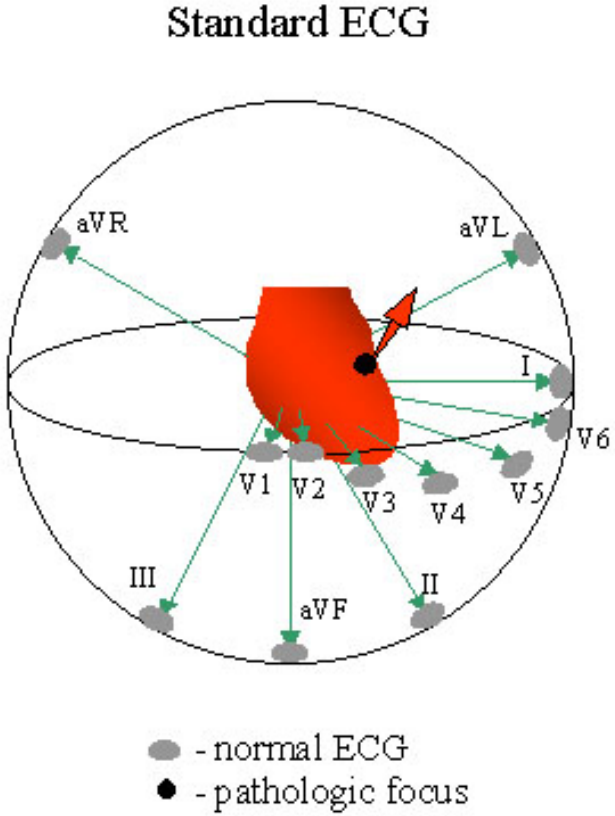
- AV blocks, RBBB, LBBB
- Chamber enlargement



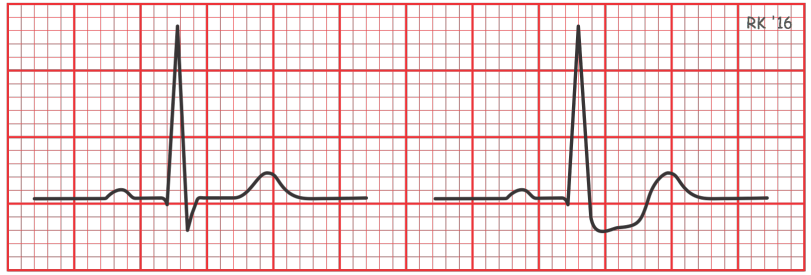
Example of morphology from select lead positions

Arrhythmia monitoring

- Risk of arrhythmia – affected by electrical depolarization and axis rotation
- Single axis lead vector complicates interpretation



Ischemic Conditions

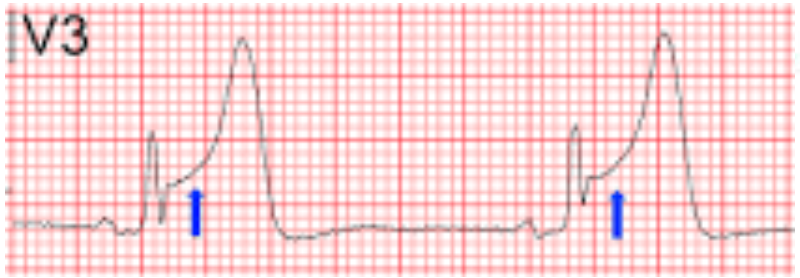


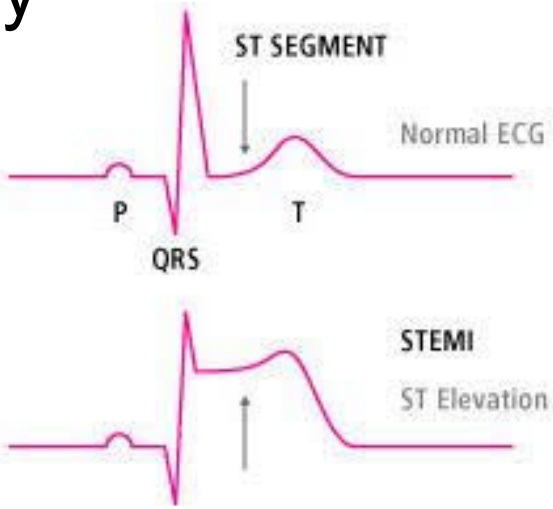
- Ischemia: restricted or reduced blood flow (thus oxygen)
- Ischemic Heart Disease: term given to heart conditions caused by a stenosis of the coronary arteries
  - Also known as: Coronary Artery Disease or Coronary Heart Disease
- Silent Ischemia: asymptomatic ischemic episodes
  - Individuals with history of MI or diabetes are at increased risk
  - An estimated 2-3 million people in the U.S. with “stable” CAD have evidence of asymptomatic ischemia (Stern et al., 2005)

