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Cardiovascular Imaging

MR methodology and applications

Preparatory course to certification in CMR

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ESC
European Society
of Cardiology

Disclosures of interest

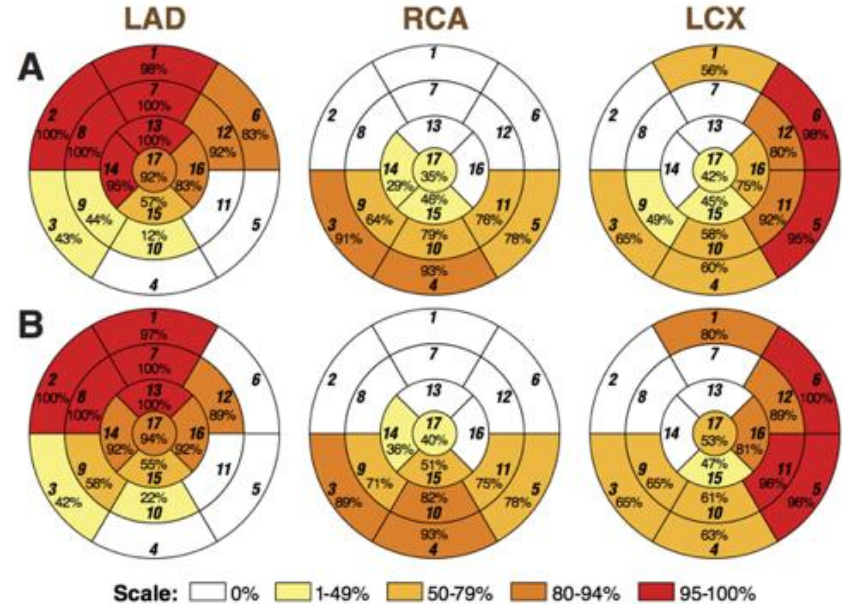
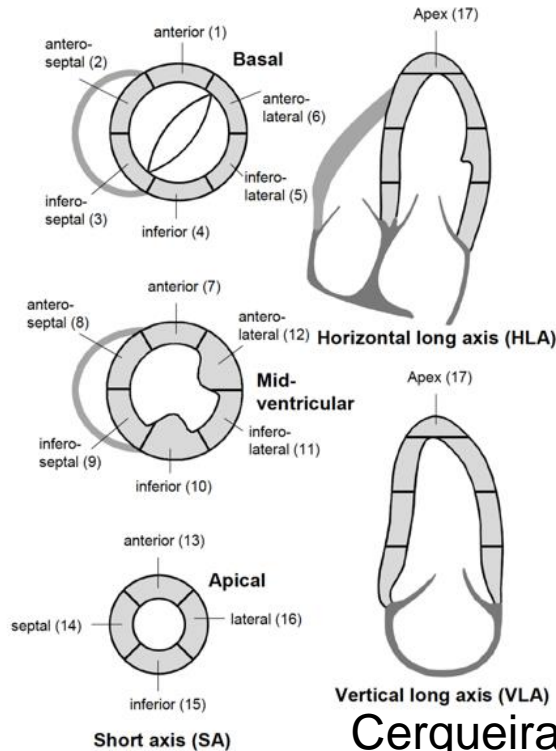
- **Consultancy, Circle Cardiovascular Imaging, Inc., Calgary, Alberta, Canada**

- **1.3.1. Cardiac anatomy including AHA model**
- **1.3.2. Cardiac function**
 - 1.3.2.1. LV volumes
 - 1.3.2.2. RV volumes
 - 1.3.2.3. Regional wall motion abnormalities (tagging, TPM, DENSE, Tissue tracking)
- **1.3.3. Tissue characterisation**
 - 1.3.3.1. Non-contrast T2-STIR
 - 1.3.3.2. Contrast: EGE/LGE
- **1.3.4. CMR stress imaging**
 - Myocardial perfusion imaging
 - Dobutamine stress CMR
- **1.3.5. Blood flow**

