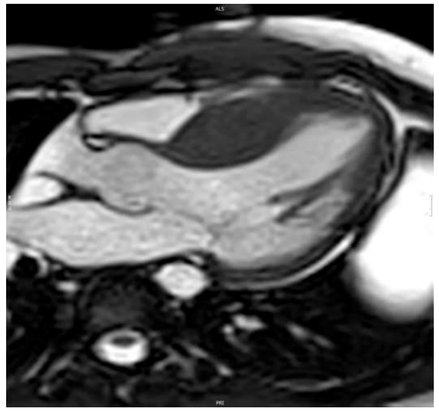
Advanced cross-sectional imaging in refining aircrew risk - the current and emerging role of cardiovascular CT and MRI

Wg Cdr E D Nicol MD MBA FRCP FACC FRAeS
RAF

Chairman, NATO HFM 251 PANEL



Disclosure Information

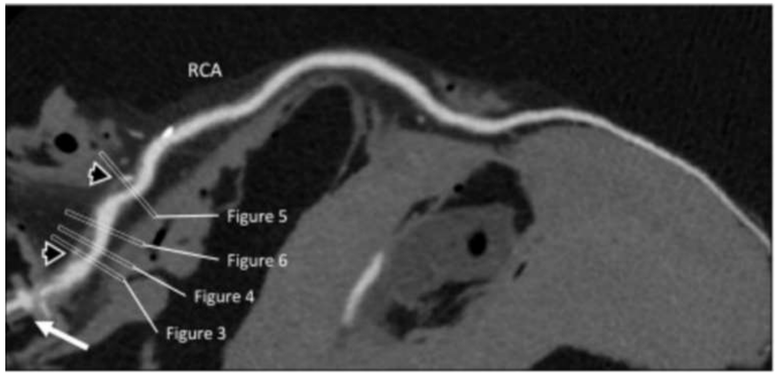
ECAM 2018

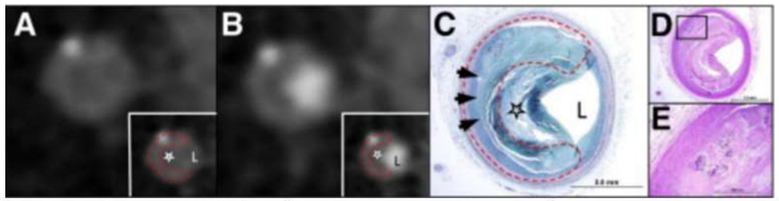
Wg Cdr E. Nicol

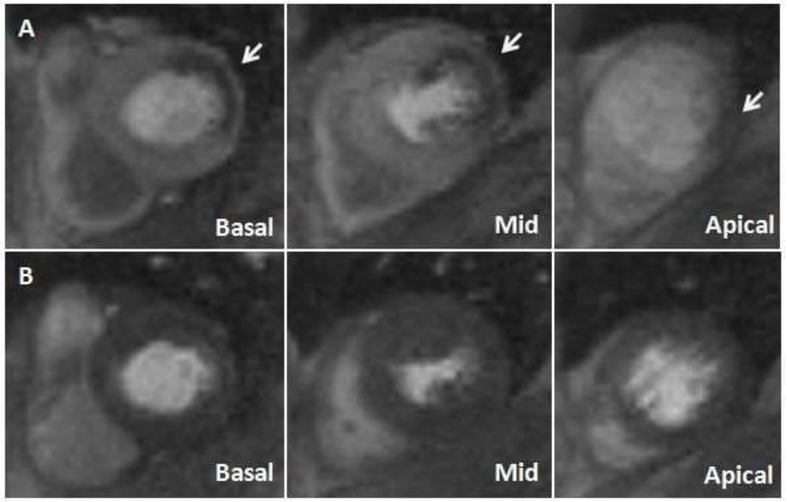
I have no financial relationships to disclose.

Scope

- Background – Ex ECG
- CT assessment
- RAF AMCS use of CTCA
- CMR assessment
- RAF AMCS use of CMR
- Conclusion







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?**

Ex ECG

Test with 60% Sensitivity, 90% Specificity

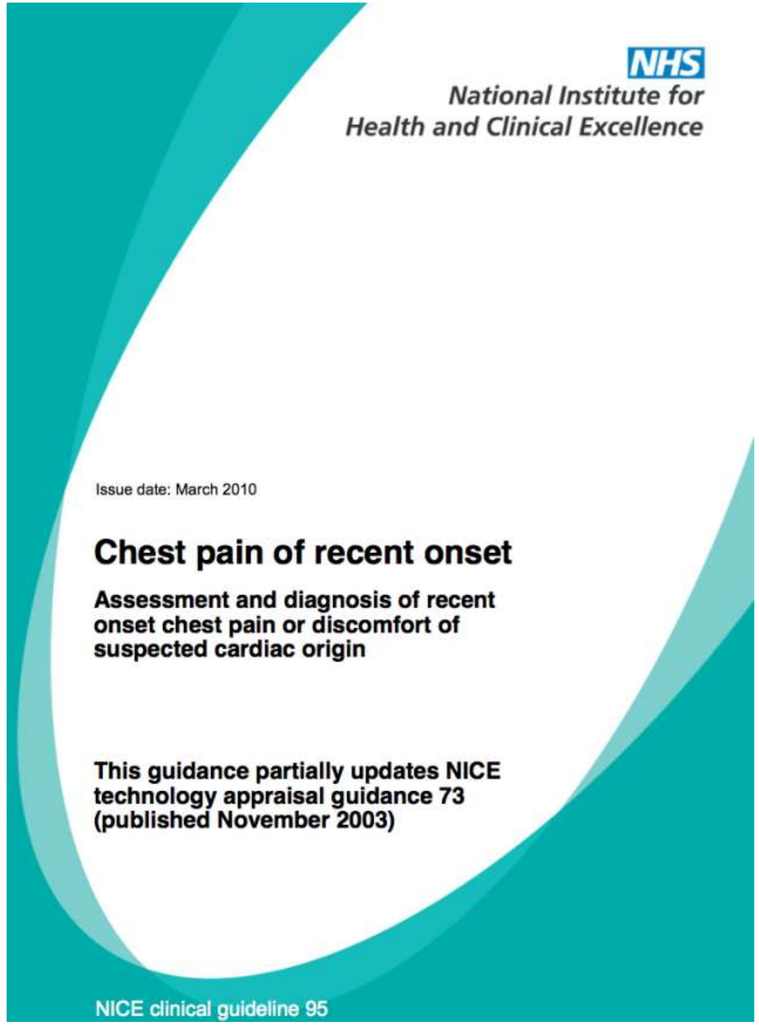
Population 20,000 subjects, **5% prevalence CAD**

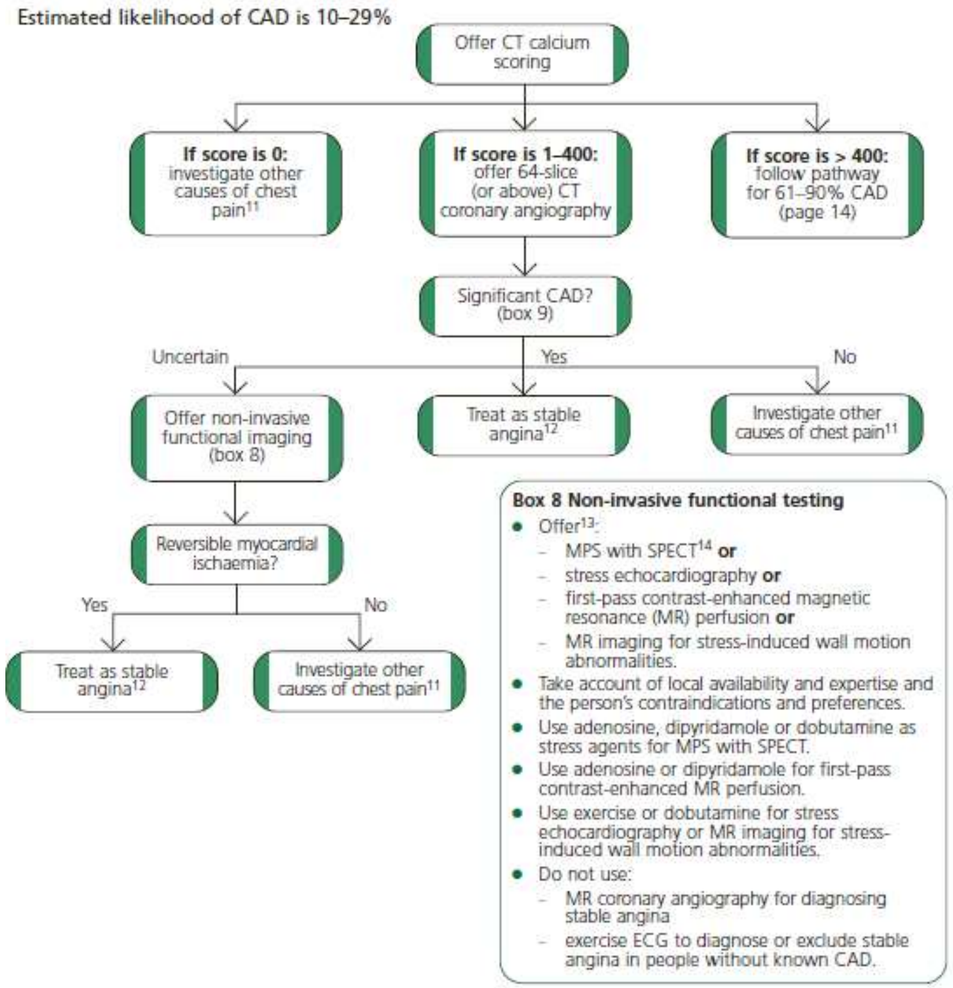
	Significant CAD	No Significant CAD
Abnormal Test	600 (TP)	1,900 (FP)
Normal Test	400 (FN)	17,100 (TN)

PPV = TP/(TP+FP) = *24%*

NPV =(TN/(TN+FN) = *98%*

Low to intermediate likelihood of CAD– role of ExECG?