Ischemic Monitoring

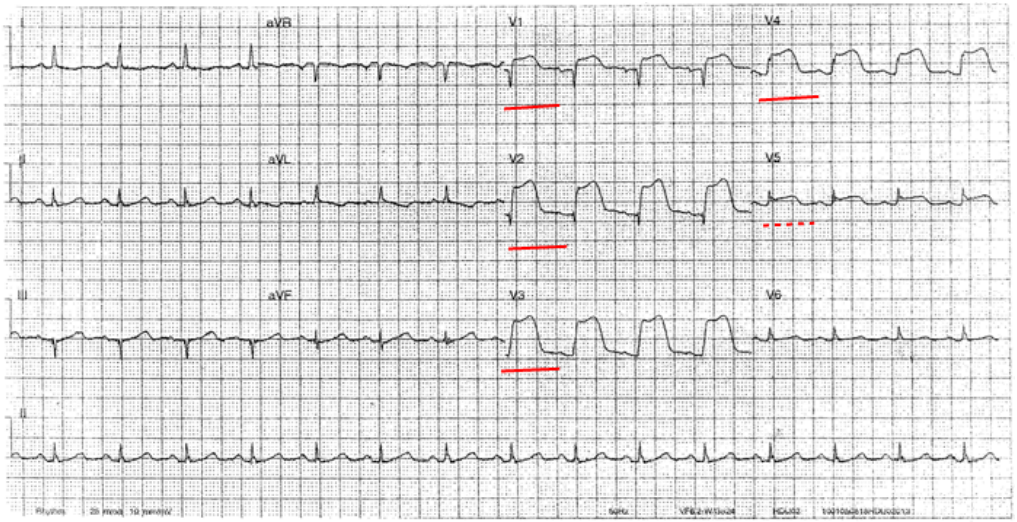
Acute myocardial injury patterns

- Anterior infarction
- ST elevation





Anterior infarction



infarction is visible in some of the V1-V6, I and aVL leads

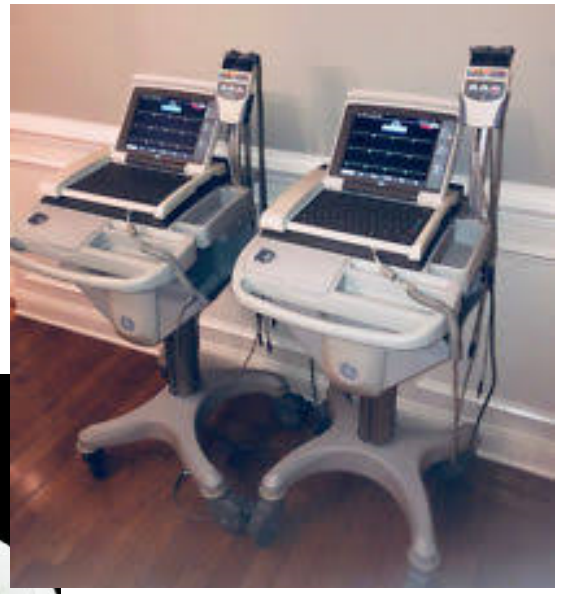
SCE & ECG Concerns

- Can a Single Lead (SL) ECG show ischemic changes leading up to a SCE?
- How will work/movement affect ECG signal
- Nontraditional electrode placement

Modern ECG Systems

Cardiographs

- Philips Cardiograph: STAR
- Mortara Cardiograph: Veritas
- GE cardiograph



Holter:

- Philips
- Nassif

Patches

- Corventus/Medtronic PiiX
- Medtronic SEEQ
- iRhythem Zio
- Cardiocom Heartcheck

Mobile

- AliveCore

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- The SMARTER study focused efforts on exploring:
  - WASP (Zephyr) System
  - Equivital
  - AliveCor

WASP (Zephyr) System

- Flame-resistant baselayer shirt and Zephyr Bioharness 3 technology
- Real-time and recorded HR, RR, skin temperature, estimated core temperature, GPS
- Recorded ECG (single lead)
- Many additional fitness variables

