

CMR References & Recommended Reading

for the technologists section of SCMR

To help you, please find below a useful reference point for researching and learning about cardiovascular magnetic resonance. It's not an exhaustive list, just a starting point. Most items are listed with the most recent at the top. There are 2 parts; each divided into several sections: Part 2 is based on the standardized CMR image acquisition protocols, available at www.scmr.org/documents/scmr_protocols_2007.pdf. This document has many embedded hyperlinks for further reading. For this reason it is better to read this document online.

Part 1: Introduction to CMR

1. *MRI physics*
2. *CMR introduction and textbooks*
3. *CMR official documents*

Part 2: CMR standard techniques and protocols.

CMR general techniques

1. Stress and safety equipment
2. LV structure and function module
3. Gadolinium dosing module.
4. First pass perfusion module
5. Late gadolinium enhancement module

Disease specific protocols

Ischemic heart disease

6. Acute MI
7. Chronic Ischemic heart disease and Viability
8. Dobutamine stress
9. Adenosine stress perfusion

Angiography:

10. Peripheral MRA
11. Thoracic MRA
12. Anomalous Coronary arteries
13. Pulmonary Vein Evaluation

Others

14. Non-ischemic cardiomyopathy
15. ARVC
16. Congenital heart disease
17. Valvular heart disease
18. Pericardial disease
19. Masses

Part 1: Introduction to CMR

1. MRI physics

Online

There are plenty of online physics courses. If you are an SCMR member, see the [members' only online education](#), where there is:

- a [15 module physics course from GE](#)
- a [238 page physics course from Siemens](#).
- a [cardiac anatomy overview by Siemens](#)
- a ['cardiac views' by Philips](#)

see also:

[Revisemri.com](#) also has great interactive and animated tutorials.

[Hull physics lecture series.](#)

<http://www.cis.rit.edu/htbooks/mri/>

<http://www.simplyphysics.com/MAIN.HTM>

<http://www.mritutor.org/mritutor/>

<http://www.mr-tip.com/serv1.php?type=ldir1&dir=MRI%20Physics>

http://web2.uwindsor.ca/courses/physics/high_schools/2006/Medical_Imaging/mriphysic_s1.html

Books

MRI made easy (...well almost). Published by Schering, author Prof Dr Hans H Schild. This is a really great introduction. It can be bought online, or via Schering (now Bayer), who make magnevist, and sometimes give away copies at meetings.

MRI in practice, Catherin Westbrook, Carolyn Kaut Roth, Blackwell publishing; ISBN-13:978-14051-2787-5

The Physics of Clinical MR Taught Through Images. [Val M. Runge](#), ISBN-13: 9781588903228, ISBN-10: 1588903222 Publisher: THIEME NEW YORK

All You Really Need to Know about MRI Physics [Moriel NessAiver](#), ISBN-13: 9780966098204, ISBN-10: 096609820X Publisher: SIMPLY PHYSICS

2. CMR introduction and textbook

Small books:

Cardiovascular Magnetic Resonance Made Easy (Paperback) by Anitha Varghese and Dudley J. Pennell. This is due out October 2007.

Pocket Atlas of Cardiac MRI (Radiology Pocket Atlas) by Pamela K Woodard, Jeffrey J. Brown, and Charles B. Higgins (Paperback - 1 Sep 2004)

An Introduction to Cardiovascular Magnetic Resonance by Raad H. Mohiadin (Paperback - Aug 2002)

Big Textbooks:

Cardiovascular Magnetic Resonance Imaging: A Guide for Fellows in Training (Contemporary Cardiology) by Peter G. Danias (Hardcover - April 2008)
Cardiac Computed Tomography and Magnetic Resonance by John R. Lesser and Robert S. Schwartz (Hardcover - 15 Dec 2007)
Cardiovascular MR Imaging: Physical Principles to Practical Protocols by Vivian S. Lee (Hardcover - 1 Dec 2005)
Clinical Cardiac MRI (Medical Radiology / Diagnostic Imaging) by Jan Bogaert, S. Dymarkowski, and A.M. Taylor (Paperback - Aug 2005)
Atlas of Practical Applications of Cardiovascular Magnetic Resonance (Developments in Cardiovascular Medicine) by Guillem Pons-Llado and Francesc Carreras (Hardcover - April 2005)
Cardiovascular Magnetic Resonance by E Nagel, A.C Van Rossum, and E. Fleck (Hardcover - April 2004)
Cardiovascular MRI and MRA by Charles B. Higgins, Albert de Roos, and Albert De Roos (Hardcover - Sep 2002)
Manning, Warren J., Pennell Dudley J., *Cardiovascular Magnetic Resonance*, ISBN 0-443-07519-0 Churchill Livingstone Publishers, 2002

3. *CMR official documents*

Training and credentialing

[Training in Advanced Cardiovascular Imaging \(Cardiovascular Magnetic Resonance \[CMR\]\).](#)

[Indications for CMR](#)

[SCMR Standardized protocols](#)

[ACR guidelines](#)

[Appropriateness Criteria for CCT and CMR](#)

Part 2: CMR standard techniques and protocols.

