DETECTING CLINICALLY SIGNIFICANT CARDIAC ABNORMALITIES WITH PRE-PARTICIPATION ECGS IN COLLEGE ATHLETES

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PROFESSIONAL CASES

HANK GATHERS: Age 23

- March 4th, 1990
- Collapsed during Loyola Marymount vs University of Portland game
- COD: Sudden Cardiac Death (SCD) due to cardiomyopathy
- Family sued cardiologist and Loyola Marymount for negligence for millions
PROFESSIONAL CASES

REGGIE LEWIS: Age 27

- July 27th, 2003
- Collapsed during basketball practice
- COD: SCD due to hypertrophic cardiomyopathy (HCM)
RECENT PROFESSIONAL CASES

RYAN SHAY: Age 28
- November 3rd, 2007
- Collapsed during the US Olympic Marathon Trials in NYC
- COD: Cardiac arrhythmia due to cardiac hypertrophy

ZEKE UPSHAW: Age 26
- March 24th, 2018
- Collapsed during a basketball game between Grand Rapids and the Long Island Nets
- COD: SCD due to unknown cardiac abnormalities
RECENT COLLEGE CASES

DARIUS MINOR: Age 18

- July 24th, 2018
- University of Maine football practice
- COD: Aortic dissection with cardiac tamponade and contributary HTN
- University of Maine has yet to update policies
RECENT HIGH SCHOOL CASES

JAVON CRADDOCK: Age 16
- May 16th, 2018
- Basketball game
- COD: HCM

KAI LERMER: Age 16
- March 25th, 2019
- Pickup Basketball
- COD: Cardiac arrest driven by Wolff Parkinson White
- Fundraiser created for defibrillators and CPR classes in the Waukesha School District (WI)

COLIN SEELEY: Age 16
- April 2nd, 2019
- Running Laps
- Cardiac Arrest: Critical Condition
- Brevard High Schools: 4 students in basketball, football, soccer, and running experienced SCD/SCA in last decade
- Schools added additional cardiac screenings and training via non-profit support
SUDDEN CARDIAC DEATH

- Definition: Death with exertion or shortly (< 1 hour) thereafter, or within 24 hours of being seen well
- More than 350,000 incidents of cardiac arrest per year
- Fatality rate:
  - 65% despite CPR and defibrillation
  - 80% without CPR+ measures\textsuperscript{15,16}
- Causes:
  - >35 years old: Atherosclerosis (>80%)
  - <35 years old: Structural cardiac and conductive system abnormalities
CAUSE OF DEATH IN NCAA ATHLETES

- SCD is the leading cause of nontraumatic death amongst NCAA athletes averaging 1 in 53,703 athlete-years\textsuperscript{20}

- 2.5\times higher risk of SCD in athletes than non-athletes counterparts

- From 2000-2016:
  - 33 NCAA football players have died in sport\textsuperscript{1}:
    - 27 nontraumatic deaths
      - 9 from SCD
    - 6 traumatic deaths
    - 4.5 nontraumatic deaths for every traumatic death
  - About 2 NCAA football players die per season

Figure 1: Adapted from Harmon\textsuperscript{11}
ATHLETE’S HEART

- Bradycardia
- Repolarization variances
- Chamber enlargement with voltage shifts