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WASP (Zephyr) System

- Omnisense Software
  - Live
  - Analysis and Data View

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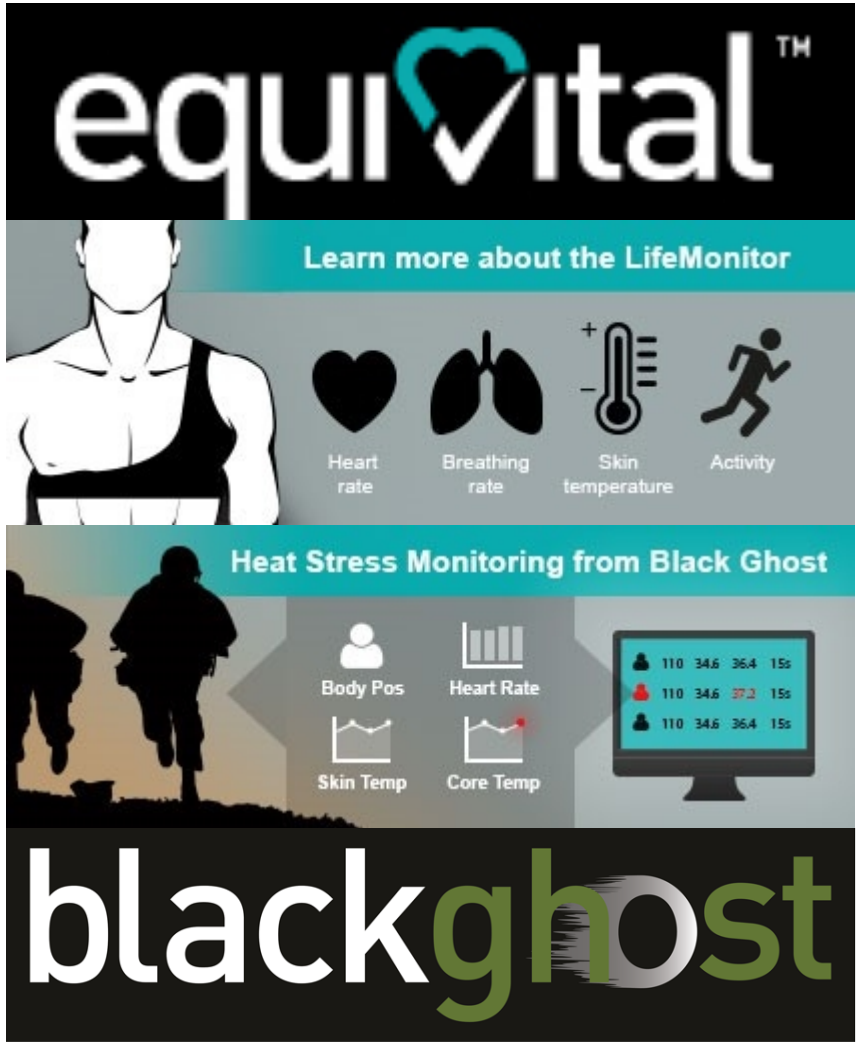
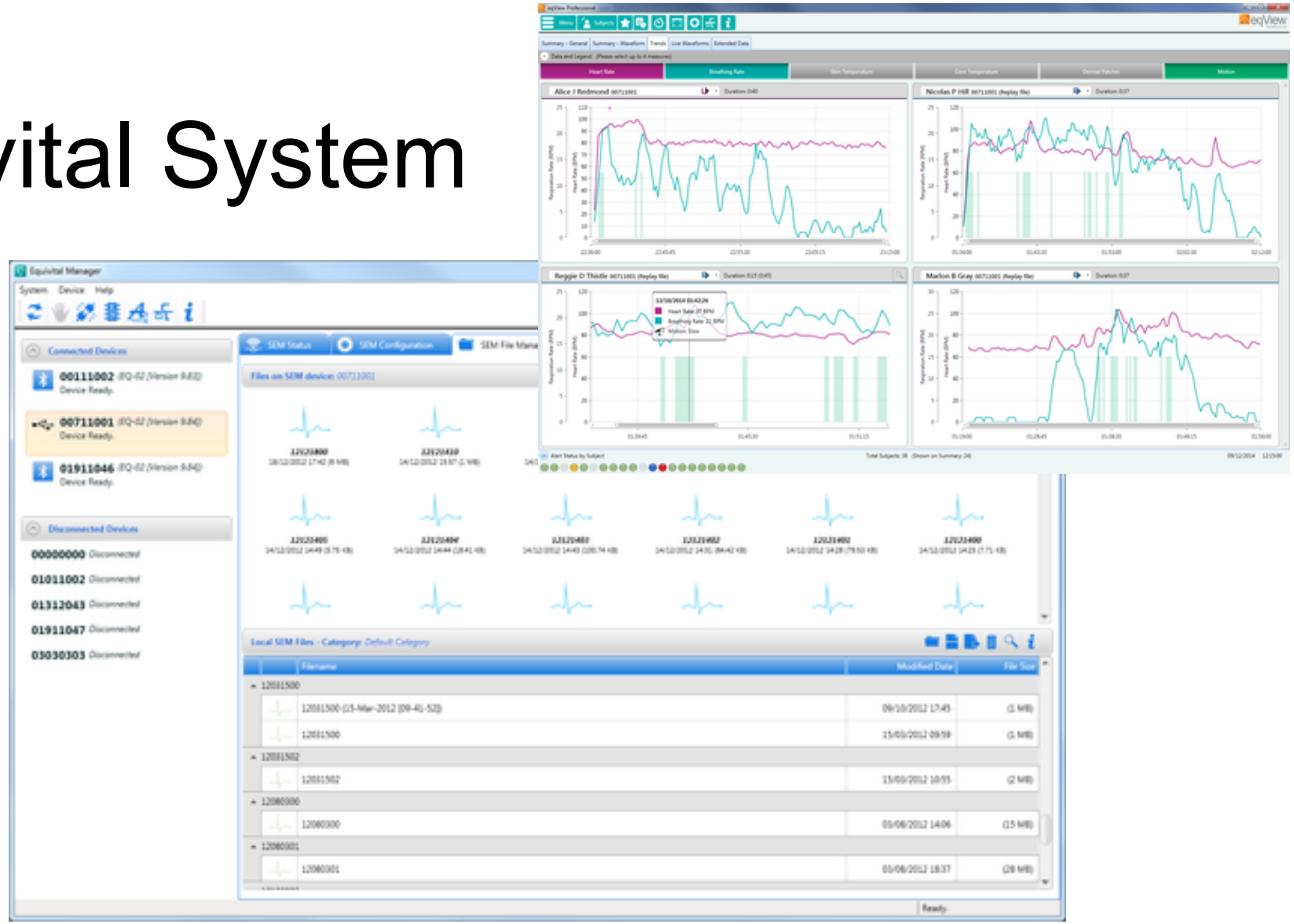
Hidalgo Equivital System

- LifeMonitor
  - Real-time and recorded ECG, HR, RR, skin & core temperature (with capsule), body position, GPS
- Black Ghost
  - Heat stress, safety, and performance monitoring. Other measures mirror the LifeMonitor.



