Sudden Cardiac Arrest in Athletes: Can We Prevent Sudden Death?

David Berkson, MD, FAAFP
Department of Family, Community, and Preventive Medicine
Heart conditions lead to death

- 16 year-old girl was cross-country runner  
  08/17/06  
  Shadvina Leavell

- 17 year-old died from HCM  
  02/20/03  
  Ryan Boslet
Sudden Cardiac Death

- The catastrophic death of a young athlete stimulates debate on appropriate preparticipation screening and emergency planning at athletic events.
Goals

1) Review SCD in young athletes
2) Discuss the challenges and limitations of CV screening in athletes
3) Examine the potential value and controversies of ECG screening in athletes
Sudden Cardiac Death

• Sudden cardiac arrest (SCA) is the leading cause of death in young athletes – accounting for 75% of all deaths

Maron; Am Heart Assoc 2006
Incidence of SCD

- Traditional estimates limited by lack of mandatory reporting system and likely underestimate the true incidence of SCD
  - High school: 1:100,000 to 1:200,000
    - Van Camp; Med Sci Sports Exerc 1995
    - Maron; JAMA 1996
  - College athletes: 1:65,000 to 1:70,000
    - Van Camp; Med Sci Sports Exerc 1995
    - Drezner; Med Sci Sports Exerc 2005
Incidence of SCD

- **Sudden Death in Young Athletes Registry**
  - Maron; *Am Heart Assoc* 2006
  - 1,463 cases (organized athletics only)
  - >90% in males
  - Approx. 115 deaths per year
  - 1 death every 3 days in the U.S.

- **Calculated incidence of SCD:**
  - 5 million high school athletes
  - 500,000 college athletes
  - = 1:50,000
SCD in Children & Adolescents

- An estimated 7,000-14,000+ children and infants die annually from SCD
- Heart Rhythm Society: Press Release; May 21, 2004
Hank Gathers

December 19, 1989

March 4, 1990
Etiology of SCD

- <35 yo = congenital cardiac abnormalities
- >35 yo = CAD causes over 75% of SCD in older athletes
Cardiovascular Causes of Sudden Death

Combined prevalence of these cardiac diseases in the general athletic population is 0.3% (or 3 in 1,000)

From the Minneapolis Heart Foundation Registry  AHA
Scientific Statement: 2007
Hypertrophic Cardiomyopathy

- Leading cause of SCD (approx. 1/3 cases)
- Prevalence 1:500 general population
- Autosomal-dominant with variable expression
- >200 mutations in 10 genes coding for cardiac sarcomeric proteins Binder; NEJM 2005
- Disorganized cellular architecture

Maron; Circulation 1995
Hypertrophic Cardiomyopathy

**History:**

- Most athletes with HCM have no symptoms
  - Only 21% of athletes who died from HCM had premonitory signs or symptoms of CV disease
  - ie. chest pain, dyspnea, lightheadedness, syncope
  - Maron; *JAMA* 1996

**Physical:**

- Most athletes with HCM have no heart murmur
  - Only 25% of patients with HCM have the type (obstructive) which causes a heart murmur
  - Maron; *Lancet* 1997
Diagnosis of HCM: EKG

Electrocardiogram (EKG):

- Abnormal in 90-95% pts with HCM
  - Deep, broad Q-waves
  - Huge QRS voltage
  - Shoulder-shaped ST elevation
  - ST depression
  - Giant negative T-waves

- Maron; *Circulation* 1982
- Maron; *JAMA* 2002
- Montgomery; *Am J Cardiol* 2005

Binder; *NEJM* 2005
Diagnosis of HCM: Echo

Echocardiogram

- Asymmetric LV hypertrophy (*sine qua non*)
  - Increased LV wall thickness \( \geq 16\text{mm} \) (Normal \( \leq 12\text{mm} \))
  - Septal-free wall ratio > 1.3
  - Non-dilated LV
  - Diastolic dysfunction (impaired filling)