**Electrical**

- Increased chamber wall thickness and cavity sizes

**Structural**

- Enhanced diastolic filling
- Greater stroke volume

**Functional**

Adapted from Sydney Cardiology
# CAUSES OF SCD

<table>
<thead>
<tr>
<th>CONGENITAL/GENETIC</th>
<th>STRUCTURALLY NORMAL HEART</th>
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<tbody>
<tr>
<td><strong>STRUCTURALLY ABNORMAL HEART</strong></td>
<td><strong>STRUCTURALLY NORMAL HEART</strong></td>
</tr>
<tr>
<td>Hypertrophic Cardiomyopathy (HCM)</td>
<td>Congenital Long QT Syndrome</td>
</tr>
<tr>
<td>Arrhythmogenic Right Ventricular Cardiomyopathy (ARVC)</td>
<td>Catecholaminergic Polymorphic Ventricular Tachycardia</td>
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<tr>
<td>Dilated Cardiomyopathy</td>
<td>Wolf-Parkinson-White Syndrome or Other Accessory Pathway</td>
</tr>
<tr>
<td>Other Cardiomyopathy (Left Ventricular Cardiomyopathy)</td>
<td>Brugada Syndrome</td>
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<tr>
<td>Congenital Anomalies Of Coronary Origin and Course</td>
<td>Other Ion Channelopathies</td>
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<tr>
<td>Aortopathy (Marfan’s Syndrome, Ascending Aortic Aneurysm/Dissection)</td>
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<tr>
<td>Valvular Heart Disease (Congenital Aortic Stenosis, Mitral Valve Prolapse)</td>
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<table>
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<th>ACQUIRED</th>
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<tr>
<td><strong>STRUCTURALLY ABNORMAL HEART</strong></td>
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<tr>
<td>Atherosclerotic Coronary Artery Disease</td>
</tr>
<tr>
<td>Kawasaki’s Disease</td>
</tr>
<tr>
<td>Myocarditis</td>
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</table>

Table 1: Harmon

[Image of a book cover with VCOM and Virginia Tech Sports Medicine logos]
WHY ECGS?

ECGs Detection
- 66%-100% detection of silent cardiovascular diseases in athletes
- United States: HCM is the leading cause of SCD in athletes
  - 90% of athletes with HCM will have ECG changes

Italian Study (1981-2006)
- Italy: Arrhythmogenic Right Ventricular Cardiomyopathy (ARVC) is the leading cause of SCD
  - Epsilon Wave on ECG
- 89% reduction in SCD incidence in screened athletes over a 25 year period
REGULATION

MARCH 2015
– Dr. Brian Hainline (NCAA Chief Medical Officer) recommends all male college basketball players should undergo ECG preclearance

RESULT
– Overwhelming outcry
– Over 100 team physicians countered questioning the use of ECGs due to high rates of false positives
– 0.5% of all ECGs screened actually abnormal
– Concern over false disqualifications from sport
– Dr. Hainline backed off recommendation

CURRENT STANCE?
– NCAA developed guidelines for managing SCD but is far from endorsing routine use of ECGs
  – Cardiovascular Care Checklist via NCAA Sport Science Institute
  – American Heart Association (AHA) and the American College of Cardiology remain opposed to routine ECG use
  – The NCAA estimates about 40% of DI Power 5 Conferences use ECGs as a supplemental tool
  – University of Florida
Disqualifications

- Goal of ECGs is not to disqualify athletes from sport
- About 1% of athletes screened are disqualified
  - Prevalence of cardiovascular abnormalities yielding disqualification estimated at 0.3%
- Disqualification standards based on 2005 Bethesda Guidelines

University of Florida Athletics

- Since 2012:
  - Florida reports screening all athletes and Spirit Squad members with ECGs as part of their preparticipation exam (PPE)
- Disqualifications from Sport:
  - 2017 Recruit:
    - James Robinson- Unspecified heart condition
  - 2018 Recruit:
    - Randy Russell- HCM
WHO SHOULD BE SCREENED?