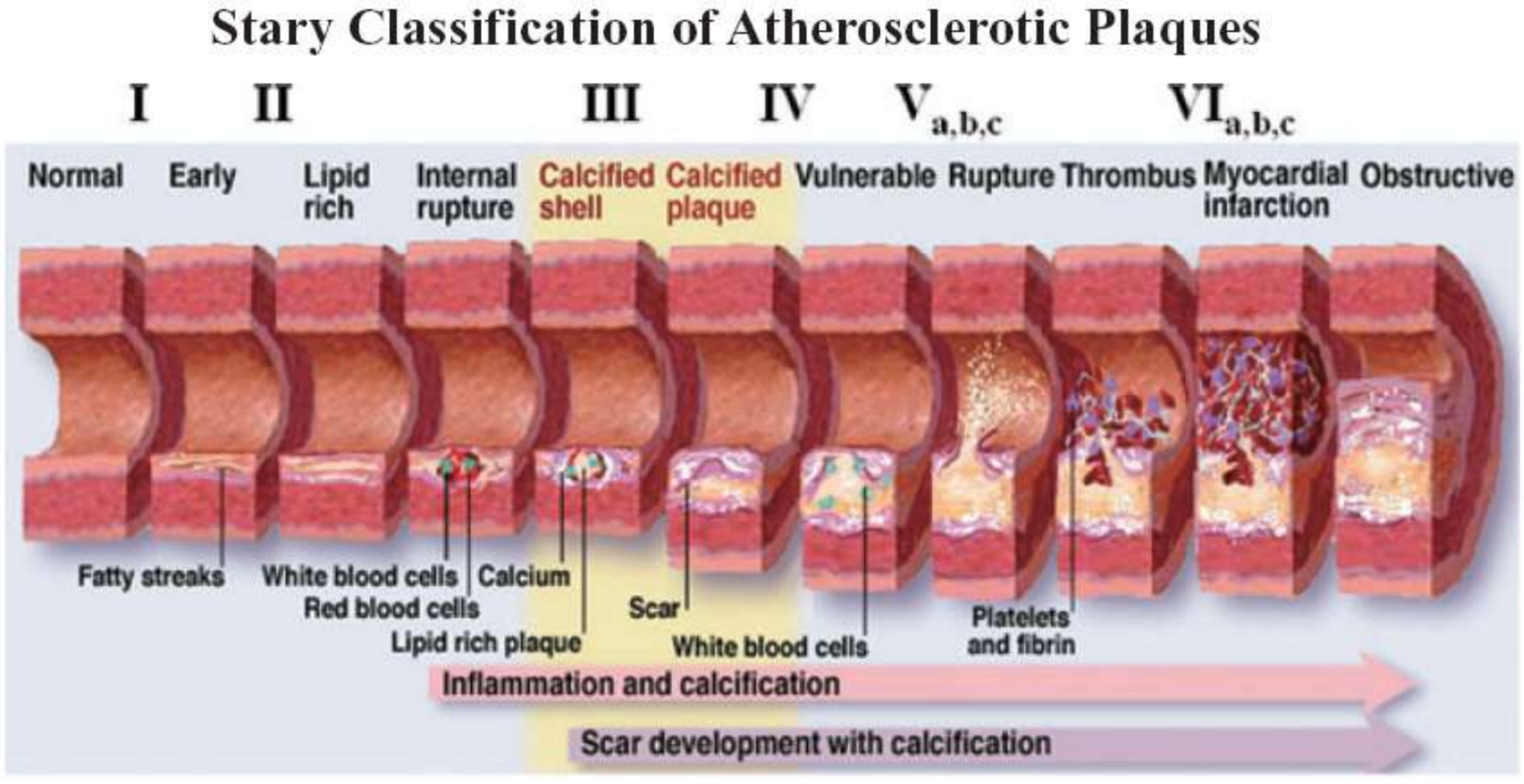




Enhanced Screening

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

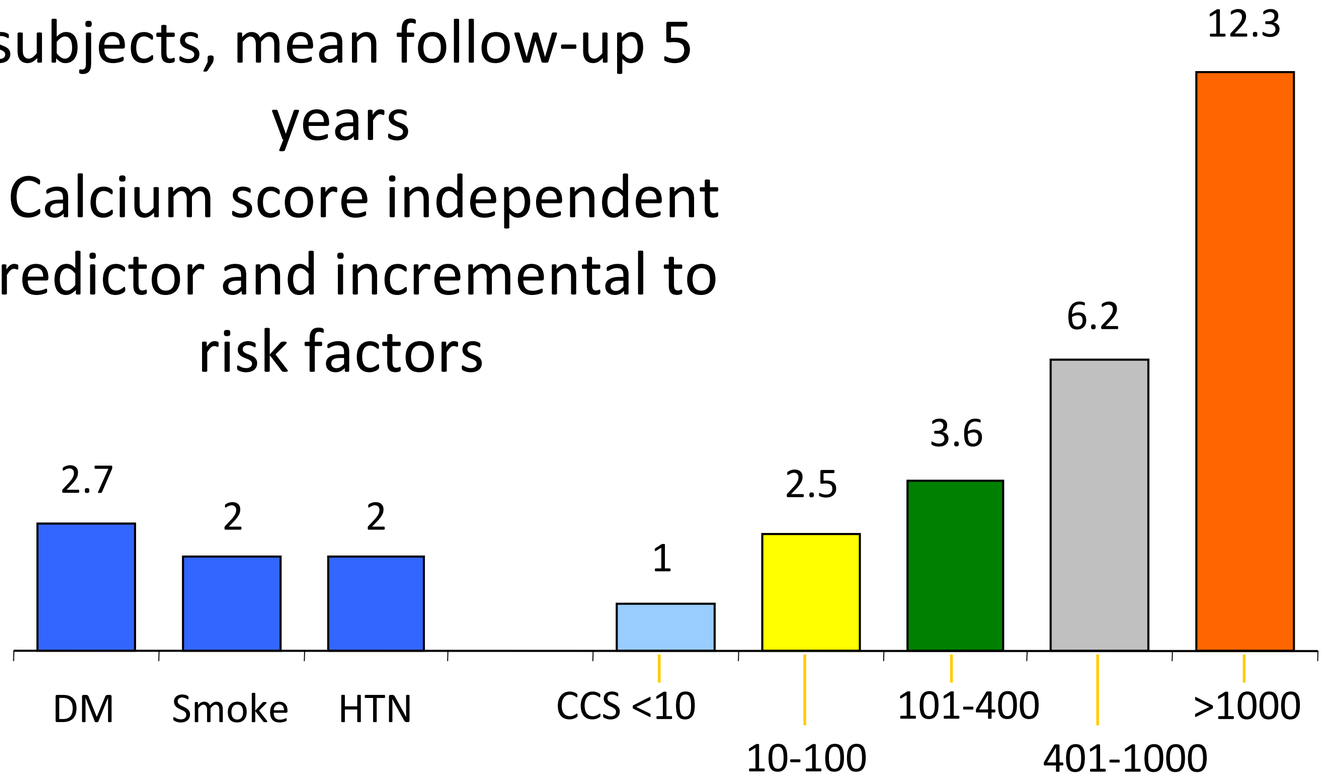
Coronary Artery Calcification



Royal Brompton & Harefield NHS
NHS Foundation Trust

Epidemiology

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



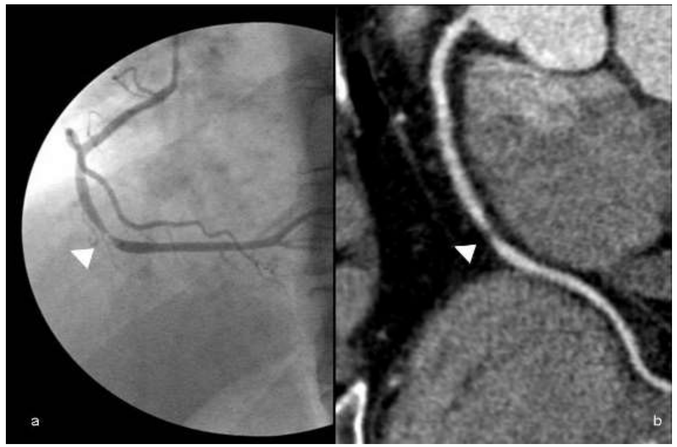
Shaw LJ. Radiology 2003; 228: 826

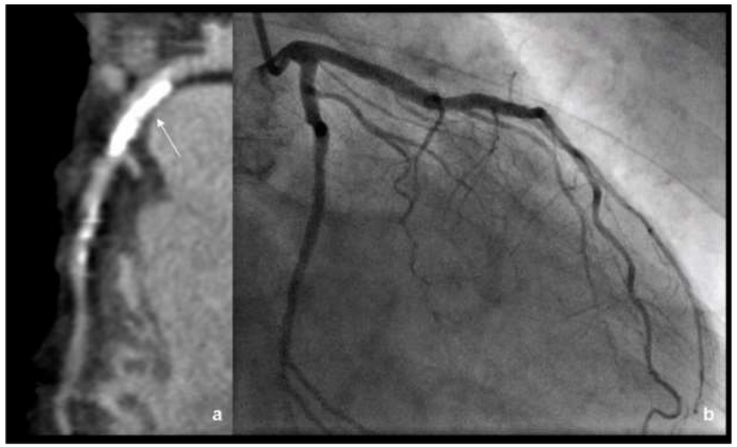
CACS

- US
  - Score <10 – unrestricted
  - >10 grounded
- UK
  - <10 not reassuring
  - >100 may be OK

CAC Score:	0	1-9	10-99	100-399	400-999	>1000
n	249	51	202	263	212	112
CD/MI/ revasc	3	0	6	8	17	12
Annual event rate	0.45%	0.00%	***1.11%***	***1.14%***	***3.00%***	***4.01%***