Cardiac anatomy: 17 segment model and variability of blood supply



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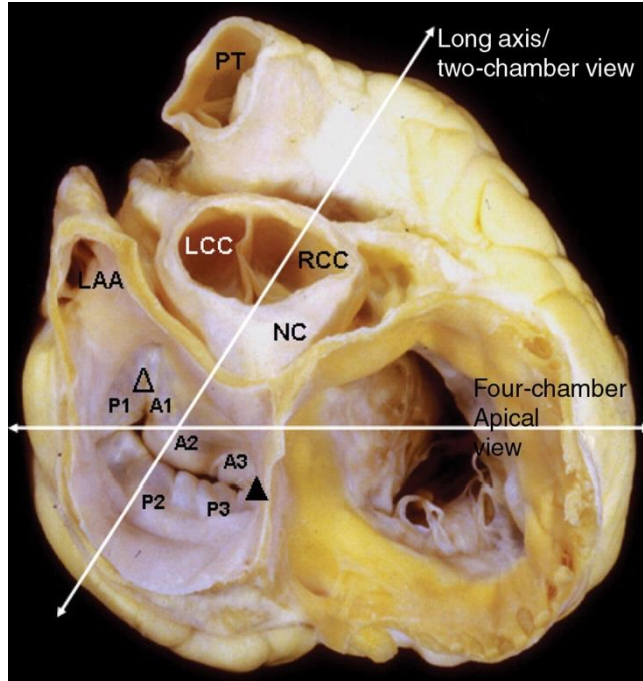
Ortiz-Pérez JT et al. JACC Cardiovasc Imaging. 2008

Cerqueira MD et al, Circulation 2002

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Cardiac anatomy: Aortic and mitral valve



Specimen picture showing the base of the heart with the location of two- and four-chamber echocardiographic views superimposed (double-headed arrows).

Cardiac anatomy: Chest anatomy

- <https://mrimaster.com/anatomy%20chest%20axial.html>

Cardiac function

- **LV volumes**
- **RV volumes**
- **Regional wall motion abnormalities**
 - Tagging
 - Dense
 - Tissue phase mapping
 - Feature or tissue tracking

Cardiac function: Bread and butter of all protocols



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Kramer et al. *Journal of Cardiovascular Magnetic Resonance* (2020) 22:17
<https://doi.org/10.1186/s12968-020-00607-1>


Journal of Cardiovascular
Magnetic Resonance

RESEARCH

Open Access

Standardized cardiovascular magnetic resonance imaging (CMR) protocols: 2020 update



Christopher M. Kramer^{1*} , Jörg Barkhausen², Chiara Bucciarelli-Ducci³, Scott D. Flamm⁴, Raymond J. Kim⁵ and Eike Nagel⁶

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Cardiac function: Analysis and interpretation



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Schulz-Menger *et al.* *Journal of Cardiovascular Magnetic Resonance* (2020) 22:19
<https://doi.org/10.1186/s12968-020-00610-6>

Journal of Cardiovascular
Magnetic Resonance


POSITION STATEMENT

Open Access

Standardized image interpretation and post-processing in cardiovascular magnetic resonance - 2020 update



Society for Cardiovascular Magnetic Resonance (SCMR): Board of Trustees Task Force on Standardized Post-Processing

Jeanette Schulz-Menger^{1*}, David A. Bluemke², Jens Bremerich³, Scott D. Flamm⁴, Mark A. Fogel⁵, Matthias G. Friedrich⁶, Raymond J. Kim⁷, Florian von Knobelsdorff-Brenkenhoff⁸ , Christopher M. Kramer⁹, Dudley J. Pennell¹⁰, Sven Plein¹¹ and Eike Nagel¹²

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Cardiac LV function: Analysis and interpretation