Hidalgo Equivital System

- Equivital Software
  - Live View
  - Management



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KardiaMoble AliveCore System

- Live ECG monitoring with Arrhythmia detection
- FDA-cleared for medical-grade ECG recordings
- Atrial Fibrillation algorithm with 97% sensitivity and 98% specificity
- HIPPA Compliant

AliveCor

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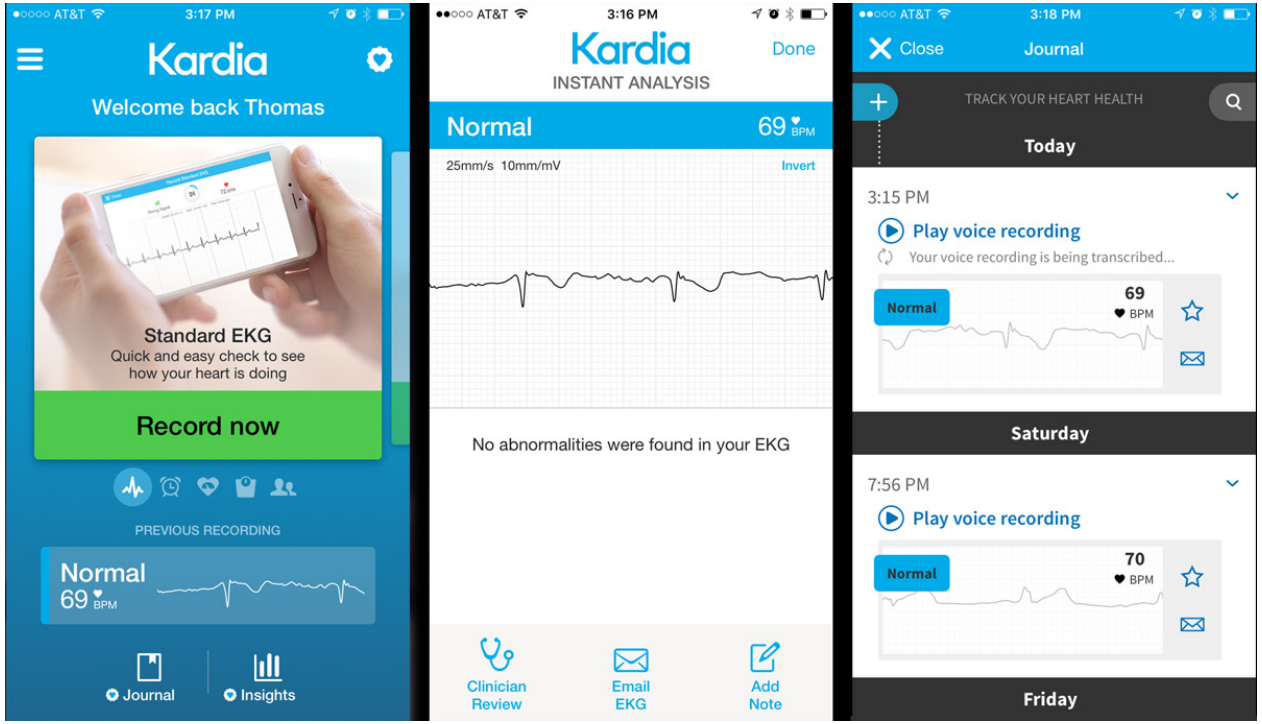
KardiaMoble AliveCore System

- Mobile and Watch Apps
  - Free app
  - Paid premium subscription
    - $9.99/month, $99/year



