Heroes with Heart Disease

Why USAF Aircrew Do Not Die from Heart Disease

Right Care Initiative - Virtual University of Best Practices - 23 Feb 2021

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Lt Col, USAF, MC, FS, Master Clinician
Chief Cardiologist, Aeromedical Consultation Service
Surgeon General Aeromedical Cardiology Consultant
Chairman NATO Occupational Cardiology Working Group
FAA Federal Air Surgeon Cardiology Consultant
Associate Professor of Medicine, USU of the Health Sciences

Cardiovascular Disease Background

¬ CVD is the leading cause of global death in men and women
  ¬ 81 listed cause of death on pilots and astronauts in the world.
  ¬ 17.8 million deaths a year,
  ¬ Leading cost of aircraft diversion on Airlines, over 200 a day average cost $38,000

¬ Not a disease of old age
  ¬ 62% of those with CVD are under the age of 65
  ¬ Most common cause of sudden death in Active Duty Military

¬ Modes of presentation
  ¬ Sudden cardiac death
  ¬ Myocardial infarction
  ¬ Ischemic arrhythmias

¬ 50% of those who die do so within 1 hour of symptom onset
  ¬ 25% due to sudden cardiac death

U.S. Air Force Central ECG Library

¬ Serves as a repository of all cardiovascular studies on rated aviators in the USAF, USAFR, and ANG since 1957
  ¬ AFI mandate, all rater aviators (pilots, navigators, flight docs, air battle managers, load masters) for both surveillance and other cardiac studies accomplished for any reason.

¬ Aeromedical disposition and waiver policy
  ¬ 60 yr of aviator data for a specific population
  ¬ Outcomes data and policy change almost monthly
  ¬ Work groups for normal, variant normal, and abnormal
  ¬ FCII = initial pilot training, FCIII = trained asset, FCIV = non-pilot duties

¬ Since the 1950s the library annually receives, interprets, and databases
  ¬ 25,000 ECGs, 250 echocardiograms, 250 treadmill, 175 Holter monitors
  ¬ Numerous CT/MIIs and catheterizations
  ¬ 100% digitized as of 1 Jan 2012!
  ¬ Electronic submission at >200 sites throughout the world.

Evidence Based Aerospace Cardiology

¬ Archive
  ¬ (1.2 million studies)
  ¬ (200,000 annual)

¬ Local Studies
¬ Picture Archive Communication System (PACS) – HL7, DICOM and PDF digital archive

¬ Outside clinic studies *Direct or Download

¬ 3D Echo

Evidence Based MISSION

¬ Knowledge of flight physiology
¬ Clinical knowledge / published data
¬ ACC/AHA Guidelines for Athletes
¬ Analysis of the USAFSAM Database
  ¬ Serial data gathered over decades to study natural history of progression and effect on USAF MILITARY AEROMEDICAL outcomes
International Consensus

Seven countries in North America and Europe. NATO and Partners for Peace Countries.

New partners...
- Army, Navy, Marines, Coast Guard
- FAA, EASA
- NASA, ESA, Boeing, SpaceX

Aerospace Cardiology WORLD EXPERTS

NATO - The Human Factor Medicine Panel
Aviation Cardiology Working Group
- Wg Cdr Joanna D'Arcy (UK) - Chairman
- Lt Col Eddie Davenport (USA) - Chairman
- Dr Gary Gray (Canada)
- Col Dr Olivier Manen (France)
- Lt Col Dr Norbert Guettler (Germany)
- Dr Frank Rieks (Netherlands)
- Maj Denis Bron (Switzerland)
- Maj Dr Thomas Syburra (Switzerland)
- Wg Cdr Edward Nicol (UK)

Aerospace Cardiology

Where we have been...
- Data presented at >10 international conferences
- ASMA, ICASM, ESC, ETS, Nato, NASA, FAA, ESA, NATO, USAA, FAA, ESA
- Early repolarization, CAD, LBBB, CAD with no risk factors
- A-fib return to high performance, CAD return to high performance...

Where we are going...
- Emerging Cardiovascular Imaging
- Emerging Cardiovascular Treatment
- From a consensus to GUIDELINES

International Evidence Based Cardiology

Archives
 (>5 million studies, 3 million aircraft

Disposition

Cardiovascular Effects

Pooling Begins 1-3 +Gz
Grayout 3-4 +Gz
Blackout 4-5 +Gz
Unconsciousness 5-6 +Gz

Incapacitation 3 or more -Gz
Red Out 2.5-3 -Gz
Vision Affected 1-2.5 -Gz
Pooling Begins 0-1 -Gz
Effect of 2, 3, and 4 +Gz on Selected Physiologic Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>+2 Gz</th>
<th>+3 Gz</th>
<th>+4 Gz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Rate</td>
<td>+14 bpm</td>
<td>+35 bpm</td>
<td>+56 bpm</td>
</tr>
<tr>
<td>Stroke Index</td>
<td>-24 ml/stroke/m²</td>
<td>-37 ml/stroke/m²</td>
<td>-49 ml/stroke/m²</td>
</tr>
<tr>
<td>Cardiac Output</td>
<td>-7%</td>
<td>-18%</td>
<td>-22%</td>
</tr>
</tbody>
</table>