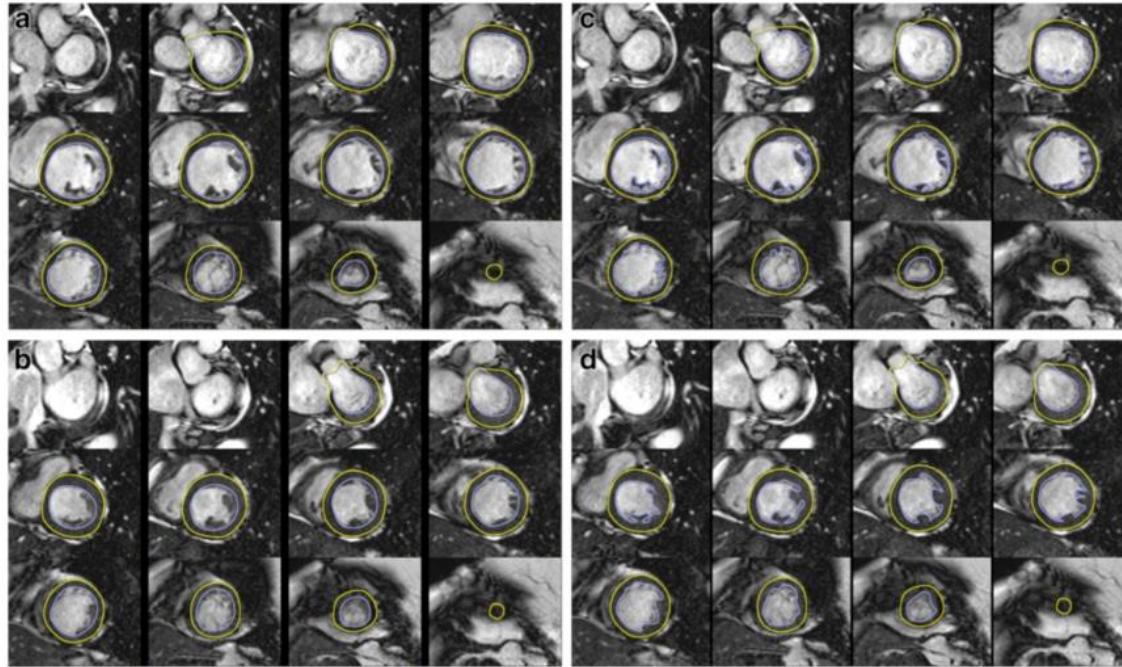


Figure 1 Left ventricular (LV) chamber quantification. For LV chamber quantification, the endocardial (blue) and epicardial (yellow) contours are delineated in diastole (top) and systole (bottom) in a stack of short axis slices that cover the whole left ventricle. **a)** and **b)** illustrates the approach with inclusion of the papillary muscles as part of the LV volume. **c)** and **d)** Shows the approach with exclusion of the papillary muscles from the LV volume.

Cardiac RV function: Analysis and interpretation

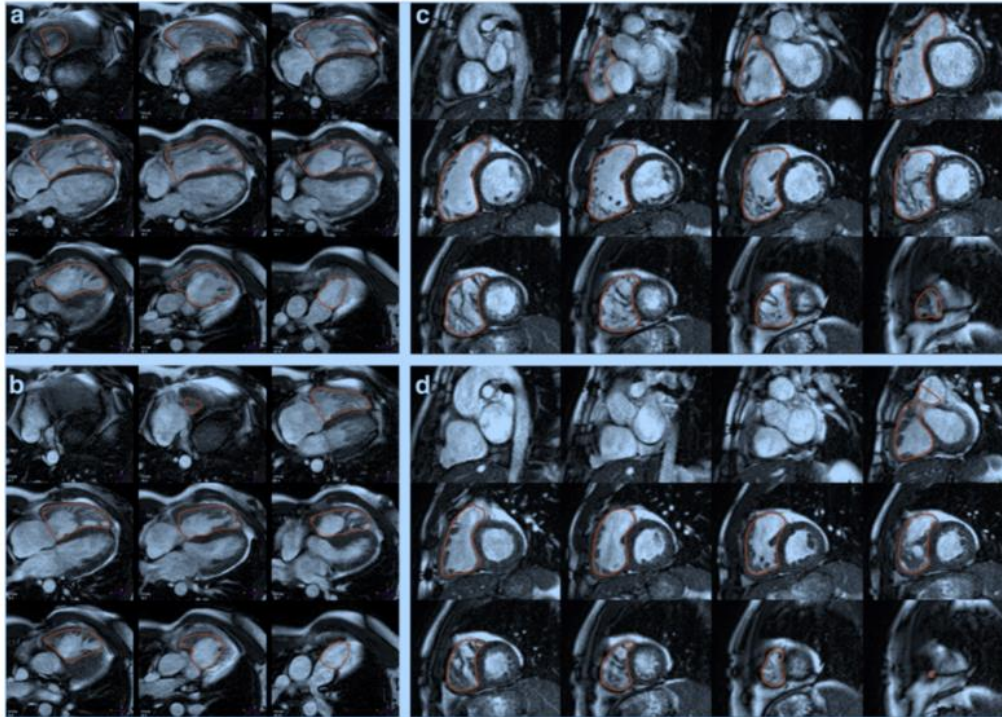


Figure 2 Right ventricular (RV) chamber quantification. For RV volume quantification, the endocardial (red) contours are delineated in diastole (top) and systole (bottom) in a stack of transaxial (a and b) or short-axis (c and d) slices that cover the whole RV.