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

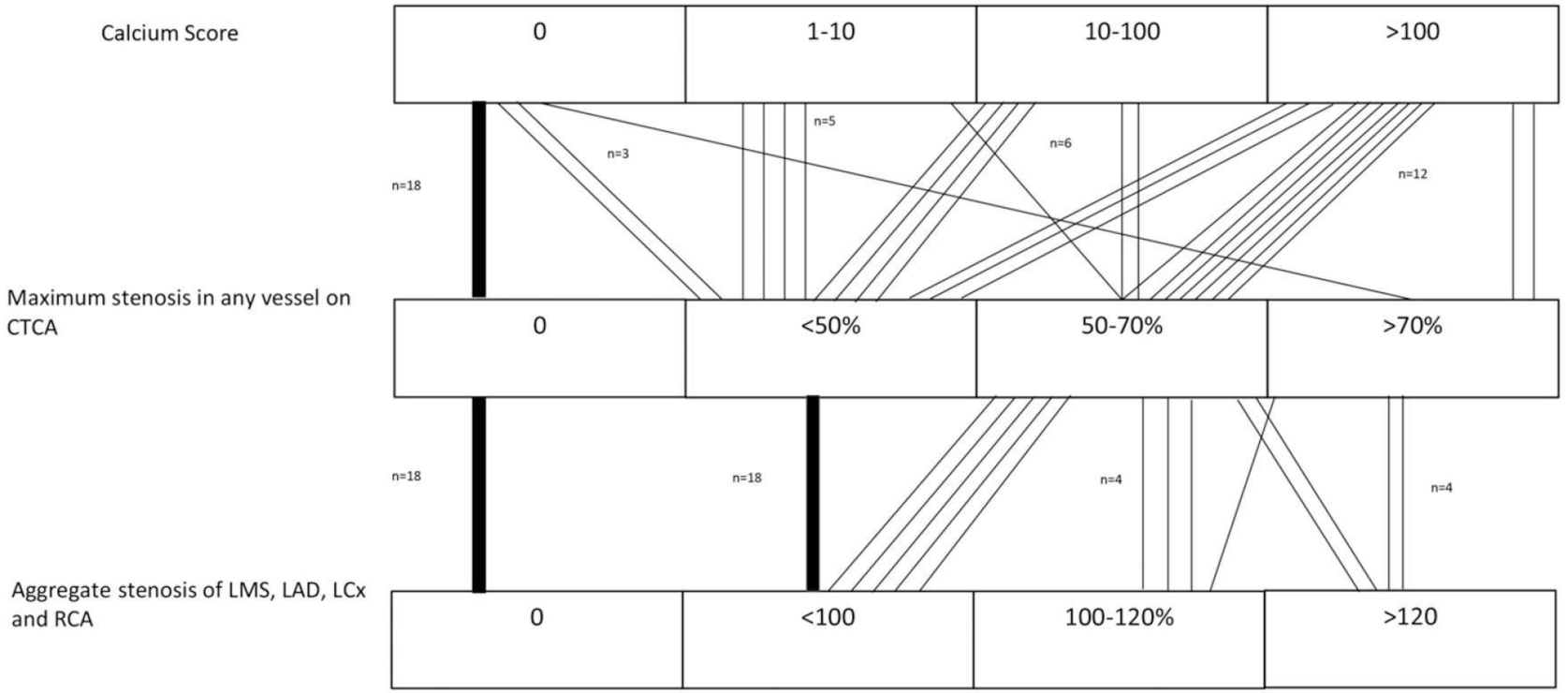


Fig. 1. Figure comparing CT calcium score, CT coronary angiography maximal stenosis, and aggregate stenosis.

CT Coronary Angiography vs. Coronary Artery Calcium Scoring for the Occupational Assessment of Military Aircrew

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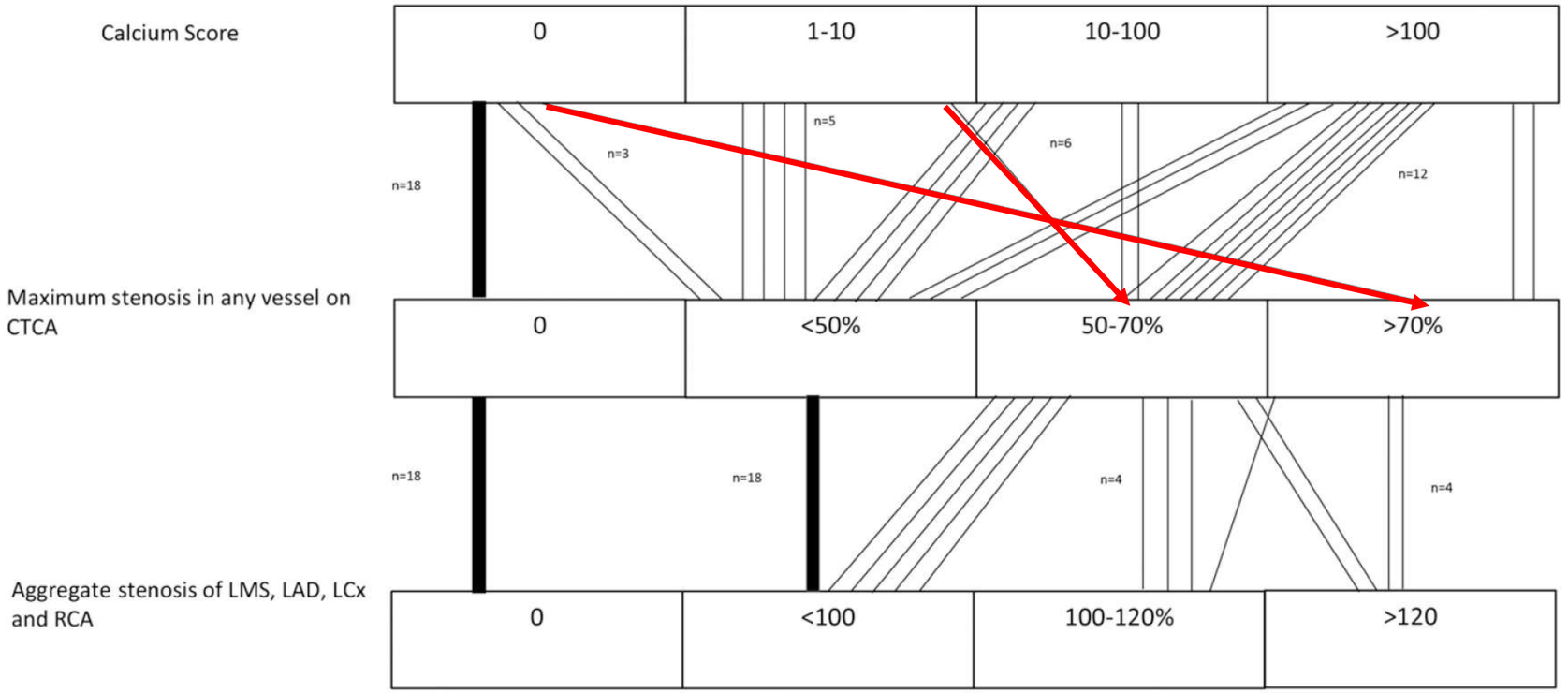

Fig. 1. Figure comparing CT calcium score, CT coronary angiography maximal stenosis, and aggregate stenosis.

Fig. 2. CT coronary angiography of a pilot with significant LAD stenosis, but a calcium score of 0, confirmed by invasive angiography (see arrows).

CT Coronary Angiography vs. Coronary Artery Calcium Scoring for the Occupational Assessment of Military Aircrew

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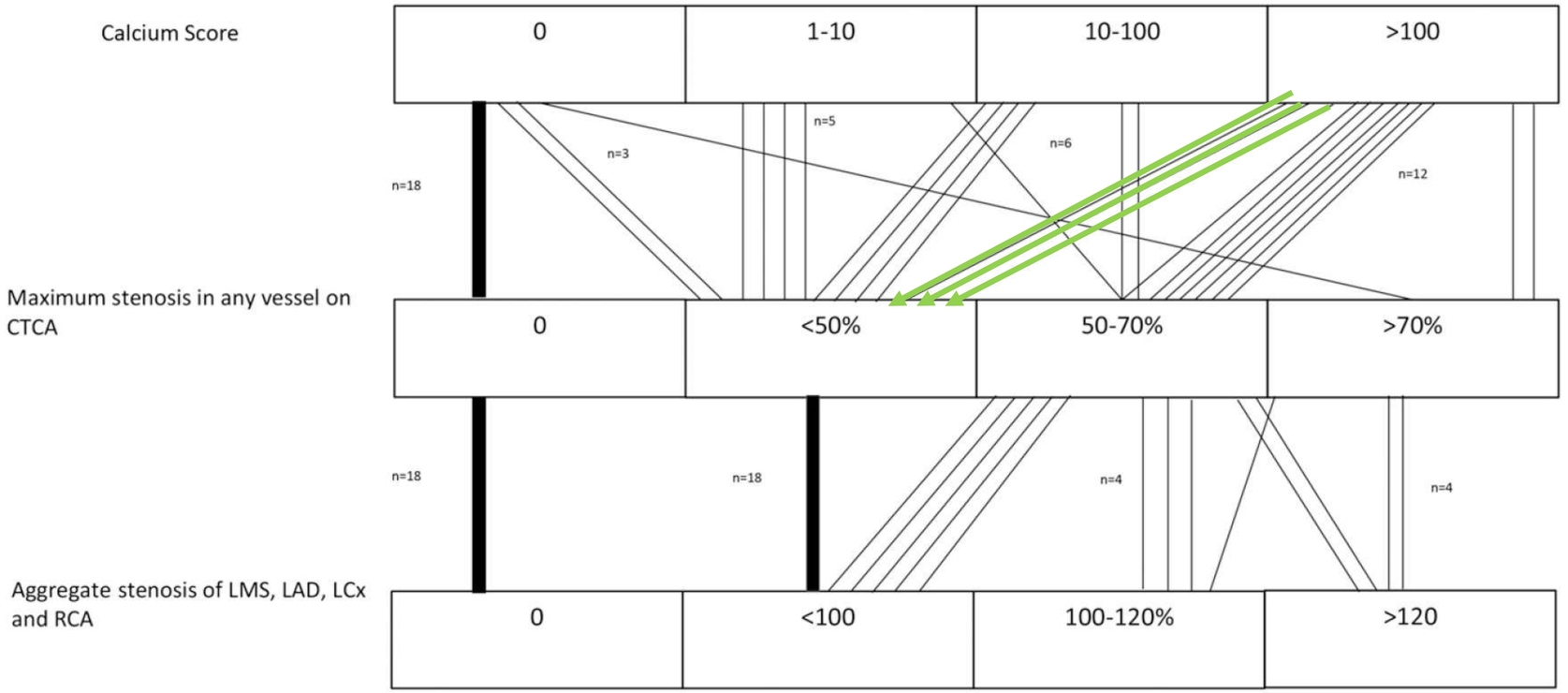


