ECG Screening for the Prevention of Sudden Cardiac Death: Is it Ready for Primetime?

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No Disclosures
Normal or abnormal?
Population

316 million: US population (2013)
85 million: 20 and under approximately*
60 million: 12 – 25 years old**
10 million: competitive athletes**
500,000: intercollegiate athletes**
5,000: professional athletes**
4.2 million: births/year*

*2010 census data **Maron, Circ 2014

When to Screen

Screening program are most effective if:

1. preclinical prevalence is sufficiently high in the screened population
2. a highly discriminatory screening test is available
3. the disease or disorder is serious
4. treatment while asymptomatic decreases morbidity and mortality more than treatment after symptoms develop

Hennekens, Epidemiology in Medicine 1987

ECG - Feasibility

- Portable
- Relatively easy to obtain
- Low cost (?)
- Able to detect disease state
**ECG - Limitations**

- Consistency
- Reproducibility
- Filtering
  - Low-pass filter limits high freq. noise but reduces R-wave amplitude
  - High-pass filter limits baseline wander but alters J-point and ST segment
- Interobserver variability
- Lack of normative data
  - Age, gender, ethnic and athletic norms
  - Intervals (QTc averaging)
  - Amplitudes
- Lack of prognostic criteria

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**Prevalence of SCD**

- General pediatric/young population
  - 6.4 Atkins, Circ 2009
  - 3.6 Meyer, Circ 2012
  - 3.3 Bardai, JACC 2011
  - 1.7 Chugh, HRI 2009
- Athletes
  - 3.6 Corrado, JAMA 2006 (pre-ECG screening)
  - 0.4 Corrado, JAMA 2006 (post-ECG screening)
  - 2.3 Harmon, Circ 2011
  - 1.2 Maron, JACC 2014

Deaths/100,000

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**Causes of sudden death in young athlete**
What can we detect?

- HCM (26%)
- LVH (8%)
- ARVC (2 – 4%)
- DCM (2 – 4%)
- LQTS (1 – 2%)
- Myocarditis (1 – 2%)
- WPW (?)
- Brugada (?)

40 - 50%

Incidence of SCD in young - Ontario

- Centralized database
  - coroners investigate all deaths that are “sudden, unexpected or from unnatural causes”
- Time period: 2005-2009
- 116 cases
  - excluded known infectious issues, significant comorbidities, drug overdoses and drowning or automobile accidents
- SCD rate: 0.78 per 100,000

Pilmer, Heart Rhythm 2014

Incidence of SCD in young - Ontario

- Cause of death
  - Myocarditis 25%
  - ARVC 16% (another 9% listed as "possible" ARVC)
  - HCM 14%
  - Other myocardial disease 16%
  - Aortic dissection 5%
  - ALCA 4%
- Activity
  - sleep 41%
  - normal ADL 41%
  - Moderate or vigorous activity was seen in only 16%

Pilmer, Heart Rhythm 2014
Assessment of the 12-Lead ECG as a Screening Test for Detection of Cardiovascular Disease in Healthy General Populations of Young People (12-25 Years of Age) - A Scientific Statement From the American Heart Association and the American College of Cardiology

Causes of Death in Young People Annually in the US, Including NCAA Athletes

Who should be screened?

A. Newborns
B. All “children” (21 and under)
C. Youth 12 - 25
D. Athletes 12 – 25
E. Athletes identified by screening H&P
F. No one
Mortality Rates in NCAA Athletes Compared With the General Population

Maron, JACC, 2014

Current ECG Screening Criteria

- European Society of Cardiology (2010)
- Seattle (International) Criteria (2013)
- Refined Criteria (2014)

ESC 2010

Recommendations for Interpretation of 12-lead electrocardiogram

Corrado, European Heart Journal 2010

Table 1: Classification of abnormalities of the athlete electrocardiogram
Early Repolarization

Normal v ARVC

Pathologic LVH
Seattle Criteria

• Goal
  – focus on athlete
  – individual who engages in regular exercise or training for sport or general fitness, typically with goal of improving performance