Cardiac function: Normal values

Kawel-Boehm *et al.* *Journal of Cardiovascular Magnetic Resonance* (2015) 17:29
DOI 10.1186/s12968-015-0111-7



REVIEW

Open Access

Normal values for cardiovascular magnetic resonance in adults and children

Nadine Kawel-Boehm¹, Alicia Maceira², Emanuela R Valsangiacomo-Buechel³, Jens Vogel-Claussen⁴, Evrim B Turkbey⁵, Rupert Williams⁶, Sven Plein⁷, Michael Tee⁸, John Eng⁹ and David A Bluemke^{8*}

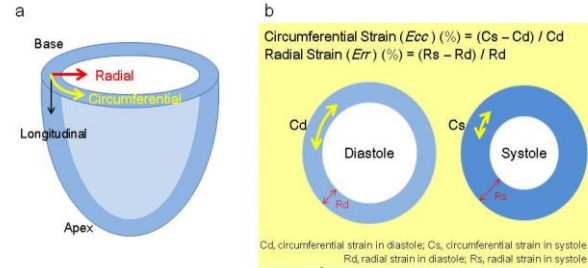
Cardiac function: Regional function

- Remember AHA segment model: tagging, DENSE, tissue phase mapping, feature/tissue tracking
- Wall thickening (mm or %) – Cines
- Strain (%)
- Strain-rate (1/s)
- Myocardial velocity (cm/s)

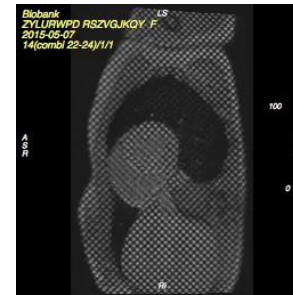
- Clinical use: tagging for pericardial adhesions

Potential applications

- Viability
- Early detection of myocardial involvement in asymptomatic patients, e.g.
 - Chemotherapy induced cardiomyopathy
 - Diabetes
 - Amyloidosis
- Heart transplant rejection
- Genotype positive, phenotype negative HCM
- Mechanical dyssynchrony -> CRT guidance



E. Tateishi, *EPOS congress*, 2014



Repetition: Describe key features of AHA segment model!



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- **Basal, mid and apical short axis slice**
- **Anterior RV/LV junction as landmark**
- **6 segments basal and mid, 4 segments apical**
- **True apical cap on long axis**
- **Start to the right of the landmark**
- **Counterclock-wise counting**

Tissue characterisation

Non-contrast techniques

- **T2-STIR**
 - Regional myocardial oedema
 - Global myocardial oedema: Signal increase in relation to skeletal muscle - T2 ratio (≥ 2 pathological)
- **T2-mapping**
 - Regional and global myocardial oedema
- **Native T1 mapping**
 - Regional and global pathology, e.g.
 - Decreased in iron overload
 - Decreased in fat
 - Decreased in Fabry's disease
 - Increased in most other pathologies with inflammation/fibrosis

Tissue characterisation

Contrast-enhanced techniques

- **Early gadolinium enhancement**
 - Microvascular obstruction: dark, \pm surrounded by LGE, h/o of recent MI
 - LV thrombus: dark, in blood pool, global/regional dysfunction
 - Hyperaemia: increased signal in e.g. myocarditis. Global early enhancement ratio (≥ 4 pathological)
- **Late gadolinium enhancement**
 - Ischaemic pattern
 - Non-ischaemic pattern
- **Post-contrast T1 mapping**
 - Reduced in most pathologies inflammation/fibrosis
 - Derive ECV (%), increased in diffuse fibrosis

Repetition: Which segments of the anterior and posterior mitral valve are closest to the LAA?

- **A1 and P1**

CMR stress imaging: Myocardial perfusion



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- **Exercise - Induces vasodilatation via an endothelium-dependent flow-mediated process**
- **Pharmacological vasodilators - Induces both direct and endothelium-mediated vasodilatation**
 - Dipyridamole
 - Adenosine
 - Regadenoson