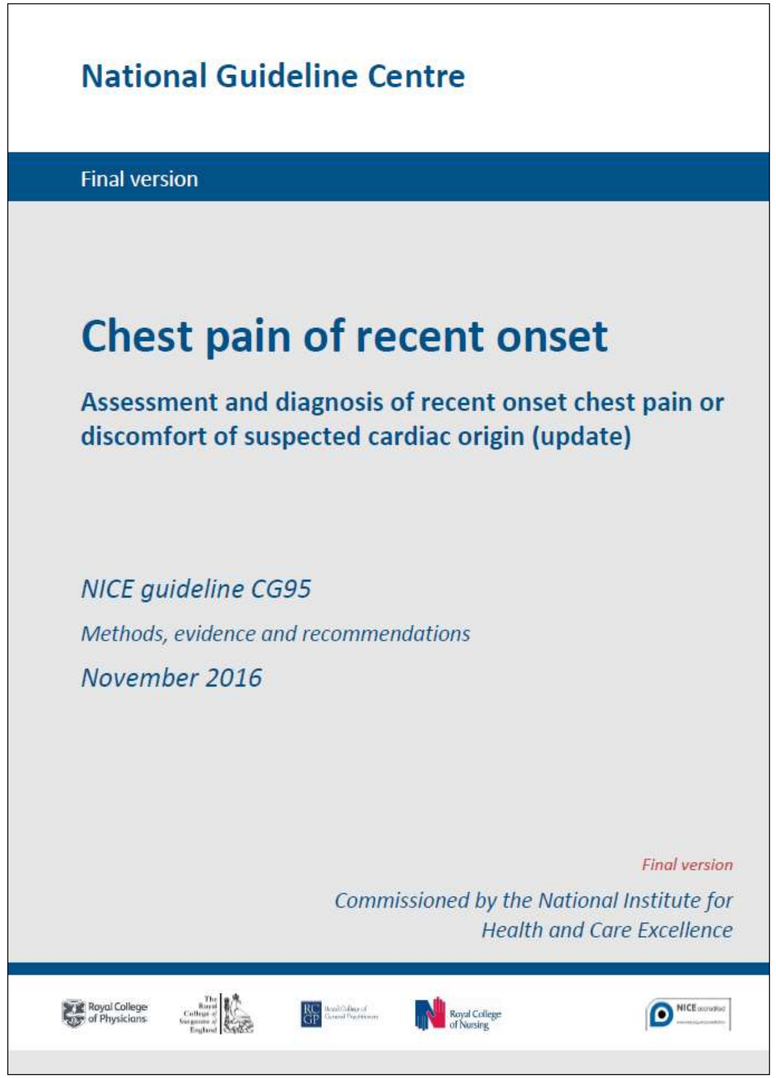
Fig. 1. Figure comparing CT calcium score, CT coronary angiography maximal stenosis, and aggregate stenosis.

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

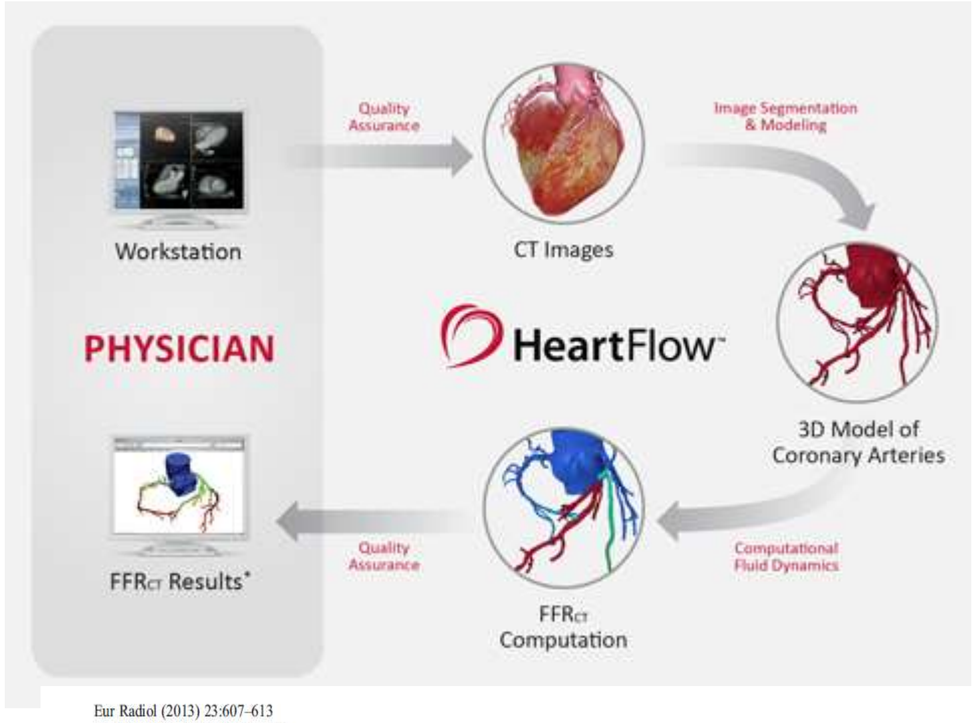


No Ex ECG
No CACS
No PTP assessment

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



Eur Radiol (2013) 23:607–613
DOI 10.1007/s00330-012-2767-9

CARDIAC

CT coronary angiography at an ultra-low radiation dose (<0.1 mSv): feasible and viable in times of constraint on healthcare costs

Filippo Cademartiri · Erica Maffei · Teresa Arcadi · Onofrio Catalano · Massimo Midiri

Received: 22 October 2012 / Revised: 13 December 2012 / Accepted: 19 December 2012 / Published online: 24 January 2013

- 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

Contents lists available at SciVerse ScienceDirect

International Journal of Cardiology

journal homepage: www.elsevier.com/locate/ijcard

Letter to the Editor

The national evolution of cardiovascular CT practice: A UK NHS perspective

T.K. Mittal [a], E.D. Nicol [a,*], S.P. Harden [b], C.A. Roobottom [c], S.P. Padley [a], G. Roditi [d], C.R. Peebles [b], A. Taylor [e], M.C. Hamilton [f], G.J. Morgan-Hughes [c], R.W. Bury [g], on behalf of the British Society of Cardiovascular Imaging

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[c] Plymouth Hospitals NHS Trust, Plymouth, UK
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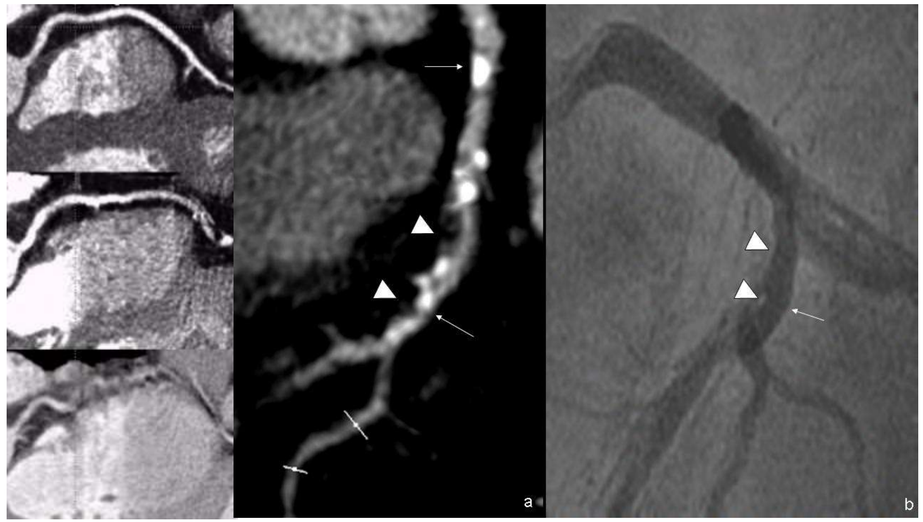
[f] Bristol Royal Infirmary, Bristol, UK
[g] Blackpool Victoria Infirmary, Blackpool, UK



- Heart rate and HRV limitations
- Calcium
- Radiation – PROTECTION VI study
- EHJ Aug 2018
- DLP 200 (3mSv)
- = Annual background radiation (Europe)

- Access and cost in some nations

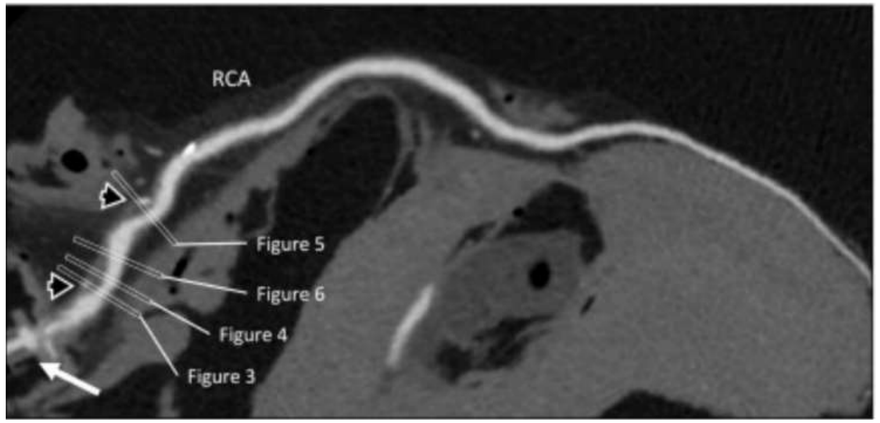
CACS from CTCA

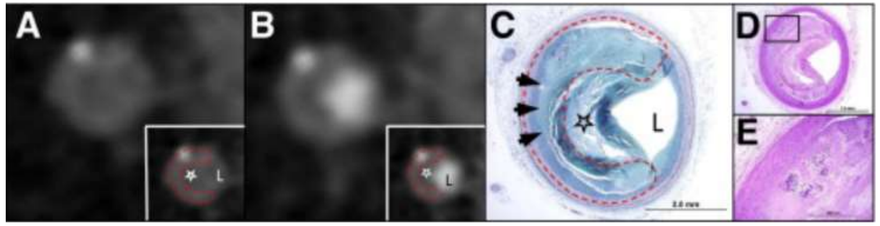
Int J Cardiovasc Imaging
DOI 10.1007/s10554-014-0439-3