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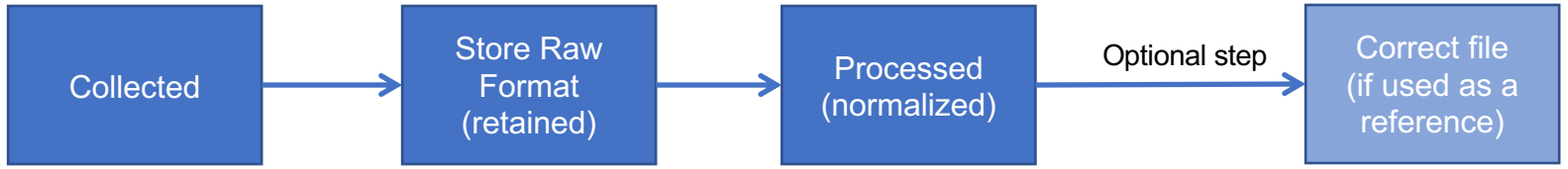
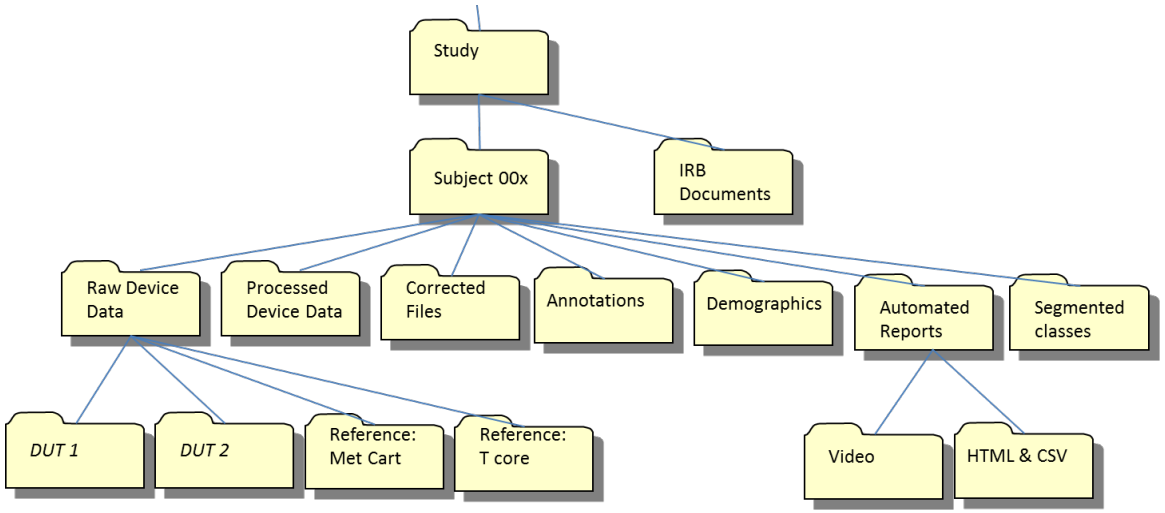
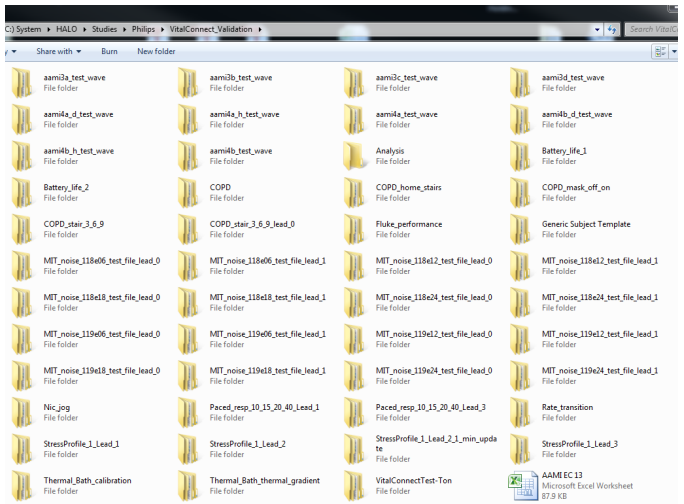
	WASP/ Zephyr System	Equivital (Hidalgo)	AliveCor (KardiaMobile)
Pros	• Has a commitment for integration within the fire service • Options for use: patch, shirt, harness • Shirt manufactured by Globe designed to serve as base-layer	• ”Live” ECG signal • Black Ghost system being used in military	• Readily available, commercial device • Supporting the Apple Heart Study (Stanford University) • Real-time detection • Easy to wear/use • Allows for simultaneous recording of symptoms
Cons	• Does not provide ”live” ECG • No arrhythmia detection software • Must export data to view waveform	• Harness is more difficult to wear • Harness is not NFPA approved • No arrhythmia detection software • Requires core temp capsule	• Requires an app with “baseline” reading • Requires 30 seconds of rest/connection with electrode • No heat stress information

Data handling in this study





Study/ DB master file



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Test file structure

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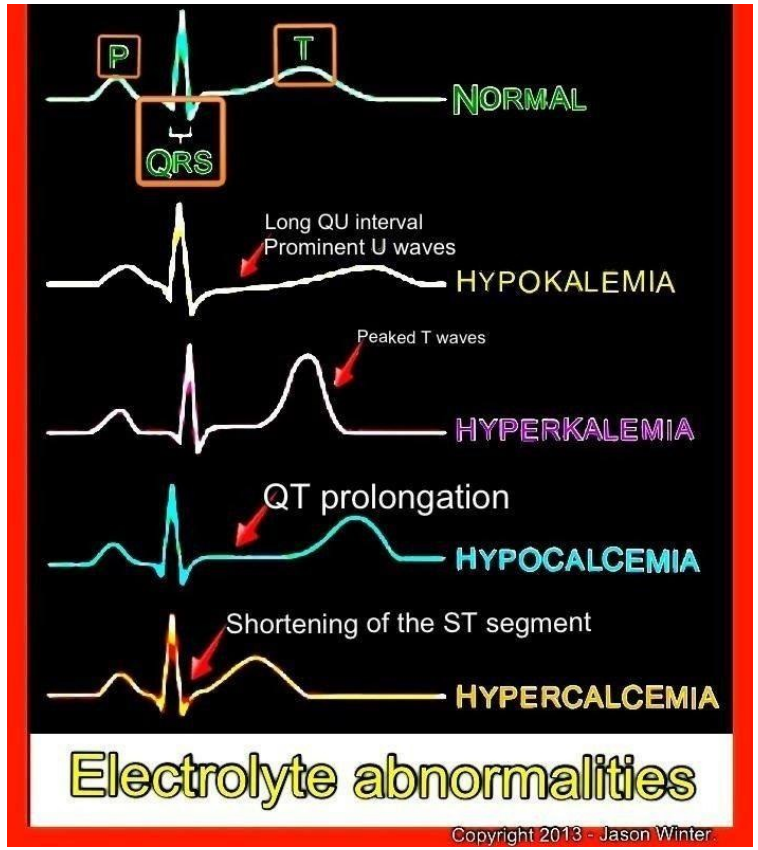
Challenges with SL Arrhythmia Monitoring