CMR stress imaging: Myocardial perfusion



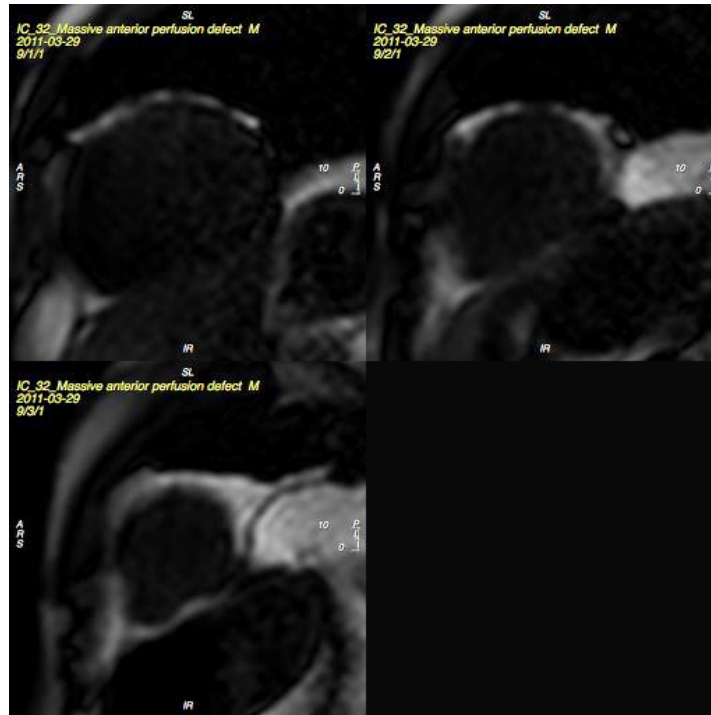
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- **Characterised by the delayed first-pass myocardial perfusion**
- **Based on contrast-enhanced T1-weighted sequences**
- **Usual Protocol involves administering a pharmacological vasodilator stress agent and gadolinium based contrast, followed by image acquisition**
- **These sequences are repeated without the stress agent after a 'wash-out' period**

CMR stress imaging: Myocardial perfusion



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Pharmacological vasodilator agents

- **Dipyridamole - Inhibits adenosine reuptake -> Increases endogenous adenosine**
- **Adenosine – Non-selective Adenosine receptor agonist (*Risk of bronchospasm*)**
- **Regadenoson – Selective adenosine A2A receptor agonist -> Improved tolerance**



Adenosine

- **Short half-life of five seconds**
- **Avoid caffeine intake**
- **Avoid Aminophylline**
- **Avoid Dipyridamole**
- **Severe asthma is contraindicated**
- **High grade heart blocks contraindicated**

Perfusion – Adenosine

- **Refrain caffeine minimum 6 hours**
- **Minimum 3 minutes**
- **140 μ g/Kg/min**
- **Observe heart rate and BP**
- **No haemodynamic response**
 - Increase to 175 μ g/Kg/min (pressure wire)
 - Increase to 210 μ g/Kg/min (nuclear)
- **Splenic switch-off if adenosine response adequate**

Regadenoson

- **Rapid onset (30 seconds) for a longer period (approximately two to five minutes) than adenosine, which permits more convenient administration (injection over 10 seconds)**
- **The half-life for regadenoson has an initial intravenous peak hyperaemia phase of two minutes and a longer intermediate phase of 30 minutes**

Dipyridamole



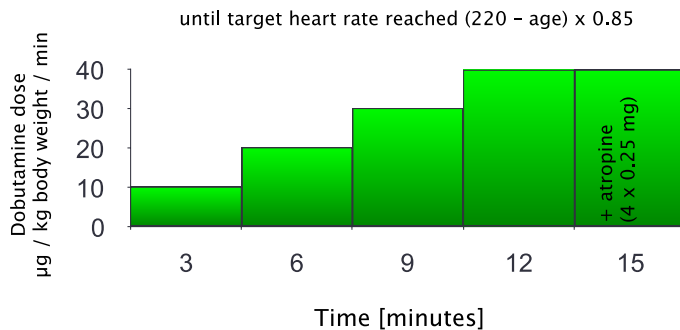
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- **Biologic half-life of dipyridamole is 30 to 45 minutes**
- **Primarily metabolized in the liver, and only small amounts are excreted in urine**
- **Infused at a dose of 140 mcg/kg per minute for four minutes, up to a maximum dose of 0.56 mg/kg**

Dobutamine

- **Positive inotropic**
- **Positive chronotropic**
- **Vasodilation**
- **-> can induce true ischaemia (unlike pure vasodilators)**