- 8 million high school athletes
  - Would cost roughly $2 billion in 1st year
  - 7% go on to college varsity athletics
    - 2% go on to DI programs

- 420,000-500,000 college athletes
  - DI: 179,200 athletes
  - DII: 121,900 athletes
  - DIII: 190,900 athletes

SCD RISK

- 70% are Males\textsuperscript{13, 14}
  - Males 3x more likely than Females
- 52% are black athletes\textsuperscript{13, 15}
  - Black athletes at 3x greater risk than white athletes
- More than $\frac{2}{3}$ are basketball or football players\textsuperscript{15}
  - Represent only 23% of male NCAA athletes but 50% of all SCD cases\textsuperscript{10}
**SCREENING PROTOCOL**

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**Cardiovascular screening Flow Chart**

- **Routine PPE**
  - Normal Exam
    - No Symptoms
      - No Further Intervention
  - Abnormal Exam
    - Cardiac Symptoms*
      - Basketball Player
      - Football Player
      - Mediterranean Descent
      - ADHD Dx/Tx
      - **ABNORMAL**
        - Cardiac Workup**
          - **ABNORMAL**
            - EKG
              - NORMAL
              - No Further Intervention
      - **NORMAL**

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* Syncope, Presyncope, Frequent/Severe Palpitations, Light-headedness, Previous Cardiac History (Question #5 on blue new PPE form)
** EKG. Cardiac Referral with appropriate testing
  - > Sinus bradycardia < 30bpm, 1st degree AV block with PR > 0.36sec, 2nd/3rd degree AV block, LBBB, Prolonged QTc (440ms females, 480ms males), Sustained SVT, WPW, Atrial Fibrillation/Flutter, Ventricular arrhythmia, Q waves > 4mm depth > 2 leads, Inverted T-waves > 2 leads, LAD < 30°, RAD > 110°

***Prolonged QTC: Women, >460ms; Men >450ms; and Short QTC: Women and Men <390ms (Circulation 2009; 119:e241-250)***
### Table 1: Normal ECG Finding in Athletes

1. Sinus Bradycardia (>30bpm)
2. Sinus Arrhythmia
3. Ectopic Atrial Rhythm
4. Junctional Escape Rhythm
5. 1° AV Block (PR>200ms)
6. Mobitz Type 1 (Wenckebach) 2° AV Block
7. Incomplete RBBB (IRBBB)
8. Isolated QRS Voltage Criteria for LVH
9. Early Repolarization
10. Convex ST Elevation with T wave Inversions

### Table 2: Abnormal ECG Finding in Athletes

1. T Wave Inversion in two+ leads not in III, aVR or V1
2. ST Segment Depression
3. Pathological Q Waves
4. Left Bundle Branch Block (LBBB)
5. Intraventricular Conduction Delay (QRS >140ms)
6. Left Axis Deviation (LAD)
7. Left Atrial Enlargement (LAE)
8. Right Ventricular Hypertrophy (RVH) with Right Axis Deviation (RAD)
9. Ventricular pre-excitation upstroke in QRS (PR>120 with delta wave)
10. Long/Short QTc Interval (Seattle: Prolonged >470/480ms (m/f) Shortened <320 ms
    VT: Prolonged >450/460ms (m/f) Shortened <390ms
11. Mobitz Type II 2° AV Block/ 3° AV Block
12. Brugada-like ECG pattern elevation
13. Profound Sinus Bradycardia (<30bpm)
14. Atrial Tacharyrhythmias or Atrial Flutter (AFIB)
15. Premature Ventricular Contractions (PVCs) >2
16. Ventricular Arrhythmias and Tachycardia
CASE 1

Electrocardiogram

- Vent. Rate: 45 bpm
- P Duration: 86 ms
- QRS Duration: 110 ms
- PR Interval: 116 ms
- QT Interval: 476 ms
- QTc Interval: 450 ms
- QT Dispersion: 26 ms
- P-R-T Axis: 36° 79° 13°

Stable 40 Hz
Percentage of Bradycardia/Tachycardia
Only ECGs

7%

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8. Isolated QRS Voltage Criteria for LVH
9. Early Repolarization
10. Convex ST Elevation with T wave Inversions
CASE 2

ECG Tracing:

- Vent. rate: 66 bpm
- PR interval: 162 ms
- QRS duration: 108 ms
- QT/QTc: 414/434 ms
- P-R-T axes: 74 -22 -46
Table 1: Normal ECG Finding in Athletes
1. Sinus Bradycardia (>30 bpm)
2. Sinus Arrhythmia
3. Ectopic Atrial Rhythm
4. Junctional Escape Rhythm
5. 1st AV Block (PR>200ms)
6. Mobitz Type 1 (Wenckebach) 2:1 AV Block
7. Incomplete RBBB (IRBBB)
8. Isolated RBBB Voltage Criteria (QRS <120 ms)
9. Early Repolarization
10. Convex ST Elevation with T wave Inversions

Table 2: Abnormal ECG Finding in Athletes
1. T Wave Inversion in two leads not in III, aVR, or V1
2. ST Segment Depression
3. Pathological Q Waves
4. Left Bundle Branch Block (LBBB)
5. Sinoatrial Block (P-R >140ms)
6. Left Axis Deviation (LAD)
7. Left Atrial Enlargement (LAE)
8. Right Ventricular Hypertrophy (RVH) with Right Axis Deviation (RAD)
9. Ventricular pre-excitation: upstroke in QRS (PR<120 with delta wave)
10. Long/Short QT Interval (Seattle: Prolonged >470/490ms (nW): Shortened <320 ms)
11. Mobitz Type II 2:1 AV Block 3:1 AV Block
12. Brugada-like ECG pattern elevation
13. Prolonged Sinus Bradycardia (>300 bpm)
14. Atrial Tachyarrhythmias or Atrial Fibrillation (AFIB)
15. Premature Ventricular Contractions (PVCs)>2
16. Ventricular Arrhythmias and Tachycardia

Tall P waves: RAE
RESULTS

7425 Rostered Athletes

662 Screened

48 ECHOs

Athletes Screened via ECGs by Gender

WOMEN, [VALUE]

MEN, [VALUE]
ATHLETES PER TEAM SCREENED

Number of EKG per Sport 2008-2018

<table>
<thead>
<tr>
<th>Sport</th>
<th>Number of EKG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men's Baseball</td>
<td>16</td>
</tr>
<tr>
<td>Women's Basketball</td>
<td>47</td>
</tr>
<tr>
<td>Men's Cheer</td>
<td>36</td>
</tr>
<tr>
<td>Women's Cross Country</td>
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<tr>
<td>Men's Cross Country</td>
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<tr>
<td>Men's Football</td>
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<td>Men's Golf</td>
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<tr>
<td>High Jinks</td>
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<td>Women's Lacrosse</td>
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<td>Men's Volleyball</td>
<td>14</td>
</tr>
<tr>
<td>Women's Volleyball</td>
<td>16</td>
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</table>

Number of EKG per Sport 2008-2018
RESULTS

- Of 688 ECGs, 1089 findings were noted which included a finding of “No Pathology”
  - “No Pathology”: Did not meet any Seattle Criteria outside Sinus Arrhythmia
  - 25.0% were “No Pathology”
- 6.2% of “Detected Findings” were denoted abnormal as defined by the Seattle Criteria
- 7.3% of students required additional screenings via Echocardiograms (ECHO)
MOST COMMON FINDINGS

- Early Repolarization (15.6%)
- Bradycardia (14.1%)
- Nonspecific T-wave changes (14.0%)
**FINDINGS BREAKDOWN**

**Most Common Findings in the "Other" Category**

- Ectopic Beat: 30%
- PVCs: 4%
- PAC: 4%
- RAH: 9%
- RVH: 11%
- RBBB: 11%
- Anterior Fascicular Block: 11%
- 2nd Degree AV Block: 11%
- Flipped Biphasic P waves: 2%
- Atrial Fibrillation: 2%
- Long QRS Corrected: 2%