Maron; *Circulation* 1995

Binder; *NEJM* 2005
Athletic Heart Syndrome

- Normal physiologic and morphologic adaptations to exercise
- Increased resting vagal tone
- Physiologic hypertrophy
Normal vs. Abnormal Hypertrophy

Maron; Circulation 1995
Other Causes of SCD

- Aortic rupture/Marfan’s syndrome
- Aortic valve stenosis
- Arrhythmogenic right ventricular cardiomyopathy
- Autopsy-negative sudden unexplained death
- Brugada syndrome
- Coronary artery anomalies
- Coronary artery disease
- Drugs
- Idiopathic ventricular fibrillation
- Long QT syndrome
- LV non-compaction syndrome
- Mitral valve prolapse
- Myocarditis/Dilated cardiomyopathy
- Wolff-Parkinson-White syndrome
Long QT Syndrome

- Abnormality in the heart’s electrical system, specifically during cardiac repolarization
- Five known genetic abnormalities involving potassium and sodium ion channels
- Most arrhythmias triggered by emotional or physical stress
QTc = QT/√RR

QTc > 460ms (95% chance patient has LQTS)
**Long QT Syndrome**

SYNCOPE *is NOT* Benign

## Triggers and Outcomes

<table>
<thead>
<tr>
<th>LQT Type</th>
<th>Trigger</th>
<th>Outcome</th>
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<tbody>
<tr>
<td>LQT1</td>
<td>Emotion, Exercise, Swimming</td>
<td>Many syncopes, SCD</td>
</tr>
<tr>
<td>LQT2</td>
<td>Emotion, Exercise, Auditory</td>
<td>Many syncopes, SCD</td>
</tr>
<tr>
<td>LQT3</td>
<td>Sleep</td>
<td>Few syncopes, SCD first event</td>
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Preparticipation Evaluation (PPE)

- 4th edition Monograph
- Endorsed by 6 national organizations
  - AAFP, AAP, ACSM, AMSSM, AOSSM, AOASM
- Provides a comprehensive history and physical form
Sports PPE: Purpose of screening

1. Promote athlete’s health and safety
2. Identify pre-existing conditions that predispose to injury
3. Detect life-threatening conditions that predispose to sudden death
4. Satisfy legal or administrative needs
PPE – Concerns & Criticisms

- No standardized format
- Requirements vary widely by state and institution
- Multiple healthcare professionals other than physicians allowed to perform PPE
- Screening for rare CV abnormalities
- Limited outcomes-based research that PPE is effective in preventing or detecting athletes at risk for catastrophic events
Cardiovascular Disease in Athletes

• Ultimate objective of preparticipation screening of athletes is the detection of ‘silent’ CV abnormalities that can lead to SCD

Maron, 36th Bethesda Conference; J Am Coll Cardiol 2005
Most appropriate CV screening method?

1) Basic history and physical exam
2) Expanded hx and phys guided by a comprehensive PPE form
3) Hx and phys + 12-lead ECG
4) ECG + Echo
5) No additional screening needed
CV Screening Recommendations

American Heart Association 1996 & 2007

- Comprehensive screening H&P before participation in high school and collegiate sports
- Comprehensive screen repeated every 2 years for high school athletes
- Annual update with interim history, problem-focused eval of new illnesses or injuries, BP check
- Standardized questionnaire
History: CV Screening

- Exertional syncope or lightheadedness
- Exertional chest pain/pressure
- Dyspnea or fatigue with mild exertion or less than expected activity
- Palpitations or irregular heart beat
- PMHx: heart murmur, HTN, CAD risk factors, illicit drugs, ergogenic aids
- FamHx: premature death or CV disease <50 y/o, HCM, Marfan’s, long QT, SIDS
Physical Exam: CV Screening

- Blood pressure
- Palpation of radial and femoral artery pulses
- Recognition of Marfan’s physical stigmata
- Cardiac auscultation in quiet environment
  - Supine and standing
  - Valsalva and/or squat → stand if murmur detected
Meeting the Screening Standard?