See [SCMR Standardized protocols](#) first

CMR general techniques

a. Stress and safety equipment

See ["How I Do" CMR Scanning Safely](#)

Good references:

[Shellock FG, et al.](#) Cardiac pacemakers and implantable cardioverter defibrillators: in vitro MRI evaluation at 1.5-tesla. J Cardiovasc Magn Reson. 2007;9(1):21-31.

[Shellock F. G.](#), Prosthetic heart valves and annuloplasty rings: assessment of magnetic field interactions, heating, and artifacts at 1.5 Tesla. J Cardiovasc Magn Reson. 2001;3(4):317-24

Also see the list on <http://www.mrisafety.com/>. (You must register first)

b. LV structure and function module

See ["How I Do" a CMR Volume Study](#)

And [Cardiac Views](#)

And [Cardiac MRI Morphology](#)

Good references (there are others)

[Maceira AM et al.](#): Normalized left ventricular systolic and diastolic function by steady state free precession CMR. J Cardiovasc Magn Reson. 2006;8(3):417-26.

[Hudsmith LE et al.](#) Determination of cardiac volumes and mass with FLASH and SSFP cine sequences at 1.5 vs. 3 Tesla: a validation study. J Cardiovasc Magn Reson. 2007;9(4):673-9.

[Bellenger NG et al.](#) Comparison of LV ejection fraction and volumes in heart failure by twodimensional echocardiography, radionuclide ventriculography and cardiovascular magnetic resonance: are they interchangeable. Eur Heart J 2000;21:1387-96.

c. Gadolinium dosing module.

See Gd warnings [FDA warning](#) [MHRA warning \(UK\)](#) [Omniscan statement Clin Rad article](#) [JAMA article](#) UK/European advice (27/6/2007) [here](#) review article [here](#)

d. First pass perfusion module

2 presentations to compare:

["How I Do" Myocardial Perfusion](#)

["How we do Perfusion CMR"](#)

e. Late gadolinium enhancement module

See a late enhancement imaging quiz here: [questions](#), [Answers](#)

[How We Perform Delayed Enhancement Imaging](#) here

Disease specific protocols

Ischemic heart disease

6. Acute MI

A few good references:

[Wu KC, et al](#): Prognostic significance of microvascular obstruction by CMR in patients with acute myocardial infarction. *Circulation*. 1998;97:765-72.

[Gerber BL, et al](#): Microvascular obstruction and left ventricular remodeling early after acute MI. *Circulation*. 2000;101:2734-41

[Choi KM, et al](#): Transmural extent of acute myocardial infarction predicts long-term improvement in contractile function. *Circulation* 2001;104:1101-7.

[Kwong RY et al](#) .Detecting acute coronary syndrome in emergency department with CMR .*Circulation*. 2003;107:531-537

See a case [here](#) and [here](#)

7. Chronic Ischemic heart disease and Viability

A few good references:

[KimRJ et al](#), The Use of Contrast Enhanced MRI to Identify Reversible Myocardial Dysfunction. *N Engl J Med* 2000;343: 1445-53

[Kim RJ et al](#). Relationship of MRI delayed contrast enhancement to irreversible injury, infarct age and contractile function. *Circulation* 1999;100:1992-02.

[A. Wagner et al H](#). Contrast-enhanced MRI and routine SPECT perfusion imaging for detection of subendocardial MIs: an imaging study. 2003;361:374-379

Cases [here](#) and [here](#)

Full text review [here](#)

8. Dobutamine stress

See "[How we do Dobutamine Stress CMR](#)"

A few good references:

[Jahnke C et al](#). Prognostic value of CMR stress tests: adenosine stress perfusion and dobutamine stress wall motion imaging. *Circulation*. 2007;115:1769-76

[Wahl A et al](#). Safety and feasibility of high-dose dobutamine-atropine stress CMR for diagnosis of myocardial ischaemia: experience in 1000 consecutive cases.