Flight Disposition Process

- Determine threshold of acceptable risk
  - <1% / year
- Determine event horizon / timeline
  - 10-20 years
- Determine aeromedical events of concern
  - Symptoms precluding mission completion
  - Consider impact of standard-of-care medical therapy and advances in technology / new tests
  - Apply special considerations (high +Gz, mission duration, single / dual pilot, ejection seat) & treatment effects

Screening for CVD in Aircrew

- Despite better overall health of aviators, CVD still a valid concern
- Autopsy study in 710 commercial pilots
  - Atherosclerosis found in 69%
  - Severe disease in 2.5%
- Review of cardiac events in U.S. aviators
  - MI, angina, and sudden cardiac death over 5-year period
  - Average event rate 0.02%
  - While event rate low, presentation more concerning
  - Myocardial infarction and sudden cardiac death in 82%
  - NO WARNING

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Test with 80% Sensitivity, 90% Specificity

Population 20,000 subjects, 5% prevalence CAD

<table>
<thead>
<tr>
<th></th>
<th>Significant CAD (with abnormal test)</th>
<th>No Significant CAD (with normal test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abnormal Test</td>
<td>800 (TP)</td>
<td>1,900 (FP)</td>
</tr>
<tr>
<td>Normal Test</td>
<td>200 (FN)</td>
<td>17,100 (TN)</td>
</tr>
</tbody>
</table>

PPV = TP/(TP+FP) = 30%
NPV = TN/(TN+FN) = 98%

Bayesian Theory

- 1 CV death every 33 seconds
- Sudden cardiac death is the presenting symptom in 50% of people with heart disease
903 aviators with treadmill, thallium, and cardiac fluoroscopy for coronary artery calcification

Mean age 43.7 yr, mean f/u 11.8 yr

Sensitivity, specificity, positive predictive value, and negative predictive value for moderate or greater CAD (>50%) and severe CAD (>70%)

Average annual event rates at 2/5 yr

For detection of moderate or greater CAD (>50% stenosis)

<table>
<thead>
<tr>
<th>Test</th>
<th>Sens</th>
<th>Spec</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treadmill</td>
<td>54%</td>
<td>49%</td>
<td>16%</td>
<td>86%</td>
</tr>
<tr>
<td>Thallium</td>
<td>55%</td>
<td>62%</td>
<td>21%</td>
<td>89%</td>
</tr>
<tr>
<td>Fluoroscopy</td>
<td>68%</td>
<td>71%</td>
<td>29%</td>
<td>93%</td>
</tr>
</tbody>
</table>

Annual cardiac event rate (cardiac death, first nonfatal MI, or first delayed coronary revascularization) at 5 yr:

<table>
<thead>
<tr>
<th>Test</th>
<th>Abnormal test</th>
<th>Normal test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treadmill</td>
<td>0.5%/yr</td>
<td>0.5%/yr</td>
</tr>
<tr>
<td>Thallium</td>
<td>0.6%/yr</td>
<td>0.5%/yr</td>
</tr>
<tr>
<td>Fluoroscopy</td>
<td>1.3%/yr</td>
<td>0.1%/yr</td>
</tr>
</tbody>
</table>

Coronary Artery Angiography Annual Event Rates

<table>
<thead>
<tr>
<th>Category</th>
<th>Negative</th>
<th>Positive</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>0.66%</td>
<td>1.8%</td>
<td>0.006</td>
</tr>
<tr>
<td>Max Lesion</td>
<td>&lt;50%</td>
<td>&gt;50%</td>
<td>0.80%</td>
</tr>
<tr>
<td></td>
<td>0.007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate</td>
<td>&lt;50</td>
<td>50-120</td>
<td>&gt;120</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>1.1%</td>
<td>3.0%</td>
</tr>
<tr>
<td></td>
<td>0.0002</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CAD in Aviators is DEFINED BY ANATOMY
Detection of Coronary Artery Calcium by Computed Tomography

Calcium scoring simply “adds up” the amount of coronary calcium present on the CT: the more calcium, the higher the score.