Glover; Circulation 2006 – State data

- 81% of states have adequate questionnaires (>9 of 12 AHA recommended elements)
- 2% of states have inadequate questionnaires (<4 of 12 AHA recommended elements)
- 35% of states permit chiropractors and naturopathic practitioners to screen athletes
Meeting the Screening Standard?

Pfister, Puffer, Maron; JAMA 2000 – NCAA data

• Only 26% of all institutions used at least 9 of the AHA recommended screening items

• Many PPE forms did not include relevant and important screening items
PPE Limitations

Maron; *JAMA* 1996

- 134 athletes with SCD
- 115 had PPE
- Only 18% had CV symptoms in 36 months preceding death
- Only 4 (3%) suspected of CV disease and 1 (0.9%) diagnosed correctly on PPE
Screening for a needle in a haystack?

www.jolyon.co.uk
Can we do better?

Noninvasive CV Screening Tests

- Added value of ECG and/or Echo in addition to screening hx and exam?
- Concern for cost and false-positives in population with low frequency of disease
- Studies limited by small sample size, variable study design, and criteria for “abnormal”
- Discordance between U.S. and European studies
Screening ECG

Maron; J Am Coll Cardiol 1987

- 501 intercollegiate athletes (hx, PE, ECG)
- 102 (20%) positive screens
- 65 (13%) positive by ECG alone
  - Deep T wave inversions, marked LAD, Qs, deep S
- Echo 90 →
  - 72 normal (15% false-positive)
  - 14 mild MVP (1 with cardiac sx’s of CP, syncope)
  - 3 with mild septal hypertrophy
- Authors’ conclusions: No cases of lethal CVD found. No added value of ECG.
Screening ECG

Fuller; *Med Sci Sports Exerc* 1997

- ECG 5,615 high school athletes
- 146 (2.6%) positive ECG screen
- Echo normal 130 (2.3% false positive)
- 16 positive ECG and not approved for athletics
  - 6 preexcitation, 4 RBBB, 1 chronic SVT
- No definitive cases of lethal CVD found.
- ECG more effective than hx or PE in detecting CV abnormalities that require further testing.
Screening Echo

Lewis; *Am J Cardiol* 1989
- Echo 265 college athletes, 99% black
- 234 (88%) normal
- 30 (11%) had MVP, 1 small ASD
- 29 (11%) had ventricular septum ≥ 13mm
- No definitive HCM

Weidenbener; *Clin J Sport Med* 1995
- Limited Echo (single view parasternal long- and short-axis)
- 2,997 high school athletes
- 64 abnl (MVP and bicuspid aortic valve most common)
- No athlete barred from competition
Noninvasive CV Screening Tests

AHA Recommendations

1996:
• No role for routine use of ECG or Echo
• Low prevalence of disease
• False-positive rate
• Poor cost-efficiency

2007:
• Not practical for mass universal screening
• Size of athlete cohort
• Low prevalence of CV dz
• Limited resources
• Absence of physician cadre prepared to interpret ECGs
The Italian Perspective

National Pre-Participation Screening Program

• Mandated by law 12-lead ECG (in addition to hx, famhx, and PE) for all persons age 12-35 involved in organized and competitive athletics (since 1982)
Italian Screening Program – Part 1

Corrado; *N Engl J Med* 1998

- Compared SCD in athletes vs. nonathletes age 12-35 from 1979-1996
- 33,735 young athletes screened (hx, famhx, PE, + ECG)
- 269 sudden deaths (49 athletes)
- ARVC (22.4%), ASCAD (18.4%) and anomalous origin of coronary arteries (12.2%) were the most common causes of sudden death
Cardiovascular Causes of Sudden Death in the Athlete (Veneto Region, Italy 1979-1996)

- ARVC 24%
- Obstructive CAD 18%
- Other 18%
- Hypertrophic Cardiomyopathy 2%
- Mitral Valve Prolapse 11%
- Myocarditis 9%
- Conduction System Pathology 7%
- Congenital Coronary Anomaly 11%