Dobutamine

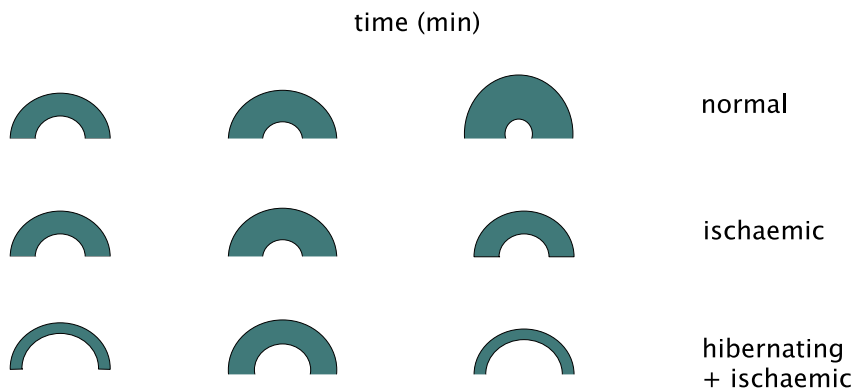


Patient instructions

No β -blockers and nitrates 24 hours prior to the examination

Antidote

β -blocker (esmolol)
0.5 mg/kg as slowly injected bolus, additional bolus of 0.2 mg/kg as needed; sublingual nitroglycerine



Courtesy of Prof E. Nagel

Side effects with pharmacologic stress agents



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Frequency of side effects (percent) with pharmacologic stress agents

	Dipyridamole	Adenosine	Regadenoson	Dobutamine
Chest pain	20	34	7	11
Headache	12	21	26	2
Dizziness	1	7	8	0.3
Nausea	5	5	6	4
Hypotension	5	3	2	5
Flushing	3.4	35	16	0.3
Palpitations	3.2	–	¶	49*
Dyspnea	2.6	19	28	0.3
Paresthesias	1.3	–	¶	12
ST segment changes	7.5	12.5	12	50
Major event	0.3	0.2	0	0.4
Fatal MI	0.05	0	0	0
Nonfatal MI	0.05	0	0	0.2
Bronchospasm	0.15	0.16	¶	NA
Any side effect	47	79	73	76

NA: not applicable.

* Any cardiac arrhythmia as a consequence of dobutamine infusion.

¶ Data not available.

Adapted from: Mahmarian JJ, Verani MS. *Cardiol Clin* 1994; 12:223.