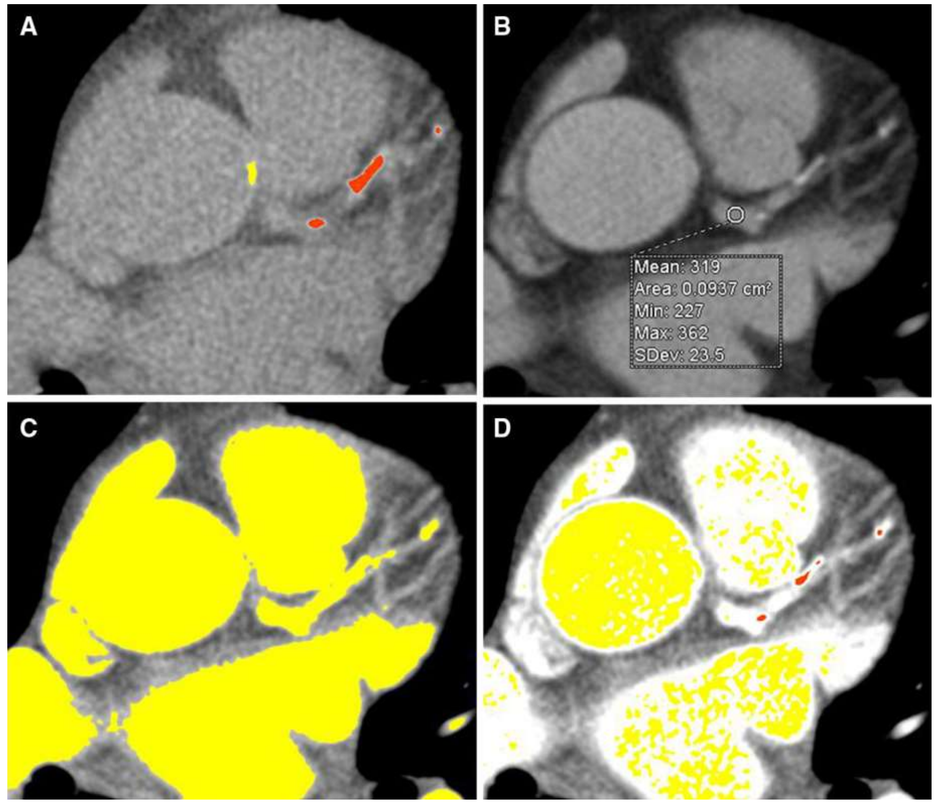
ORIGINAL PAPER

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



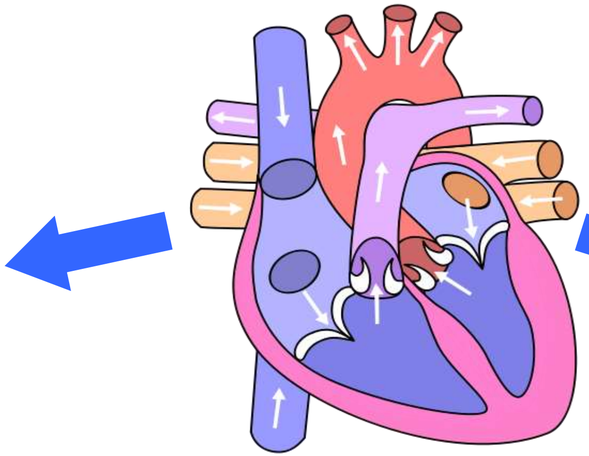




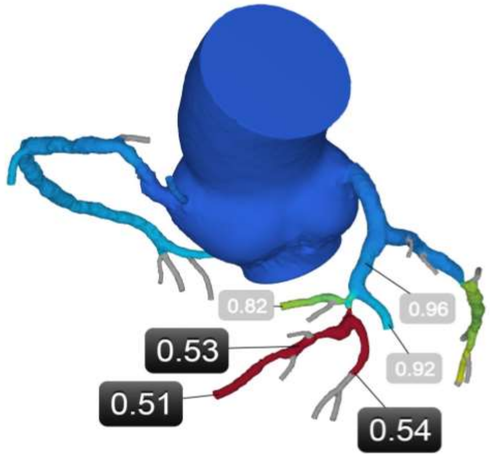
J Am Coll Cardiol Img. 2010;3(4):440-444

CCT-Comprehensive Cardiac Examination

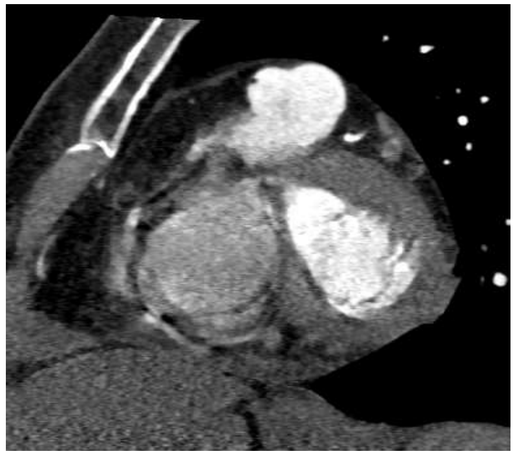
Anatomy



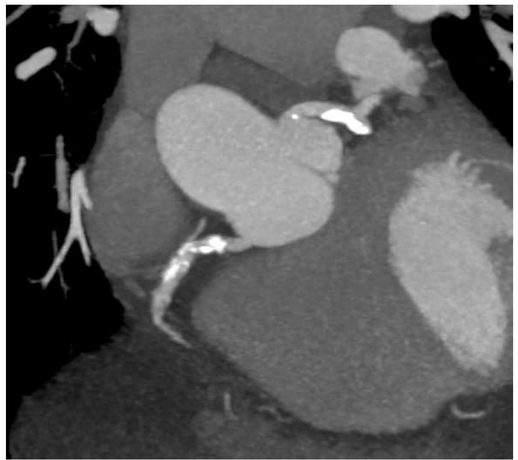
CT-FFR



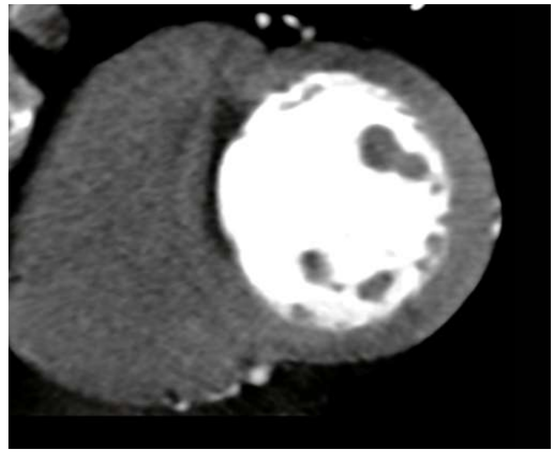
Function



Coronary Plaque/Stenosis



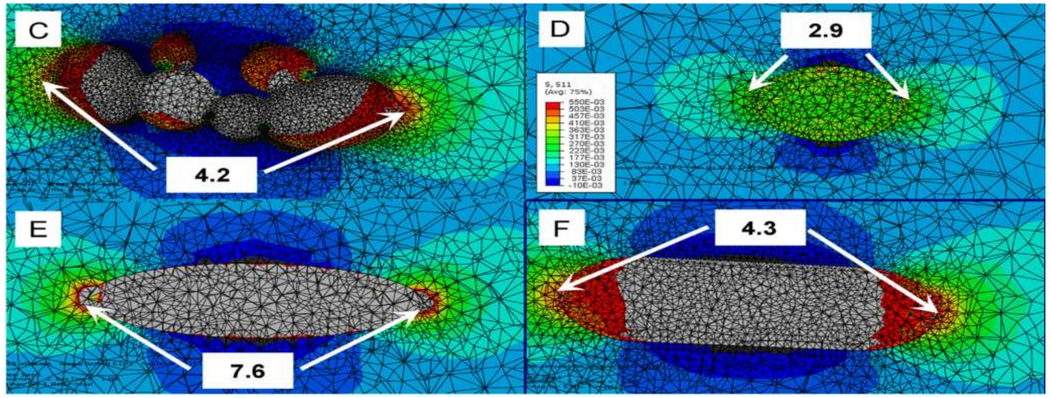
Stress Perfusion



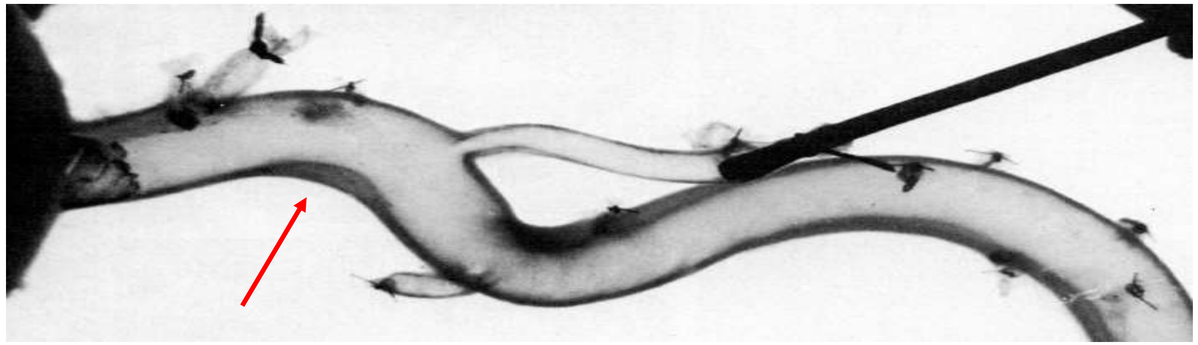
Source: Salerno M, University of Virginia