• Specific for age group 14-35 years
• Goal to differentiate normal athlete ECG changes from abnormal conditions (training resource)
Refined Criteria

Comparison of Electrocardiographic Criteria for the Detection of Cardiac Abnormalities in Elite Black and White Athletes

Nabed Sheikh, MBACP, Michael Popeliski, MBACP, Saqib Qureshi, MBACP, Abboo Zaheer, MBACP; Sabita Giri, MBACP, Paolo Enrico Adamo, MD, Francois Card, PhD; Pelin Arica, PhD; Matthew Wilson, PhD, Palomy Arica, MD, William McKenna, MD, DSc, FESC; Sanjay Munna, MD, FRCP, FESC (UK)

Sheikh, Circulation, 2014

Refined Criteria

- 2000 – 2011 “elite athletes” evaluated
- 1208 black athletes
- 4297 white athletes
- 103 young athletes with HCM (IVS ≥ 1.5 cm)
- Evaluated by history, examination, 12-lead ECG, and further investigations as appropriate
- ECGs retrospectively analyzed according to the ESC, Seattle, and proposed refined criteria

Sheikh, Circulation, 2014
**ECG Criteria Stats**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Black Athletes (n=50)</th>
<th>White Athletes (n=500)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>75.0</td>
<td>80.0</td>
</tr>
<tr>
<td>Specificity</td>
<td>75.1</td>
<td>80.0</td>
</tr>
<tr>
<td>Positive Predictive Value</td>
<td>84.3</td>
<td>94.1</td>
</tr>
<tr>
<td>Negative Predictive Value</td>
<td>89.2</td>
<td>96.3</td>
</tr>
<tr>
<td>False Positive Rate</td>
<td>15.7</td>
<td>16.0</td>
</tr>
<tr>
<td>False Negative Rate</td>
<td>15.7</td>
<td>16.0</td>
</tr>
</tbody>
</table>

- High false positive in black athletes (all criteria)
- Refined criteria lower false positive rate

**ECG Screening Criteria Comparison**

- Refined criteria significantly reduces the number of false-positive ECGs in both elite black athletes and white athletes without compromising sensitivity
- Coupled with appropriate training of physicians in ECG interpretation, refinement of ECG screening criteria would minimize the risk of an erroneous diagnosis in black athletes and lead to substantial savings from unnecessary investigations in both cohorts
Electrocardiogram Screening for Disorders That Cause Sudden Cardiac Death in Asymptomatic Children: A Meta-analysis

Rodday, Pediatrics 2012

- Focused on HCM, LQTS, and WPW
  - most common disorders potentially detectable by ECG among children
- Systematic review
  - searched the Medline database (1950 - 2010)
  - combined keywords and Medical Subject Heading terms: HCM, LQTS, WPW, SCD, ECG, echocardiography, sensitivity, specificity
- 6954 titles and abstracts screened for eligibility
- 396 articles selected
- 30 articles met eligibility criteria

Disease Prevalence

<table>
<thead>
<tr>
<th>Disease</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCM</td>
<td>1%</td>
</tr>
<tr>
<td>LQTS</td>
<td>1%</td>
</tr>
<tr>
<td>WPW</td>
<td>1%</td>
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</tbody>
</table>

Impact of Disease Prevalence

The Impact on Positive Predictive Value (PPV) as Prevalence Changes, for a test with 99% Sensitivity and 99% Specificity

<table>
<thead>
<tr>
<th>Prevalence</th>
<th>PPV (99%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>10%</td>
<td>100%</td>
</tr>
<tr>
<td>100%</td>
<td>100%</td>
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<td>99%</td>
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<td>98%</td>
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<td>97%</td>
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</tbody>
</table>
ECG Screening Meta-analysis
Illustrative point where sensitivity and specificity are equally weighted (maximal accuracy)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Prevalence/100,000</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
<th># false positive screened out</th>
<th># false negative/100,000 screened</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCM</td>
<td>45</td>
<td>0.85</td>
<td>0.85</td>
<td>1/400</td>
<td>0.99</td>
<td>3624</td>
<td>399</td>
</tr>
<tr>
<td>LQTS</td>
<td>7</td>
<td>0.86</td>
<td>0.86</td>
<td>1/2324</td>
<td>0.99</td>
<td>16,592</td>
<td>2323</td>
</tr>
<tr>
<td>WPW</td>
<td>136</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>735</td>
<td>0</td>
</tr>
</tbody>
</table>

* Prevalence based on meta-analysis

Rodday, Pediatrics 2012

How long is too long?