- Movement artifact
- Waveforms will be likely be more dynamic during job performance
- Lead placement is a nontraditional vector
  - Repolarization exaggerated
  - Myocardial rotation
  - Exaggerated biphasic presentation
- Irregular rhythms preclude use of beat anticipation methods



Processing with confidence filter

Data tested for corresponding confidence

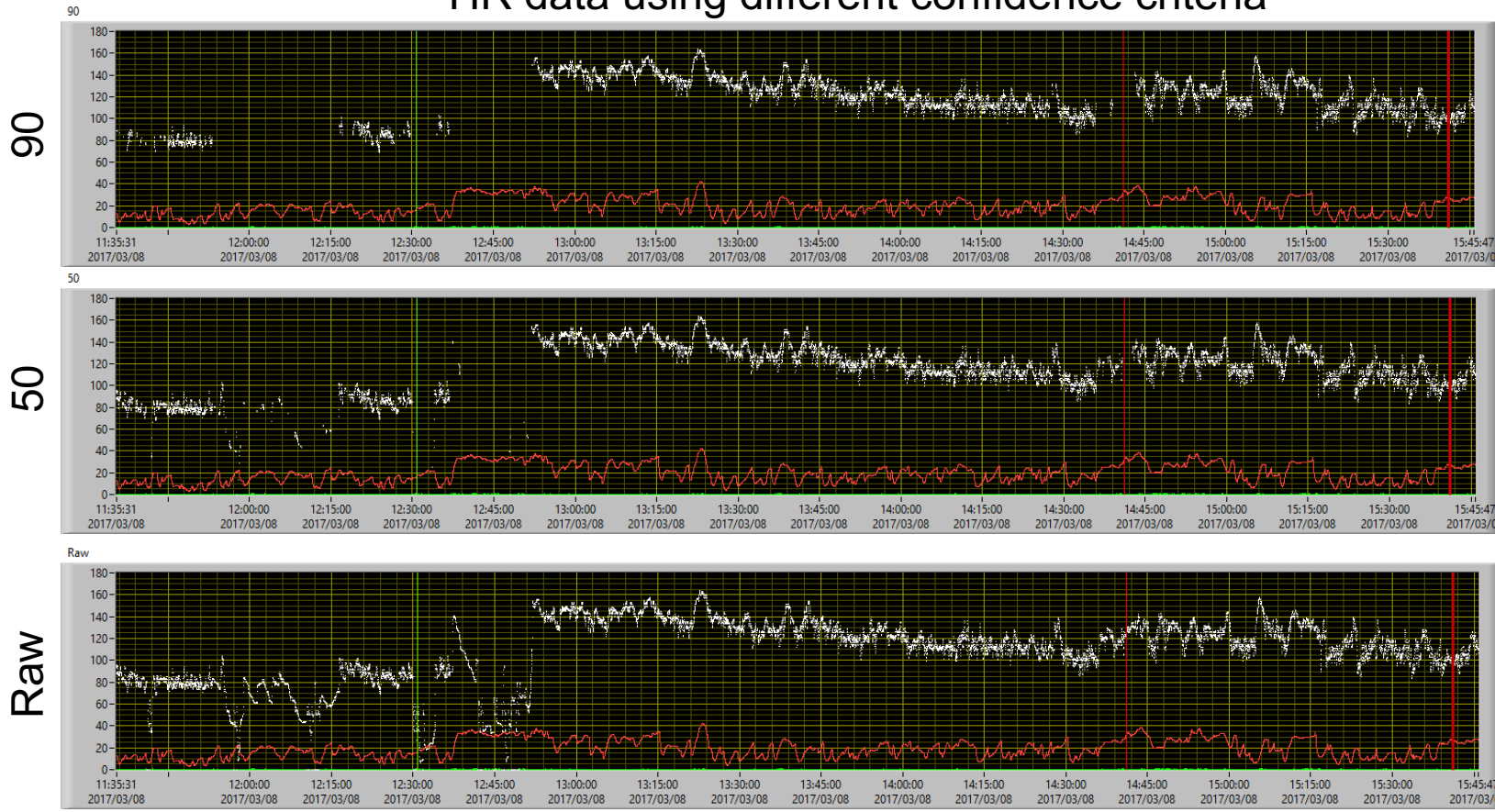
Date below a threshold is discarded

Raw (unfiltered), 50% and 90% data used

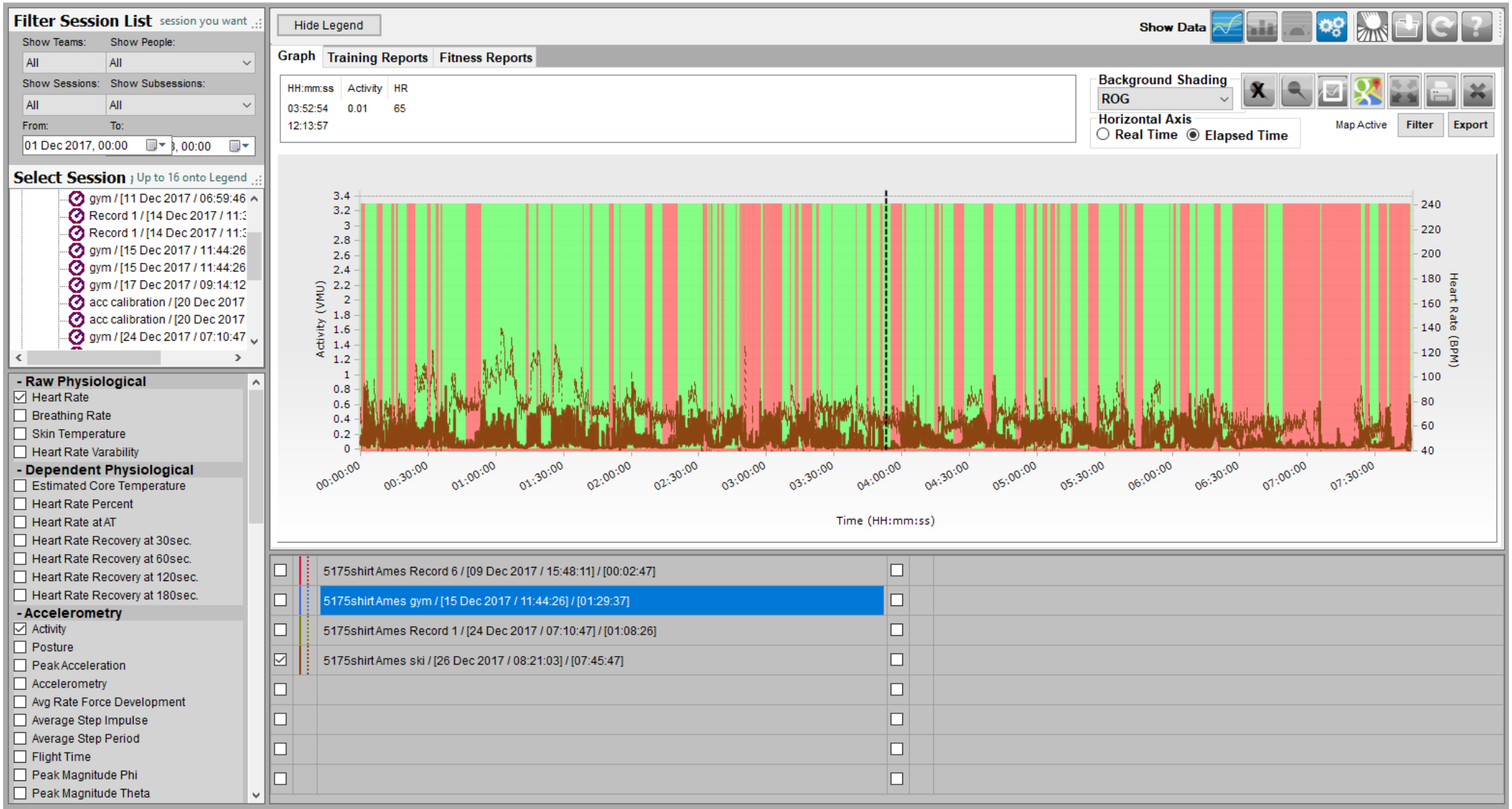
Statistics (Median, Mean, Mode, Min, Max Ave)

If a HR had a confidence below the criteria, it was discarded from the statistics

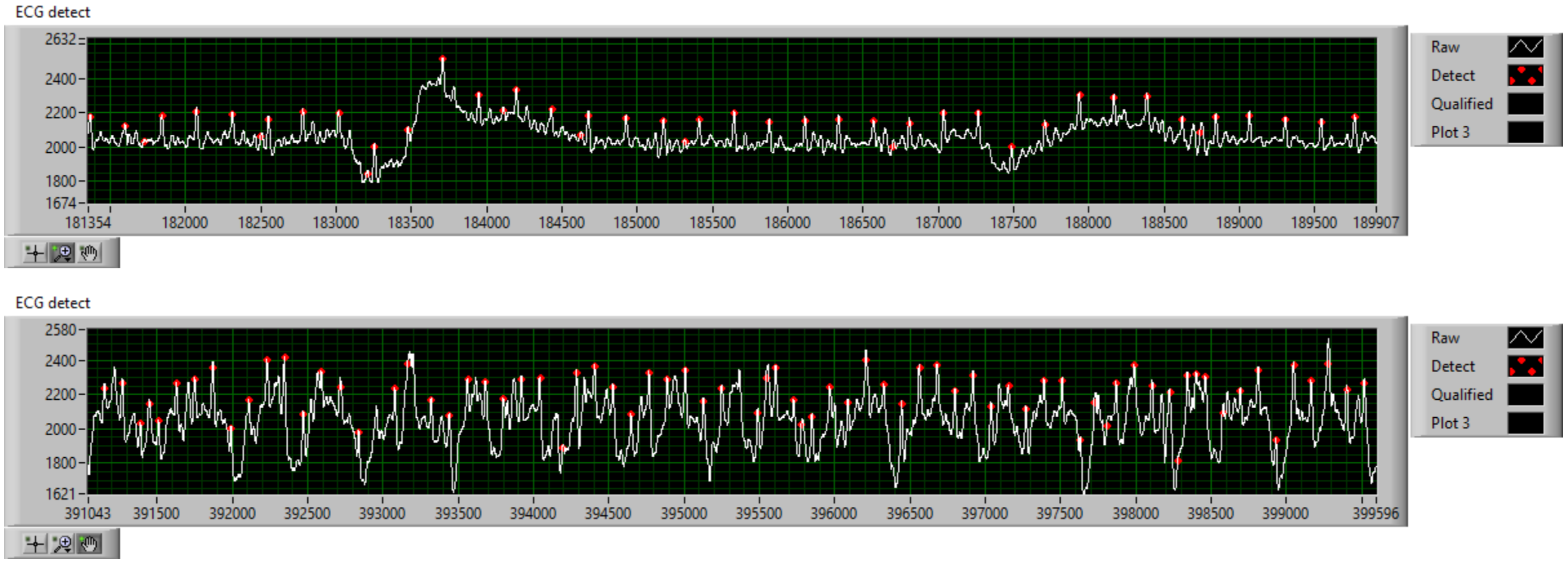
HR data using different confidence criteria