**Seattle Criteria Denoted Abnormal Breakdown**

- T wave changes (2 Leads) (Not III, aVR, V1): 49%
- T wave changes (Continuous): 12%
- Intraventricular Conduction Delay (QRS >140ms): 2%
- Long QTC (>470/480ms): 2%
- Atrial Fibrillation: 12%
- Left Axis Deviation: 2%
- PVCs >2 per 10s: 2%
- Left Atrial Enlargement: 2%
Combined high risk sports (men’s basketball, football, and soccer) accounted for:

- N/S Twave Changes (2 leads) (Not III, aVR, V1): 86%
- N/S Twave Changes (Consecutive): 60%
- LVH: 76%
- L Axis Deviation: 67%
- LAE: 100%
- PVCs >2 Of Abnormal Seattle Criteria: 100%
- Of Abnormal Seattle Criteria: 76%
- ECHO: 63%
- All Findings (No pathology and SA): 69%

High risk sport analysis.
**ECHOS**

**COST ANALYSIS**

ECHOs as a percent of athletes screened and Seattle abnormal ECGs:

- % of ABN Seattle: 32%
- % of Athletes: 7.25%

- Targeted screening cost $70,080 over 10 years
  - $60 per ECG*
  - $600 per ECHO*
- Screening the masses of rostered student-athletes would have cost $768,500
  - $445,500 for ECGs
  - $323,000 for ECHOs**

- No students were subsequently disqualified from sport participation

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*Cost average for Southwest VA region

**Given a similar ratio of 7% of athletes
### MOVING FORWARD

- Potential for translation to Division II/III and High School levels

- **TEXAS:**
  - Bills 767/76
  - Submitted in 2013-2015 and 2018 requesting mandatory ECGs in high school athletes
  - “A school district must...also have administer to the student an electrocardiogram or echocardiogram before [student is]...allowed to participate in the activity”
  - Bill 767 stopped in the Senate in 2015

- **FLORIDA:**
  - Bill HB 4703: Heart Screening for Low Income Florida Student Athletes
  - Submitted February 2019

- **NORTH CAROLINA:**
  - Bill submitted 3/21/19
  - “An act to establish a joint legislative task force on sudden cardiac arrest in student athletes”

### COST BREAKDOWN 2007-2017

<table>
<thead>
<tr>
<th></th>
<th>MASS SCREENING OF TEXAS HS ATHLETES</th>
<th>TARGETED SCREENING OF TEXAS HS ATHLETES</th>
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<tbody>
<tr>
<td>ECG</td>
<td>$119,820,975.00</td>
<td>$40,445,985.00</td>
</tr>
<tr>
<td>ECHO (7%)</td>
<td>$83,874,682.50</td>
<td>$28,312,189.50</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$203,695,657.50</td>
<td>$68,758,174.50</td>
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</table>

*66% Cost Reduction

*Divided by 4 to determine rough estimate of freshman undergoing screening

Data pulled from the National Federation of State High School Association Participation Database

### 2017-2018 Season

- UNITED STATES: 7,980,886 High School Athletes
- TEXAS: 824,619 High School Student Athletes (10.3%)
CONCLUSION

– ECGs cannot identify all conditions associated with SCD but they can provide invaluable information in addition to the athlete’s PPE

– The current strategy at Virginia Tech enables a streamlined process in screening and identifying high-risk athletes while diminishing unnecessary exams to the masses

– Analysis showed while 516 ECGs were initially flagged for findings, only 43 ECGs were determined high risk and 7% (48) of athletes underwent further testing with an ECHO with no student being disqualified

– Targeted screening led to a 91% reduction in cost or a savings of $698,441

– The success of including ECG screenings for collegiate athletes depends on athlete populations and the availability of resources which enable the identification of high risk athletes, screening, and examining the results of the ECGs

– Targeted PPE utilizing supplemental ECGs provides an opportunity for programs to identify high-risk populations for cardiac abnormalities that may predispose them to SCD that is both cost effective and life saving
QUESTIONS?
REFERENCES


Presentation of SCD

- In many cases there are NO warning signs