Italian Screening Program – Part 1

- HCM was detected in 22 athletes and accounted for 3.5% of the disqualifications.
- Death from HCM: 1 athlete (2%) vs. 16 nonathletes (7.3%).
- HCM detected in 22 athletes (0.07% or 1:1500) – none died during follow-up.
- The calculated sudden death rate was 1.6/100,000 athletes.
- Authors’ conclusions: 2-lead ECG in addition to hx and PE successfully reduced SCD from HCM.
Italian Screening Program – Part 2

Corrado; *JAMA* 2006

- Screened 42,386 athletes age 12-35 over 25 year period 1979-2004 (hx, famhx, PE, + ECG)
- 10-fold reduction in incidence of SCD in young competitive athletes
- 90% reduction in SCD due to cardiomyopathies
- 9% total ECG’s positive; 7% false-positive
  - Could mean 700,000 false postives/yr in US
- 2% of athletes ultimately disqualified
Annual Incidence Rates - SCD

Corrado, D. et al. JAMA 2006;296:1593-1601
Cardiovascular conditions causing disqualification from competitive sports in 879 athletes over 2 consecutive screening periods (1982-1992 and 1993-2004) at the Center for Sports Medicine in Padua, Italy.

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<tr>
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</thead>
<tbody>
<tr>
<td>Rhythm and conduction abnormalities</td>
<td>345 (39)</td>
<td>166 (36)</td>
<td>179 (42.2)</td>
<td>0.13</td>
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<tr>
<td>- ventricular arrhythmias</td>
<td>173 (19.6)</td>
<td>81 (18)</td>
<td>92 (21.6)</td>
<td>0.20</td>
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<td>- supraventricular arrhythmias</td>
<td>73 (8.3)</td>
<td>39 (8.6)</td>
<td>34 (8.0)</td>
<td>0.56</td>
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<td>- WPW Syndrome</td>
<td>55 (6.3)</td>
<td>29 (6.3)</td>
<td>26 (6.1)</td>
<td>0.88</td>
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<td>- LBBB or RBBB &amp; LAD</td>
<td>26 (3.0)</td>
<td>8 (1.7)</td>
<td>18 (4.2)</td>
<td>0.10</td>
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<td>- second Degree AV Block</td>
<td>13 (1.5)</td>
<td>7 (1.5)</td>
<td>6 (1.4)</td>
<td>0.89</td>
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<td>- long QT Syndrome</td>
<td>5 (0.6)</td>
<td>2 (0.4)</td>
<td>3 (0.7)</td>
<td>0.93</td>
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<td>Systemic hypertension:</td>
<td>205 (23)</td>
<td>118 (25.9)</td>
<td>87 (20.5)</td>
<td>0.96</td>
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<td>Valvular disease (including MVP):</td>
<td>184 (21)</td>
<td>106 (23.3)</td>
<td>78 (18.4)</td>
<td>0.09</td>
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<td>Cardiomyopathies</td>
<td>60 (6.8)</td>
<td>20 (4.4)</td>
<td>40 (9.4)</td>
<td>0.005</td>
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<td>- hypertrophic</td>
<td>30 (3.4)</td>
<td>14 (3.0)</td>
<td>16 (3.8)</td>
<td>0.50</td>
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<tr>
<td>- arrhythmogenic right ventricular</td>
<td>16 (1.8)</td>
<td>2 (0.4)</td>
<td>14 (3.3)</td>
<td>0.004</td>
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<td>- dilated</td>
<td>14 (1.6)</td>
<td>4 (0.9)</td>
<td>10 (2.4)</td>
<td>0.21</td>
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<tr>
<td>Coronary artery disease</td>
<td>11 (1.3)</td>
<td>2 (0.9)</td>
<td>9 (2.1)</td>
<td>0.05</td>
</tr>
<tr>
<td>Other</td>
<td>74 (8.4)</td>
<td>43 (9.5)</td>
<td>31 (7.3)</td>
<td>0.42</td>
</tr>
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</table>
“Lausanne Recommendations” on Sudden Cardiovascular Death in Sport (2004)

4 elements to preparticipation CV screening:
- Personal hx
- Family hx
- Physical exam
- 12-lead ECG

European Society of Cardiology

Corrado; *Euro Heart J* 2005

- Consensus recommendations for the implementation of a common European screening protocol based on 12-lead ECG in addition to hx and PE.