OmniSense Analysis Display



Zephyr Waveform



Early Findings

- HR usable with confidence filter
- ECG vector shows basic fiduciary references (PQRST)
- ST elevation utility needs proper study (what's the true equivalent lead)
- Unknown front end bandwidth
  - VFIB needs LF range
- Limited ischemic visibility
  - ~ V1 approximation but more posterior visibility

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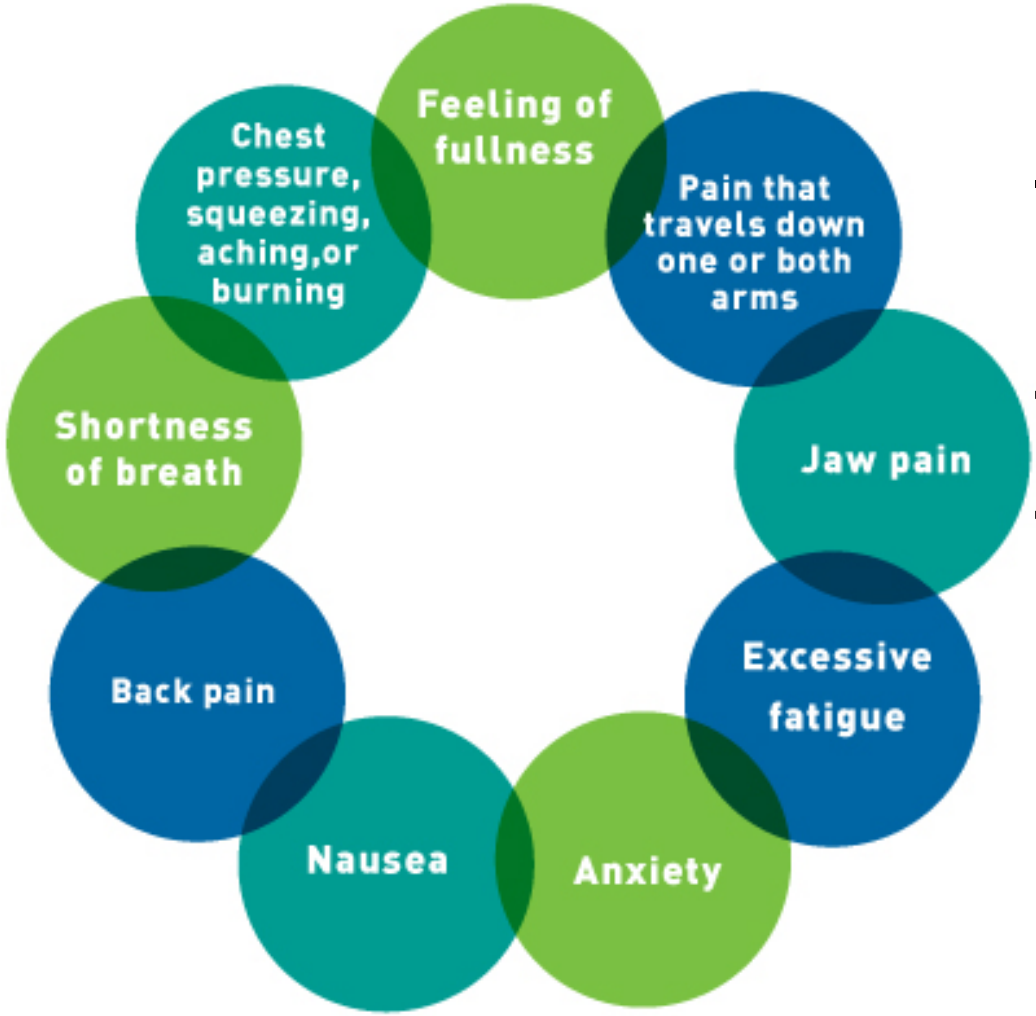
Current Recommendations

- Whenever possible, standard 12-lead ECG is highly preferred
  - IE: in REHAB setting
- Ambulation/work creates large amounts of artifact
- “Live” ECG outputs with cleaning and arrhythmia detection software are highly preferable
- Current technologies do not appear to be deployable for the purpose of ECG monitoring during firefighting

Recommendations



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"Treat the patient, not the monitor"

Educate all personnel on signs and symptoms of sudden cardiac events

Encourage prevention

Emphasize early action

- Speak up **early** when experiencing symptoms- seek help
- 85% of damage to the heart happens within two hours of blockage
- Early Heart Attack Care (EHAC-ACC)

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Early Heart Attack Care

EHAC Pledge

"I understand that heart attacks have beginnings that may include chest discomfort, shortness of breath, shoulder and/or arm pain, and weakness.

These may occur hours or weeks before the actual heart attack.

I solemnly swear that if it happens to me or anyone I know, I will call 9-1-1 or activate our Emergency Medical Services."

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FIRE DEPARTMENT
INCIDENT REHAB
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Questions?

Thank you!

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