Screening and Imaging for Coronary Artery Disease in Aircrew

NATO Aviation Cardiology Working Group (RTG HFM-251)

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Chair, NATO Aviation Cardiology Working Group
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Ed Nicol

I have no financial relationships to disclose

I will not discuss off-label use and or investigational use in my presentation
Coronary Artery Disease and Aircrew

The post mortem examination revealed evidence of a myocardial infarction (heart attack). The pathological evidence suggests that the sequence of events was initiated by this myocardial infarction which probably occurred in the early morning of the day of the accident. Although this was not fatal at the time it is believed that the infarction extended while the pilot was initiating his second take off and that he became incapacitated. This led to the aircraft deviating to the left of the runway and subsequently crashing. The pilot had utilised the full shoulder harness fitted to the aircraft and suffered only minor injuries as a result of the impact.
NATO HFM-251
proposed guidelines
Detecting Plaque before the accident

• Screening for CAD
  – First line screening
  – Enhanced screening
  – Second line investigations
Military Guidelines

- US – early use of CACS and then MPS or ICA
- UK – ECG then ETT, then usually CTCA
- Germany – ETT as a baseline, early use of CTCA
- NDL – ETT as a baseline, considering CTCA routinely

- Civil approaches also variable and counter-intuitive

- Evidence in aircrew is lacking – what is the correct approach?
Risk Calculators

- Usually used in conjunction with 12-lead ECG
- Many available – Framingham, PROCAM, AGLA, Qrisk, Reynolds
- Limitations include age cut-offs, geographical population specific
- 10 year event rate – based on hard events (MI/CVA/death)
- FHx and possibly hsCRP add value

- Reynolds is probably the most appropriate risk calculator for aircrew
INITIAL SCREENING
All aircrew ≥ 40 yrs
Calculate 10-yr CAD Risk using an appropriate risk calculator

> 10% risk
Lifestyle Management as appropriate to decrease CV Risk

> 10% risk

ENHANCED SCREENING
Cardiac CT – CACS or CTCA (per agency)
± Functional exercise testing
± Vascular imaging – carotid plaque area

Low risk
CACS <100 or CTCA <50% stenosis
Good functional capacity
Carotid imaging normal

Fit for aircrew duties
Risk factor modification for all CACS>0

No stenosis >50%
No functional ischemia

High risk
CACS >100 or CTCA >50% stenosis
Associated risks observed on functional testing or vascular imaging

SECOND LINE INVESTIGATIONS
Anatomic Imaging - ICA or CTCA
Functional testing – stress myocardial function, stress myocardial perfusion imaging (ground while awaiting results)

Stenosis >50% and/or demonstrated functional ischemia

Remain grounded pending agency risk assessment and disposition
Enhanced Screening

• Cardiac CT
  – CACS – indicates atheroma but poor discriminator at individual level
  – CTCA gives both true anatomic detail – requires contrast

• ExECG – poor for sig CAD assessment but good for aerobic assessment

• Vascular Imaging – ultrasound carotids/femoral arteries
**Ex ECG**

Test with 60% Sensitivity, 90% Specificity  
Population 20,000 subjects, **5% prevalence CAD**

<table>
<thead>
<tr>
<th></th>
<th>Significant CAD</th>
<th>No Significant CAD</th>
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</thead>
<tbody>
<tr>
<td><strong>Abnormal Test</strong></td>
<td>600 (TP)</td>
<td>1,900 (FP)</td>
</tr>
<tr>
<td><strong>Normal Test</strong></td>
<td>400 (FN)</td>
<td>17,100 (TN)</td>
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</tbody>
</table>

\[ PPV = \frac{TP}{TP+FP} = 24\% \]

\[ NPV = \frac{TN}{TN+FN} = 98\% \]
Low to intermediate likelihood of CAD—role of ExECG?

Estimated likelihood of CAD is 10-29%

- Offer CT calcium scoring
  - If score is 0: investigate other causes of chest pain
  - If score is 1-400: offer 64-slice (or above) CT coronary angiography
  - If score is > 400: follow pathway for 61-90% CAD (page 14)

Significant CAD (box 9)
- Uncertain
  - Offer non-invasive functional testing (box 8)
    - Risk of myocardial ischemia
      - Yes
        - Treat as stable angina
      - No
        - Investigate other causes of chest pain
    - No
      - Investigate other causes of chest pain

Box 8 Non-invasive functional testing
- Offer:
  - MPS with SPECT or stress echocardiography or first-pass contrast-enhanced magnetic resonance (MRI) perfusion or MR imaging for stress-induced wall motion abnormalities
  - Take account of local availability and expertise and the patient’s contraindications and preferences.
  - Use adenosine, dipyridamole or dobutamine as stress agents for MPS with SPECT.
  - Use adenosine or dipyridamole for first-pass contrast-enhanced MRI perfusion.
  - Use exercise or dobutamine for stress echocardiography or MRI imaging for stress-induced wall motion abnormalities.
  - Do not use:
    - MRI coronary angiography for diagnosing stable angina
    - exercise ECG to diagnose or exclude stable angina in people without known CAD.
Enhanced Screening