Shear stress

Shape and regularity

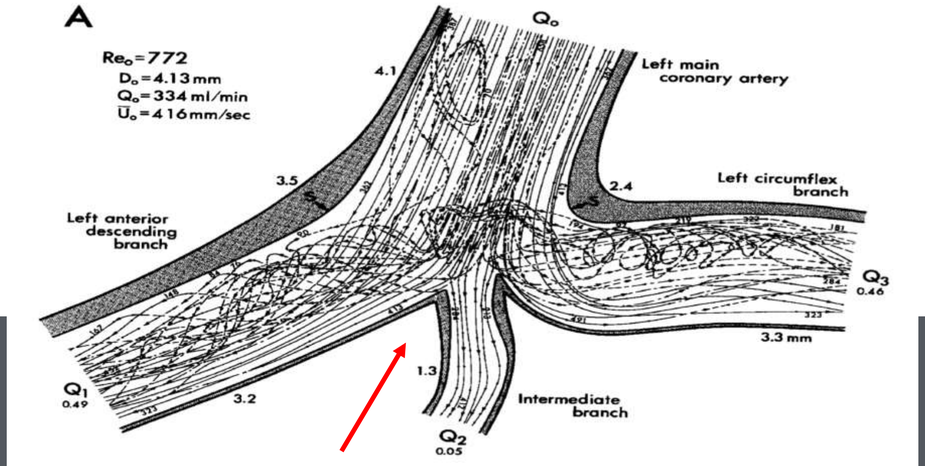


Cardoso et al. J Biomech 2014

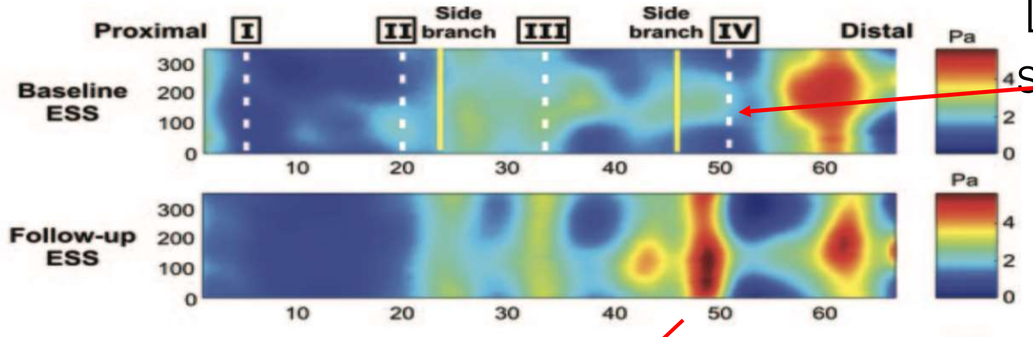


Asakura et al. Circ Res. 1990

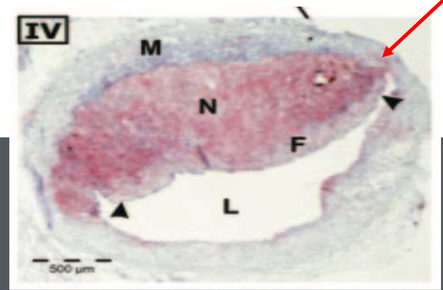
Location



Asakura et al. Circ Res. 1990



Low shear stress area

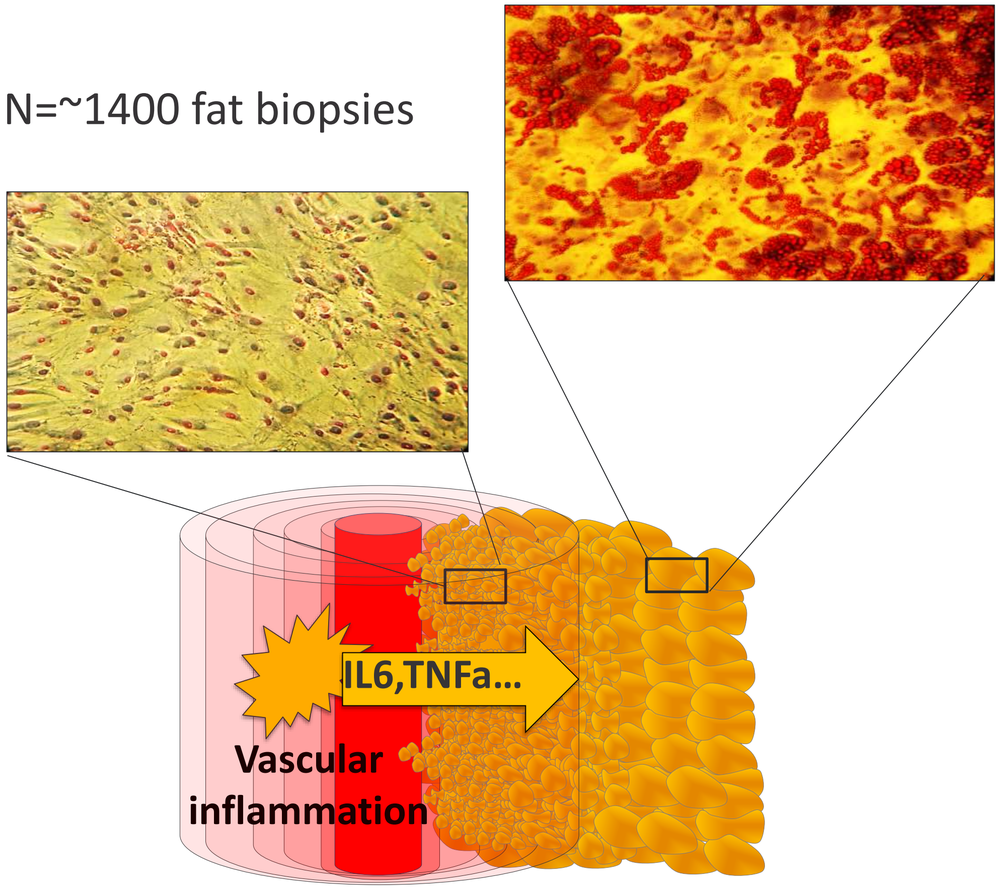


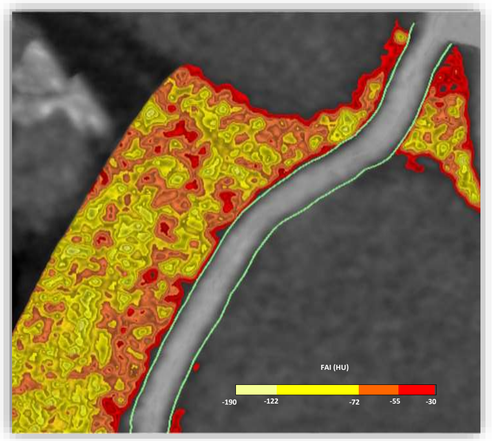
Development of plaque

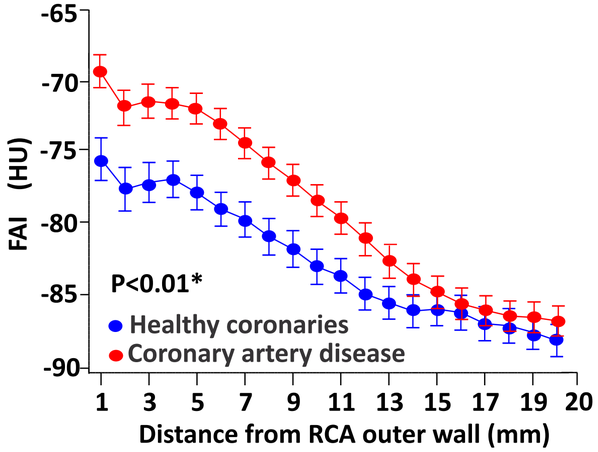
Chatzisisis et al. Circulation 2008

Perivascular Fat Attenuation Index: A new way to identify vascular inflammation

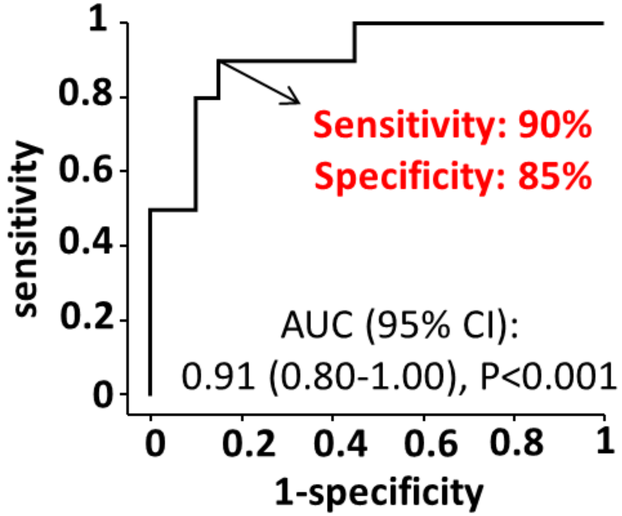
N=~1400 fat biopsies







Detecting culprit lesions in NSTEMI



Vascular inflammation creates a gradient of adipocyte lipid content in perivascular fat

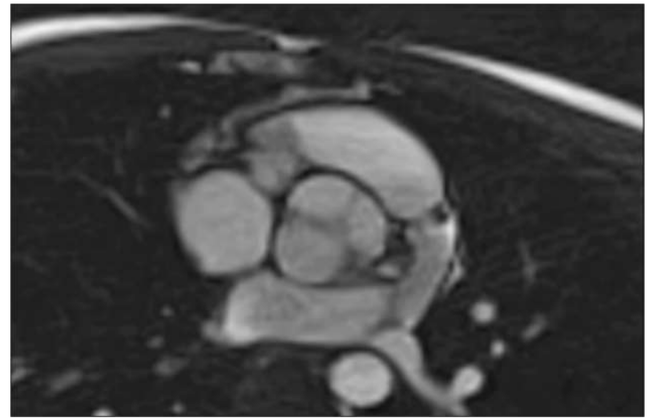
3D changes of PVAT attenuation can be quantified in contrast CTA

Perivascular Fat Attenuation Index: Excellent sensitivity/specificity to detect culprit lesions

Antoniades et al - Sci Transl Med. 2017

CMR

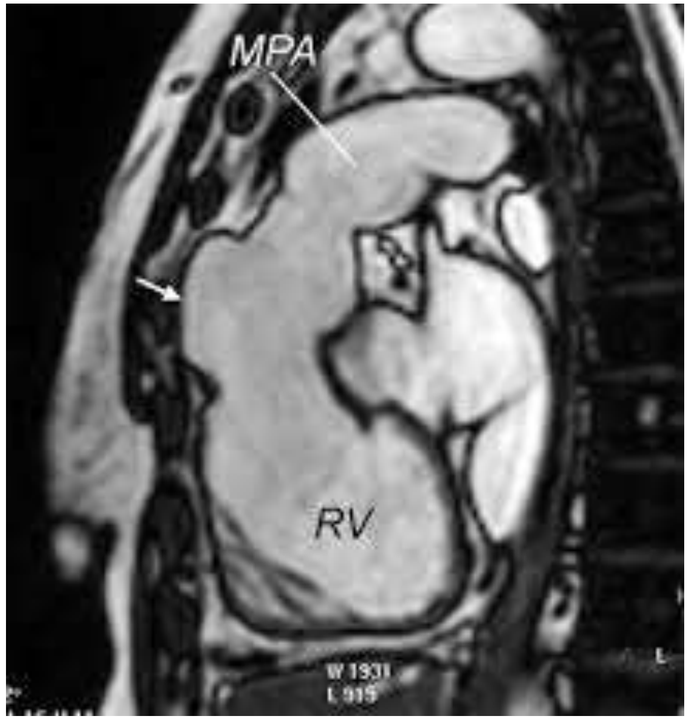
- CMR provides highly accurate morphological and functional assessment
- Excellent reproducibility permitting accurate quantification, or highly sensitive exclusion, of pathology.
- ‘Gold-standard’ for ventricular volumes and mass
- Late gadolinium contrast enhancement (LGE) provides tissue characterisation
- Accurate imaging of the valves and great vessels
- BUT it’s expensive, and time-consuming