Rozanski et al., JACC 2007

<table>
<thead>
<tr>
<th>CAC Score:</th>
<th>0</th>
<th>1-9</th>
<th>10-99</th>
<th>100-399</th>
<th>400-999</th>
<th>&gt;1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>249</td>
<td>51</td>
<td>202</td>
<td>263</td>
<td>212</td>
<td>112</td>
</tr>
<tr>
<td>CD/MI/re-vasc</td>
<td>3</td>
<td>0</td>
<td>6</td>
<td>8</td>
<td>17</td>
<td>12</td>
</tr>
<tr>
<td>Annual event rate</td>
<td>0.45%</td>
<td>0.00%</td>
<td>1.11%</td>
<td>1.14%</td>
<td>3.00%</td>
<td>4.01%</td>
</tr>
</tbody>
</table>

Note: All with a normal Stress test; Annual Event Rates jump to > 20% with a positive CAC AND positive stress test!!!

Comparison of Event Rates

<table>
<thead>
<tr>
<th>Angiography Summed Score</th>
<th>CAC Score (literature)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min CAD (aggregate &lt; 50%):</td>
<td>• CAC 0-9: 0.00% /yr</td>
</tr>
<tr>
<td>Annual Re-eval:</td>
<td>• CAC 10-100: 0.5% to 1.0% /yr</td>
</tr>
<tr>
<td>Mod CAD (aggregate 50-120, no lesion &gt; 70%):</td>
<td>• CAC 101-399: 1.0% to 2.0% /yr</td>
</tr>
<tr>
<td>Annual Re-eval; cath q 5 yr (NEW):</td>
<td>• CAC &gt;400: 3.00% /yr and up</td>
</tr>
<tr>
<td>Sev CAD (aggregate &gt; 120 or lesion &gt; 70%):</td>
<td></td>
</tr>
<tr>
<td>3.0% /yr; DQ = no waiver</td>
<td></td>
</tr>
</tbody>
</table>

Said Another Way…

Outcomes for individuals with CAD are driven by the overall burden of disease

- Invasive assessment: summation of all angiographically visible lesions
- Noninvasive surrogate: Coronary Artery Calcium

Both measures are predictive of future events in aviators with asymptomatic coronary artery disease

Prevalence (%) of Coronary Calcium: U.S. Adults 45 to 84 Years of Age

Go A et al. Circulation 2014;129:e28-e292

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Hazard Ratios (HR) for Coronary Heart Disease Events Associated with Coronary Calcium Scores: U.S. Adults (reference group, coronary artery calcification [CAC]=0 and Framingham Risk Score <10%)

Go A et al. Circulation 2014;129:e28-e292

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Proposed Aviator Cardiovascular Screening Algorithm

What does 60 years of data on 289k aircrew tell us?
Risk Factors associated with severe CAD

- Average BMI 28 kg/m²
- Average HDL 34 mg/dL (0.9 mmol/L) Fasting Glucose 105 mg/dL
- Total Cholesterol average 198 (5.1 mmol/L)
- LDL average 136 (3.5 mmol/L), TG average 140 (1.6 mmol/L)
- Average SBP 132 mmHg
- Family history in 60%
- Average PT test score 85% = good
- NO RISK FACTORS = 2 out of 172 (one had SCD); no coffee or EtOH
- Risk if optimal risk factors = 0.007%

Risk Factors at Diagnosis

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>MODERATE</th>
<th>SEVERE / REVASC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>132</td>
<td></td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>LDL / TG (mg/dL)</td>
<td>136/140</td>
<td></td>
</tr>
<tr>
<td>HDL (mg/dL)</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Family History</td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td>PT test score</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>Tobacco (current)</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td>Alcohol – 5/wk</td>
<td>6%</td>
<td>20%</td>
</tr>
<tr>
<td>Coffee – 5/wk</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Risk Factors

- Coffee and Alcohol?
  - Positive CAD rarely did both daily
  - Daily alcohol and coffee – ZERO revascularization if mild or moderate CAD
  - If started after revascularization then associated with normal/improved 3/5 year cath, significant increase in HDL
  - Proven benefits of both coffee and Alcohol, only in moderation, with rather large increases in morbidity with excessive use. Exercise is much better...

- Exercise / Diet – to get BMI<25 kg/m2 and HDL>50
  - Exercise plus low HDL = some “over exercise” – higher risk CAD!
  - Low HDL raised by DIET and Exercise = decrease repeat revasc
  - NO consistent evidence of benefit raising HDL pharmacologically
  - More Vigorous 75-150 min/week is best

Don’t Die from CAD

- Risk Factor Control
  - Exercise
  - Coffee
  - Alcohol
  - STRESS
    - Financial – what are we working for?
    - Emotional – Joy, Integrity, Grace – 50% reduction in all cause mortality

Your Story...

- BMI 25
- 2 cups coffee
- 1 glass of wine
- 30 min of Daily Exercise

Questions?

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Aeromedical Cardiology Consultant
Chairman, U.S. Air Force occupational Cardiology
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References available on request.
Need a source for this image, even though it was previously approved.
KAWANO, ELAINE S GS-11 USAF AFMC USAFSAM/FHS, 2/6/2017