Post pubescent QTc (msec)
A. Male > 440, Female > 450
B. Male > 450, Female > 460
C. Male > 460, Female > 470
D. Male > 470, Female > 480

Accuracy QTc calculation

- Study to determine accuracy of QTc interpretation
- 2 LQTS pts and 2 healthy females
- 902 physicians (12 countries)
  - 25 world-renowned QT experts
  - 106 arrhythmia specialists
  - 329 cardiologists
  - 442 noncardiologists

Viskin, HRJ 2005
Accuracy QTc interpretation

- Correct classification ("long" or "normal")
  - 96% of QT experts
  - 62% of arrhythmia specialists
  - <25% of cardiologists and non-cardiologists
- Intra-observer agreement (kappa co-efficient)
  - 0.82 for QT experts
  - 0.44 for arrhythmia specialists
  - <0.3 for cardiologists and non-cardiologists

"Most physicians, including many cardiologists, cannot accurately calculate a QTc and cannot correctly identify a long QT."
What is LVH/HCM?

- RaVL > 9 mm (F), > 11 mm (M)
- RaVL + SV3 > 20 mm (F), > 25 mm (M)
- Sokolow-Lyon criteria: SV1 + RV5 OR RV6 (whichever is taller) > 35 mm (age >35)
- Romhilt-Estes criteria: Points are scored for QRS voltage, the presence of LAE, typical repolarization abnormalities in the absence of digitalis and a few other findings. The combination of LAE and typical repolarization abnormalities (score > 5 points) will suffice for the diagnosis of LVH, even when voltage criteria are not met.
- RV6 > RV5 (usually occurs with dilated LV)

First exclude anterior MI and establish that the R waves are roan tall in V5 and > 6 mm tall in V6 before using this criterion.

ECG Screening in Athletes

- Pelliccia, Circ 2000

10% of those classified as having “abnormal” LVH were deemed to have cardiomyopathy.
Who should read screening EKGs?

A. Pediatric cardiologist  
B. Pediatric electrophysiologist  
C. Pediatricians  
D. Specially trained health care providers (allied health professionals, nurses, medical assistants, technicians...)

3/15/2019
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ECG readers

- Pediatric cardiologists: 2,040 (2009 ACC survey)
- Pediatric electrophysiologist: 180 (8.8% of pediatric cardiologist) 2011 AHA newsletter
  - 41,700 ECGs/pediatric cardiologist
  - 472,000 ECGs/pediatric EP

Screening ECG time commitment

- Assumptions to read all ECGs in 20 and under population in US
  - Two minutes/EKG for Pediatric Cardiologist
    - 173 - 8 hour days
  - One minute/EKG for Pediatric Electrophysiologist
    - 983 - 8 hour days
Should a patient/family be allowed to refuse a screening ECG?

A. Yes  
B. No

ECG testing may not correctly determine whether your child is at risk for sudden cardiac death and may result in inappropriate restriction from sports participation.
Who should bear the cost, or share in the cost?

A. Federal government  
B. State government  
C. Insurance companies  
D. Individuals

Who is notified of abnormal ECG?

A. Family  
B. Pediatrician  
C. School/Screening Facility

Who should assume the liability of the misinterpreted ECG?

A. Government  
B. Individual reading ECG  
C. Individual over reading ECG  
D. Family/patient
**Conclusion - When to Screen**

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Hennekens, Epidemiology in Medicine 1987

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**Conclusion**

- ECG consistency can be improved
- New criteria will improve specificity of ECG during screening and reduce false positive rates
- Age, gender, race specific ECG criteria will improve sensitivity and specificity
- Cost implications need to be addressed
- ECG readers need to be identified (computers?)

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**Questions**