- ExECG – poor for sig CAD assessment – **should not be used to assess for significant CAD as a sole test**
Coronary Artery Calcification

Stary Classification of Atherosclerotic Plaques

- Normal
- Early
- Lipid rich
- Internal rupture
- Calcified shell
- Calciﬁed plaque
- Vulnerable
- Rupture
- Thrombus
- Myocardial infarction
- Obstructive
- Fatty streaks
- White blood cells
- Red blood cells
- Lipid rich plaque
- Calcium
- Scar
- Platelets and ﬁbrin
- Inflammation and calcification
- Scar development with calcification

Royal Brompton & Hareﬁeld NHS Foundation Trust
Epidemiology

- 10,377 asymptomatic subjects, mean follow-up 5 years
- Calcium score independent predictor and incremental to risk factors

Shaw LJ. Radiology 2003; 228: 826
CACS

- **US**
  - Score <10 – unrestricted

- **UK**
  - <10 not reassuring
  - >100 may be OK

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<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>
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<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/revasc</td>
<td>3</td>
<td>0</td>
<td>6</td>
<td>8</td>
<td>17</td>
<td>12</td>
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<tr>
<td>Annual event rate</td>
<td>0.45%</td>
<td>0.00%</td>
<td><strong>1.11%</strong></td>
<td><strong>1.14%</strong></td>
<td><strong>3.00%</strong></td>
<td><strong>4.01%</strong></td>
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Rozanski, et al JACC 2007
Enhanced Screening

- CACS – indicates atheroma and has strong population level data but risks being a poor discriminator at individual level – data in aircrew?
CT Coronary Angiography vs. Coronary Artery Calcium Scoring for the Occupational Assessment of Military Aircrew

Iain Parsons; Chris Pavitt; Rebecca Chamley; Jo d’Arcy; Ed Nicol

Fig. 1. Figure comparing CT calcium score, CT coronary angiography maximal stenosis, and aggregate stenosis.
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Fig. 2. CT coronary angiography of a pilot with significant LAD stenosis, but a calcium score of 0, confirmed by invasive angiography (see arrows).
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Fig. 1. Figure comparing CT calcium score, CT coronary angiography maximal stenosis, and aggregate stenosis.
Enhanced Screening

- CACS – indicates atheroma but poor discriminator at individual level –
  *If performed in isolation may not predict risk on individual basis*
CTCA
UK NICE CG95 Guidelines 2016

No Ex ECG
No CACS
No PTP assessment

1.3.4.3 Offer 64-slice (or above) CT coronary angiography if:

- clinical assessment (see recommendation 1.3.3.1) indicates typical or atypical anginal chest pain, or
- clinical assessment indicates non-anginal chest pain but 12-lead resting ECG has been done and indicates ST-T changes or Q waves.

[new 2016]
Strengths of CTCA

- Ubiquity – cardiac enabled CT
- Speed vs. ICA/MPS/CMR
- Non-invasive
- Plaque analysis
- Rapidly evolving field
- Potential for functional data
- Low dose
Weaknesses of CTCA

- Volume and Quality
- Heart rate and HRV limitations
- Calcium
- Radiation
- Access and cost in some nations
CACS from CTCA

Deriving coronary artery calcium scores from CT coronary angiography: a proposed algorithm for evaluating stable chest pain

Christopher W. Pavitt · Katie Harron · Alistair C. Lindsay · Robin Ray · Sayeh Zielke · Daniel Gordon · Michael B. Rubens · Simon P. Padley · Edward D. Nicol

J Am Coll Cardiol Img. 2010;3(4):440-444
Enhanced Screening

- CTCA gives both true anatomic detail – requires contrast - consider as alternative/addition to CACS
Second line investigation

- Anatomic – CTCA or invasive angiography

Before

- Functional imaging
  - Perfusion
  - Wall motion
- Ground whilst investigating

- A normal functional scan (without anatomic investigation) will not tell you if there is aeromedically significant coronary artery disease
Addendum to Clinical Guideline (CG95), Chest pain of recent onset: Assessment and diagnosis

Clinical Guideline Addendum: CG95.1
Methods, evidence and recommendations
April 2016

National Institute for Health and Care Excellence
Draft for consultation

1.3.5.1 Offer non-invasive functional imaging (see section 1.3.6) for myocardial ischaemia if 64-slice (or above) CT coronary angiography has shown CAD of uncertain functional significance or is nondiagnostic. [2016]
Summary

- Appropriate risk calculators should be used
- ExECG should not be used to assess for significant CAD as a sole test
- CACS alone may miss important CAD
- CTCA gives true anatomic detail non-invasively
- Anatomic imaging should be performed prior to functional imaging
QUESTIONS?
UK National Radiation Survey

- Maintaining standards and dose

1 National Institute for Health and Care Excellence. New generation cardiac CT scanners (Aquilion ONE, Brilliance iCT, Discovery CT750 HD and Somatom Definition Flash) for cardiac imaging in people with suspected or known coronary artery disease in whom imaging is difficult with earlier generation CT scanners 2012