- Key role of 12-lead ECG in detection of cardiomyopathies and channelopathies.
Screening in U.S. Pro Sports Teams

- NBA: mandatory annual screen of all athletes with ECG and Echo (beginning 2006-2007)
- NFL: 100% of teams screen with ECG
- MLB: 93% of teams screen with ECG
- NHL: 80% of teams screen with ECG

Harris; Annals of Internal Med 2006
FIFA

- Requires ECG & Echo - 2007

Miklos Feher
July 20, 1979 – January 25, 2004
Cost Considerations

AHA Scientific Statement: 2007

- Large-scale ECG screening of 10 million athletes (MS, HS, college) would cost $2 billion
  - Assumes false-positive rate of 15%
- Estimated 1:1000 or 10,000 athletes with detectable abnormalities on ECG
- Cost per detected CV abnormality >$300,000
- Cost per death prevented $3.4 million
Public Health Perspective

Resources for SCD Prevention

• CDC Advisory Committee on Immunization Practices

• Routine vaccination of all matriculating college freshmen with the tetravalent meningococcal conjugate vaccine. Bilukha; MMWR Recomm Rep 2005
  →Prevention of only 2 to 5 deaths each year.
  →Cost per death prevented of $22 to $48 million.

• How many young athlete deaths would be prevented if comparable resources were dedicated to cardiac screening?
Putting Cost in Perspective

- $2 billion - ECG screening of 10 million athletes ($3.4 million per life saved)
- $5 billion – 1 mile stretch of elevated freeway
- $500 million – new NBA basketball arena
- $26 million – bike lanes
- $4 million – parking structure at the zoo
- $∼50 – cost of a single ECG
Where do we go from here?

- Large scale implementation of preparticipation screening ECG in the U.S. presents many cost-feasibility questions:
  - Do we have the infrastructure to support mass, universal ECG screening?
  - Who will pay for and interpret the ECG?
  - What is the cost of investigating false-positives?
  - What are the ECG criteria for defining normal from abnormal?
  - Do the Italian studies apply to a U.S. population?
• Sudden death in young athletes is an relatively infrequent phenomenon accorded high public visibility

• Unsuspected congenital cardiac abnormalities are usually found at postmortem

• Insufficient evidence to support the routine use of EKG to screen for these abnormalities at the present time

Circulation. 2007;115:1643-1655
Conclusions:

• Healthy appearing athletes may harbor silent CV disease that is difficult to identify by history and physical exam

• Do large-scale studies adding ECG to the hx and PE show favorable results in reducing SCD?

• Cost-feasibility issues in the U.S. are real

• Large-scale U.S. research studies are needed

• Alternative screening models to deliver noninvasive CV screening should be considered
Most appropriate CV screening method?

1) Basic history and physical exam
2) Expanded hx and phys guided by a comprehensive PPE form
3) Hx and phys + 12-lead ECG
4) ECG + Echo
5) No additional screening needed
Counterpoint

• ECG/Echo often not “+” or “-”

• Myocardial/CAD not always clearly “present” or “absent” (?
  genetic screening)

• ECG can aid in screening, will prevent some SCD, but many athletes who would
  never have a problem are excluded
Counterpoint

- Cost (financial, psychological) of screening large pops where most abn tests will be "false positive" may be quite large.

- Outcome of disease intervention in asx pts is not as clear as we would like it to be, and all deaths cannot be prevented.
National Registry for AEDs in Sports

- www.AEDSPORTS.com
- Emergency planning
- AED utilization
- Survival following SCA in athletes
Thank You