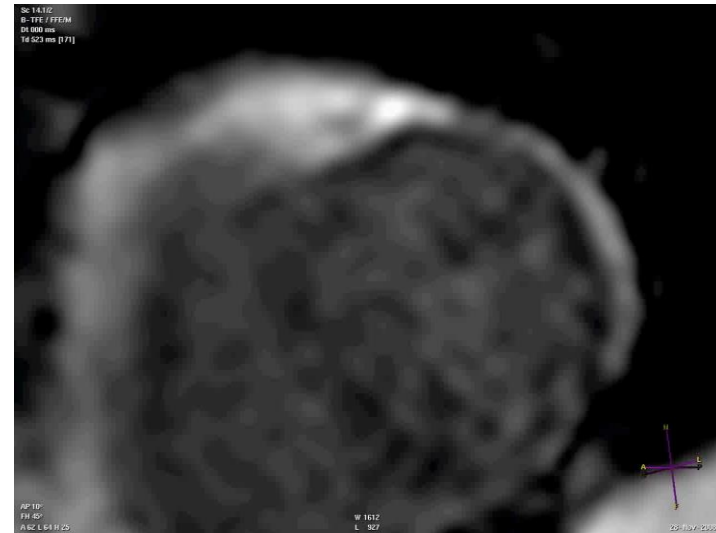
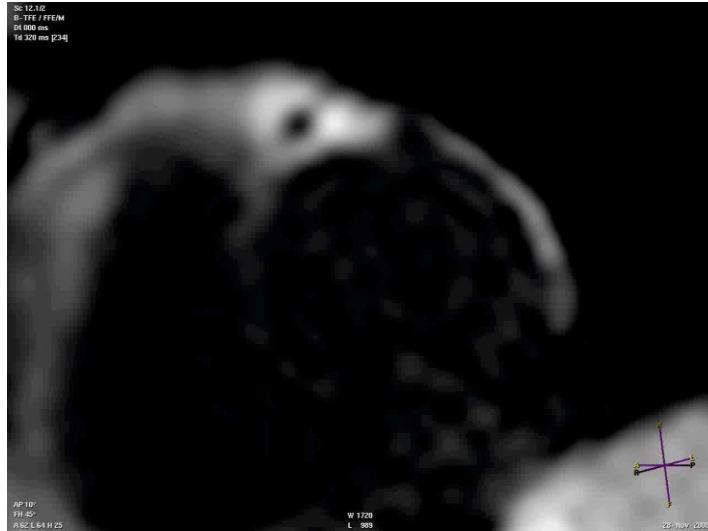
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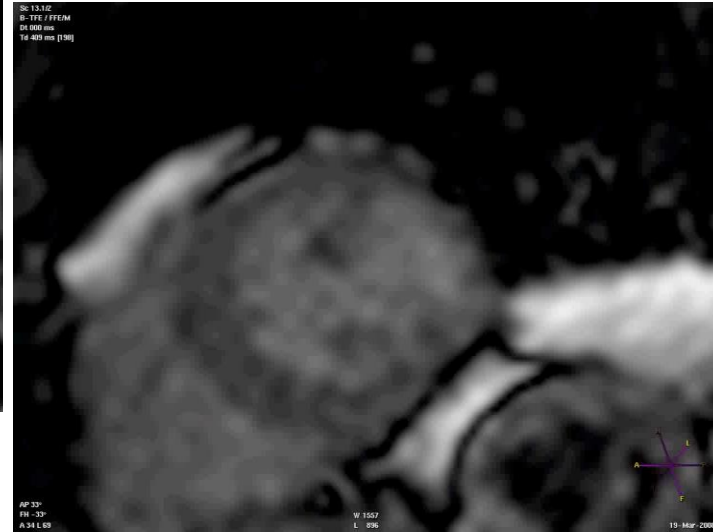
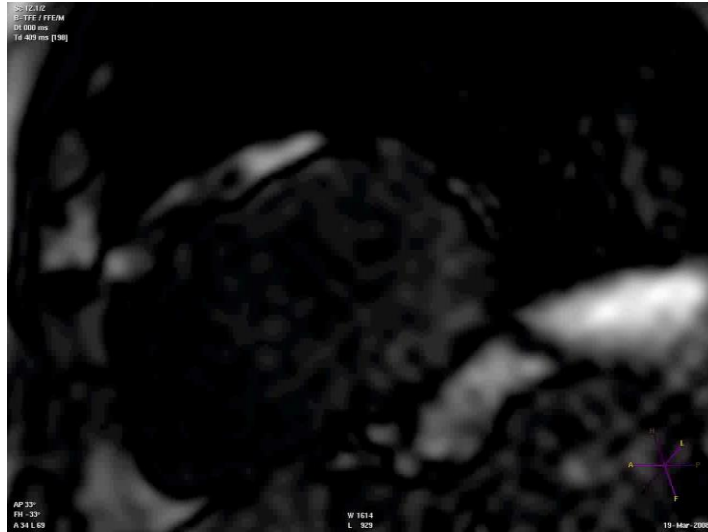
Gad-based chelates

- **Nausea, headaches, taste alteration, parasthaesia 0.4%**
- **Extravasation: low risk vs iodinated agents**
- **Anaphylactoid reactions**
 - Rare
 - Approx 0.03-0.1%
 - Rash, hives, facial swelling
 - Irritated injected veins
- **Very low nephrotoxicity**
- **Nephrogenic systemic fibrosis**

Normal perfusion

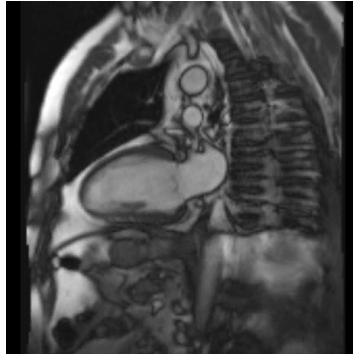


Perfusion - Ischaemia



Dobutamine CMR

Rest



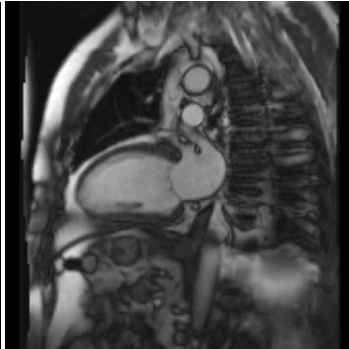
Low dose



intermediate



Peak



Courtesy of Stephen Harden (Southampton)

Blood flow

- **Lectures (physics, valves, congenital)**

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