The right ventricle

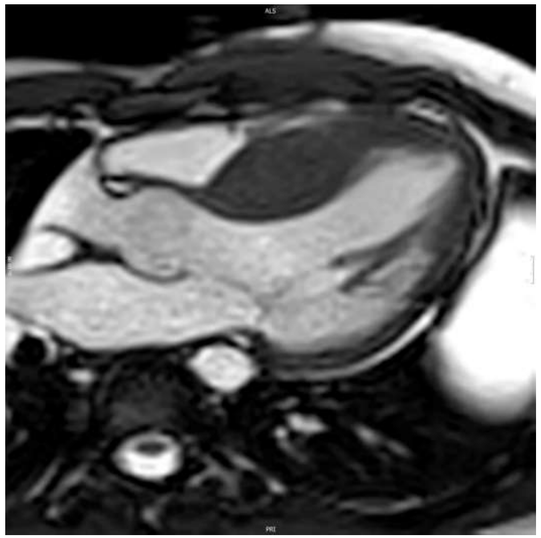
- Assessment of the right ventricle (RV) a particular strength of CMR
- Reproducible quantification of function
- Confirm/exclude dilatation and potential causes:
  - Shunt quantification
  - ASD assessment for potential closure

Aneurysmal/dyskinetic segments for query arrhythmogenic ventricular cardiomyopathy



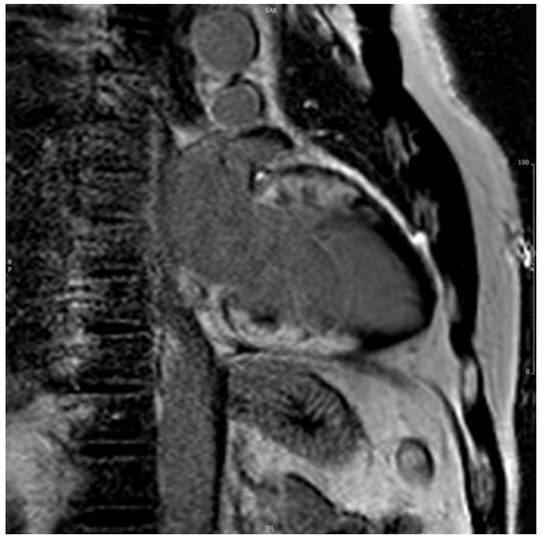
Hypertension vs HCM

- CMR may be able to distinguish between them (not 100% though)
- Asymmetry of hypertrophy, severity of hypertrophy, presence of myocardial crypts, presence of LVOT obstruction, presence of SAM of the MV
- Can assess the apex in query apical HCM, when echo may be affected by near-field artefact
- Can also look for fibrosis in a characteristic pattern, using LGE
  - typically seen as patchy/hazy enhancement in HCM, usually in areas of maximal hypertrophy



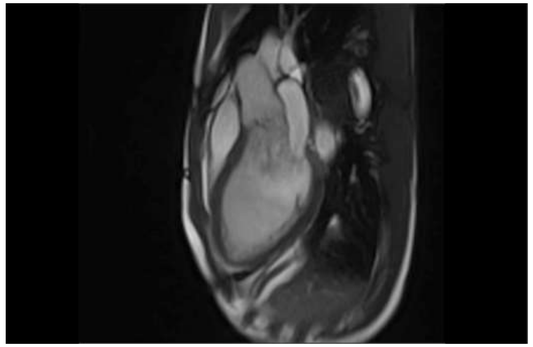
Myocarditis vs MI

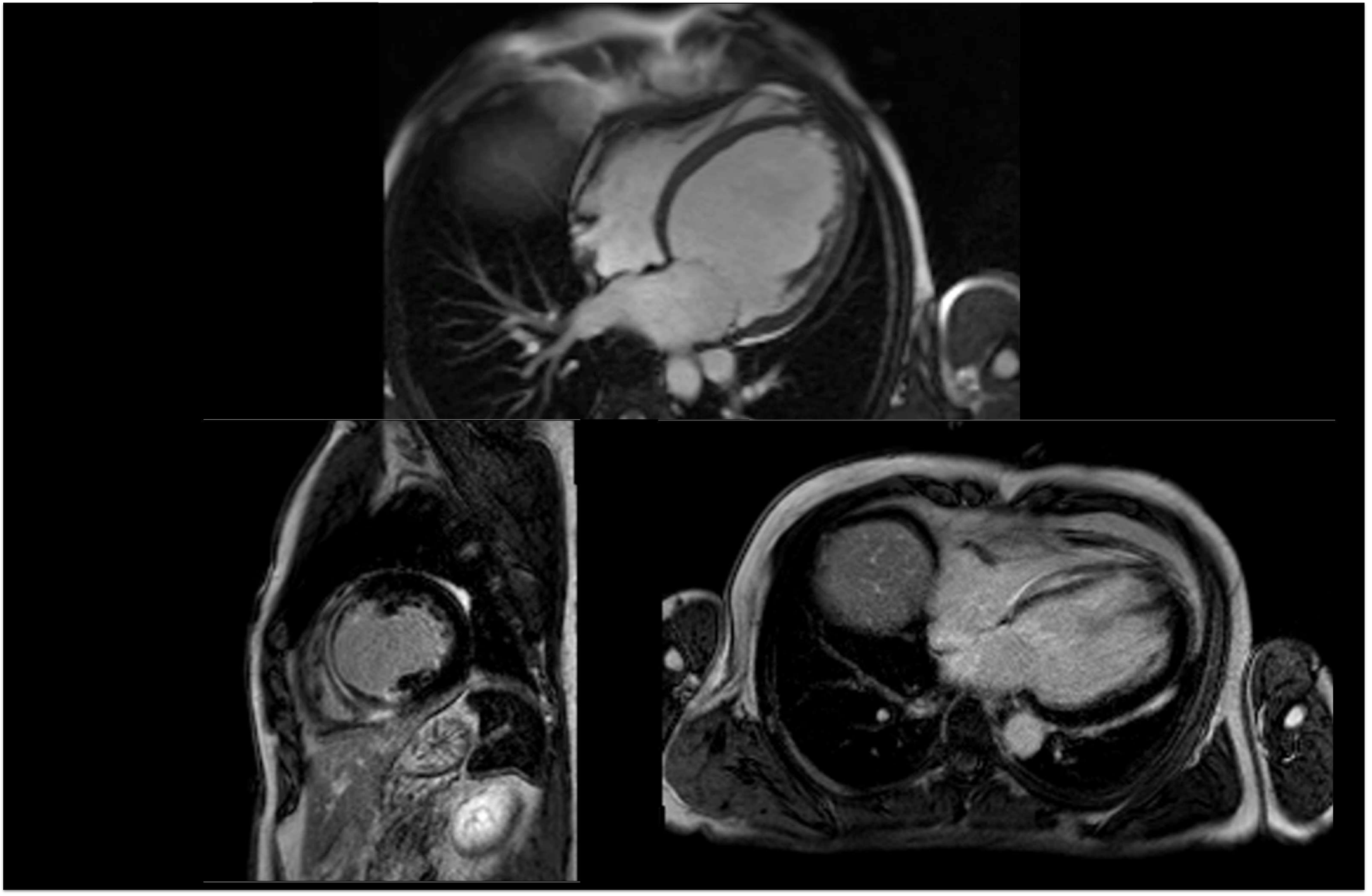
- Chest pain & ↑ troponin may occur with both
- Angiography may not be clear-cut
- Aeromedical disposition significantly different
- Confirming myocarditis, not MI, may allow a return to the cockpit much more quickly in many – LGE patten usually diagnostic
- In the acute stage, can assess inflammation & oedema - to confirm diagnosis, assess LV (dys)function and fibrosis with LGE
- For follow up, can also assess recovery of LV function, resolution of oedema or inflammation, and degree of fibrosis