[Hundley WG et al](#). Utility of fast cine magnetic resonance imaging and display for the detection of myocardial ischemia in patients not well suited for second harmonic stress echocardiography. *Circulation*. 1999;100:1697-702.

9. Adenosine stress perfusion

["How I Do" Myocardial Perfusion](#)

["How we do Perfusion CMR"](#)

A few good references:

[Gebker R et al](#). How we perform myocardial perfusion with cardiovascular magnetic resonance. *J Cardiovasc Magn Reson*. 2007;9(3):539-47.

[Schwitter J et al](#). Assessment of myocardial perfusion in coronary artery disease by magnetic resonance: a comparison with positron emission tomography and coronary angiography. *Circulation* 2001;103:2230-5.

Angiography:

10. Peripheral MRA

[Yuan C et al.](#) Identification of fibrous cap rupture with MRI is highly associated with recent transient ischemic attack or stroke. *Circulation* 2002;105:181–5.

11. Thoracic MRA

See "[How I do CMR of the Aorta](#)"

[Fayad ZA et al.](#) In vivo MR evaluation of atherosclerotic plaques in the human thoracic aorta: a comparison with TOE. *Circulation* 2000;101:2503–9.

[Wentz KU et al.](#) High-resolution MR resonance angiography of hands with timed arterial compression (tac-MRA). *Lancet* 2003;361:49–50.

See a case [here](#)

12. Anomalous Coronary arteries

[Kim WY et al.](#) Coronary magnetic resonance angiography for the detection of coronary stenoses. *N Engl J Med* 2001;345:1909

[Bunce NH et al.](#) Coronary artery anomalies: assessment with free-breathing three-dimensional coronary MR angiography. *Radiology*. 2003;227:201-8.

See [a case](#) here

13. Pulmonary Vein Evaluation

[Dill T et al.](#) Pulmonary vein diameter reduction after radiofrequency catheter ablation for PAF evaluated by contrast-enhanced 3D MRI. *Circulation* 2003;107:845–50.

Others

14. Non-ischemic cardiomyopathy

Full text review [here](#)

A good reference: DCM:

[McCrohon JA et al.](#) Differentiation of heart failure related to dilated cardiomyopathy and coronary artery disease using gadolinium-enhanced CMR. *Circulation*. 2003;108:54-9.

See "[How I do](#)" [CMR in DCM](#)

A Good reference: HCM:

[Moon JC et al.](#) Toward clinical risk assessment in hypertrophic cardiomyopathy with gadolinium cardiovascular magnetic resonance. *J Am Coll Cardiol*. 2003;41:1561-7.

"[How I do](#)" [CMR in HCM](#)

See a case [here](#) and [here](#) and [here](#)

A Good reference: sarcoid

[Smedema JP et al.](#) Evaluation of the accuracy of gadolinium-enhanced CMR in the diagnosis of cardiac sarcoidosis. *J Am Coll Cardiol*. 2005;45:1683-90.

A Good reference: amyloid

[Maceira AM et al.](#) CMR in cardiac amyloidosis. *Circulation*. 2005;111:186-93.

A Good reference: myocarditis

[Mahrholdt H et al.](#) CMR assessment of human myocarditis: a comparison to histology and molecular pathology. Circulation. 2004;109:1250-8.

See a case [here](#)

15. ARVC

A Good reference:

[Sen-Chowdhry S et al](#) CMR in arrhythmogenic right ventricular cardiomyopathy revisited: comparison with task force criteria and genotype. J Am Coll Cardiol. 2006;48:2132-40.

Also "[How I Do](#)" [CMR of ARVC/D](#)

See a case [here](#) and [here](#)

16. Congenital heart disease

See "[How I do](#)" [CMR of repaired Tetralogy of Fallot](#)

Cases [here](#) and [here](#)

Good references:

A full text review [here](#)

17. Valvular heart disease

["How I do CMR of valvular heart disease"](#)

Full text review [here](#)

See a case [here](#)

18. Pericardial disease

see "[How I Do](#)" [CMR in Pericardial Disease](#)

see a case [here](#)

Full text review [here](#)

A good reference

[Francone M et al.](#) Assessment of ventricular coupling with real-time cine MRI and its value to differentiate constrictive pericarditis from restrictive cardiomyopathy. Eur Radiol. 2006;16:944-51.

19. Masses

See cases [here](#) and [here](#) and [here](#)