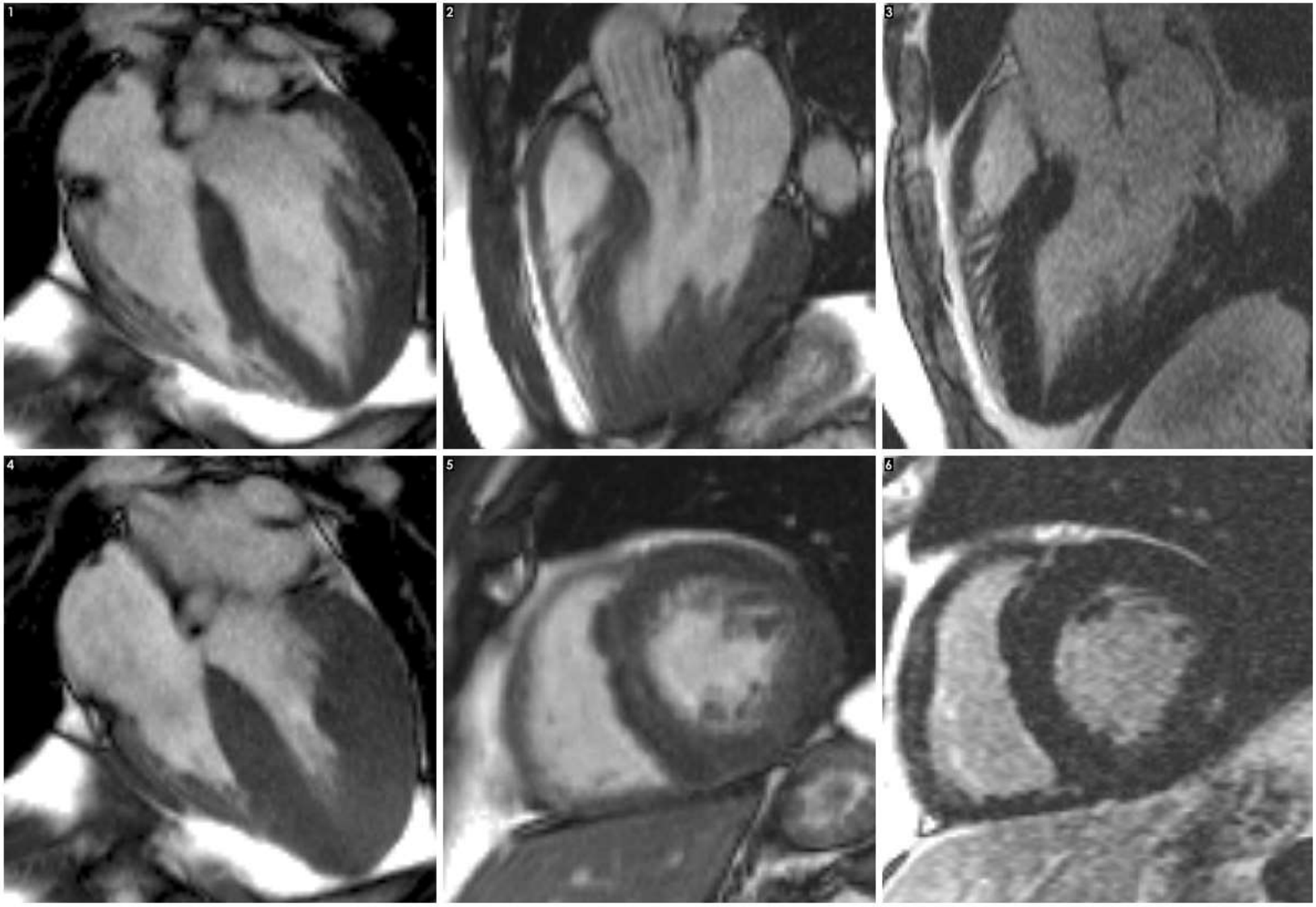


Cardiomyopathy

- Can detect cardiomyopathy (CM) before LV dysfunction seen on echo
  - Therefore may be able to detect it earlier, and limits aeromedical risk
- May show anatomy or specific patterns of LGE consistent with aetiology of CM
- Can also provide reassurance in cases where suspicion arises of query CM
- Can also be used for follow up in CM - accurate & reproducible follow up in those with CM if continued flying privileges dependent on LV/RV function
- LGE also highly sensitive for detection of cardiac sarcoid, with characteristic pattern seen, even in those with normal ECG & echo



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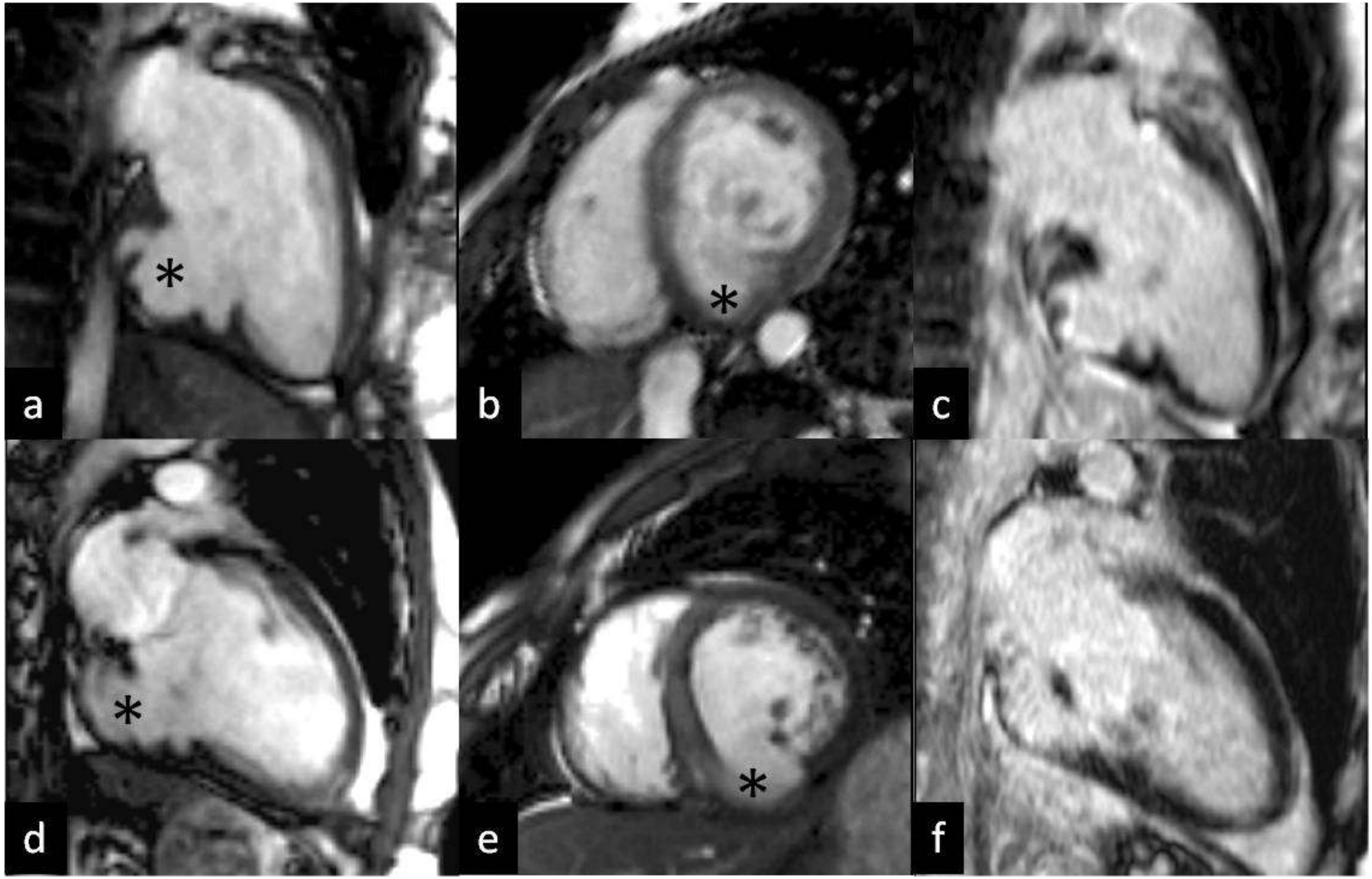


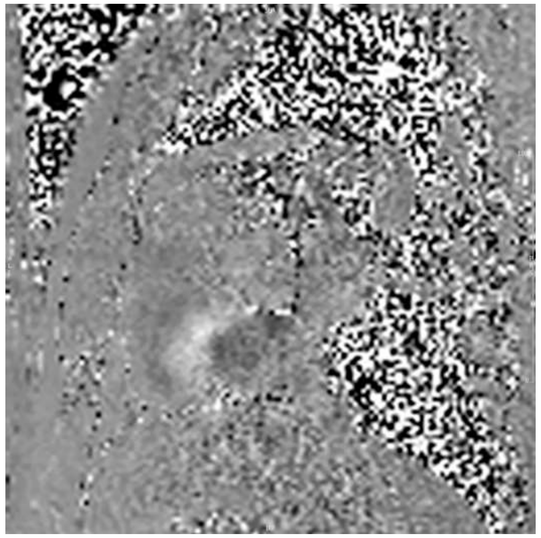
Ray R, Salukhe T, Reubens M, Nicol E. Aviat Space Environ Med 2014

AMCS cohort

- From a total aircrew population of 8000, over a two-year period, 1025 personnel were referred for clinical outpatient assessment.
- Of these, 558 referrals (54%) were for further medical evaluation of suspected cardiovascular disease.
- 52/558 (9.3%) underwent a CMR scan – abnormal ECG/Holter (46%).
- 65% to exclude a CM
- CMR cohort:
  - median age of 43 years (range 20-62 years)
  - predominantly male (96%).
  - The largest occupational group was pilots (35%)

AMCS cohort

- Of the 52 subjects assessed by CMR:
  - prior to the scan
    - 30 (58%) were grounded
    - 22 (42%) were flying with occupational restrictions
  - after the scan
    - 8 (15%) remained grounded
    - 25 (48%) were returned to flying with occupational restriction
    - 19 (37%) were cleared for unrestricted flying duties



AMCS cohort

- 24/52 patients (46%) had confirmed pathology on CMR.
- Within this group:
  - 8 (33%) had dilated cardiomyopathy
  - 6 (25%) had evidence of previous myocarditis
  - 4 (17%) hypertrophic cardiomyopathy
  - 2 (8%) bicuspid aortic valve with dilated aortic root
  - 2 (8%) had significant coronary artery disease with a perfusion defect
  - 1 patient had a previous myocardial infarction
  - 1 congenital LV aneurysm
  - **5 (21%) unclear/uncertain diagnosis (athletic heart vs. HCM) despite CMR**

Variable	Sub-variable	Total=n	Occupational restriction pre CMR			Occupational restriction post CMR			
			Grounded n (%)	Restrictions n (%)	Full Duties n (%)	Grounded n (%)	Restrictions n (%)	Full Duties n (%)	p-value for change in restriction
All aircrew		52 (100)	30 (58)	22 (42)	0 (0)	8 (15)	25 (48)	19 (37)	**<0.001**
Clinical question	Cardiomyopathy	34	19	15	0	6	18	10	**0.0002**
	Myocarditis	8	4	4	0	0	7	1	0.06
	Perfusion ?Ischaemia	7	4	3	0	0	6	1	**0.049**
	Aorta	2	2	0	0	1	0	1	-
	Other	1	1	0	0	1	0	0	-
Subsequent Diagnosis	Normal	22	9	13	0	2	11	9	**0.001**
	Dilated Cardiomyopathy	8	5	3	0	3	5	0	**0.003**
	Athletic / Cardiomyopathy*	6	5	1	0	1	4	1	0.065
	Previous myocarditis	6	4	2	0	0	5	1	**0.043**
	Hypertrophic cardiomyopathy	4	2	2	0	0	4	0	-
	Bicuspid Aortic Valve	2	2	0	0	1	0	1	-
	Myocardial Ischaemia	2	2	0	0	0	2	0	-
	Prior Myocardial Infarction	1	1	0	0	1	0	0	-
	Other	1	0	1	0	0	1	0	-

Conclusions

- Cardiovascular CT and CMR are key investigations in the occupational assessment for cardiovascular disease
- When compared with standard of care, CT & CMR increases the likelihood of a well-characterised cardiac diagnosis or the confident exclusion of pathology.
- This results in a significant increase in return to flying duties

Any questions?