BSCMR Clinical Standards 2021

Authors:
Dr Niall Keenan and Prof. Saul Myerson
on behalf of the BSCMR Board

Preamble

Cardiovascular magnetic resonance (CMR) is an advanced form of magnetic resonance imaging (MRI), utilising ECG-gating to avoid cardiac motion blurring, and providing some unique cardiac and vascular imaging capabilities. It allows the assessment of anatomy, function and viability of the heart, but can also detect ischaemia and infarction, assess congenital heart disease, heart valve dysfunction and the presence of inherited diseases. However, it requires highly specialised imaging equipment, software and expertise. Quality standards and guidance on best practice are therefore important for maintaining the quality and reliability of the technique.

This guidance updates the 2010 document *Delivering Cardiovascular Magnetic Resonance In the UK* from the British Society for Cardiovascular Magnetic Resonance (BSCMR) and the British Society for Cardiovascular Imaging (BSCI). These guidelines are referred to in this document as "BSCMR/BSCI 2010".

The Society for Cardiovascular Magnetic Resonance (SCMR), based in the USA, is the major international body in CMR and produces useful guidance and standards, principally on the indications and performance of scans, which are available at **www.scmr.org.** This BSCMR standards document is not intended to supplant the SCMR guidance, but instead aims to guide the UK-specific departmental infrastructure, training requirements, and governance frameworks that are appropriate for performing CMR in the UK.

Principal indications

CMR provides a detailed assessment of cardiovascular morphology and function, particularly where complex anatomy is involved and unable to be determined adequately by other imaging techniques. In addition, there are CMR-specific capabilities including tissue characterisation, high-resolution perfusion imaging, and quantification of flow (for valve disease and cardiac shunt lesions). A more comprehensive list of indications is available at: *http://www.scmr.org/page/WhyCMR* and in the SCMR Position Paper (2020) on clinical indications for cardiovascular magnetic resonance.[1] A concise guide to the categories of indication for CMR is included here:

- Cardiovascular anatomy
- Quantification of ventricular volumes, function and mass
- Cardiac flow and shunting
- Valvular heart disease
- Congenital heart disease
- Coronary artery disease (including stress perfusion imaging)
- Myocardial infarction / viability
- Cardiomyopathies, myocarditis, cardiotoxicity, myocardial infiltration, fatty replacement and cardiac transplantation
- Iron storage diseases
- Pericardial disease
- Cardiac tumours and paracardiac masses
- Aorta and great vessels (including contrast / non-contrast angiography)
- Acquired vascular disease

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Promoting appropriateness / recognition of risk

In general, CMR is considered appropriate where it can provide additional information which has the potential to alter the clinical diagnosis (including severity of disease) and/or management of the patient. It is not appropriate to use CMR to confirm previous findings from other modalities, unless uncertainty exists and clarification is required.

CMR is generally safe, and there are no known health risks from the high magnetic fields or radio-frequency pulses used in CMR. Precautions are however required to ensure that no ferro-magnetic objects that may damage the patient or staff if subject to the high magnetic field are brought into the MR scanner room. This excludes some patients with certain types of implants or embedded metal (e.g. shrapnel).

Patients with cardiac pacemakers/defibrillators may be scanned if either

i) The device and leads are MR-conditional (safe to scan under certain conditions), and appropriate programming of the device has occurred prior to the scan. MR conditional devices should be scanned in all major MRI centres, particularly if MR conditional pacemakers are implanted in that centre. They do not require referral to specialist centres. This approach is endorsed by both the British Cardiovascular Society and the Royal College of Radiologists.[2]

ii) Patients with 'legacy' devices that are not MR conditional may undergo CMR scanning if the information from the scan is crucial to the patient's management and outweighs the risks of scanning. This is a specialist area of practice, and in general is carried out in specific centres with the relevant experience and expertise. The following website has more details and support on this topic - *http://www.mrimypacemaker.com*

Access and timeliness – expanding to 7/7 and 24/7 working

CMR is not available in every hospital, as it requires specialist staff, equipment and expertise, and regular practise to maintain skills. It is generally performed in larger hospitals with an established cardiac centre (and should be accessible by every cardiothoracic surgical centre in the UK). Access in different regions is however variable around the UK,[3] and the BSCMR is keen to promote the availability of CMR in every region of the UK, sufficient to meet the NHS England 6-week waiting target for outpatient diagnostics. Inpatient scans should ideally be performed within 48-72 hours, but BSCMR acknowledges that variable demand means this may not be possible in all cases.

CMR is most commonly performed as an outpatient service (~95% of scans) and there are no genuine emergency indications for CMR, as other cardiac imaging modalities are usually more appropriate in this setting. 24 hour provision is therefore not required for clinical need. The provision of CMR is mainly during the working week (Monday – Friday), usually in daytime hours only. An expansion to weekend working allows easier access for many patients and is encouraged. The BSCMR recognises however that expanding the provision of CMR to 7 days a week requires greater numbers of specialist staff, which is difficult to achieve in many areas, and may not be the most appropriate priority for healthcare resources.

Equipment specification / replacement cycle

(see also NHS England Service Specification for CMR [4])

Equipment

MRI scanner

- A fully maintained, shared or dedicated MRI scanner (minimum 1.5 Tesla) with cardiac capability.
- Sufficient magnet access to achieve minimum annual unit numbers (see below)
- Procedures in place to ensure a safe environment and quality.
- ECG gating, patient monitoring (including BP, oxygen saturation), contrast pump.

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For a new CMR installation, BSCMR recommends:

- RF receiver: 16 or more RF channels (torso/body/cardiac receiver array with multiple elements).
- Minimum gradient specifications: 30mT/m, 150mT/m/msec.
- Artefact resistant electrocardiogram (ECG) hardware/software (e.g. vectorcardiogram).

Specific cardiac sequences

Minimum:

- Steady State Free Precision (SSFP) cine imaging (bFFE, FIESTA or TrueFISP).
- Black blood prepared T1/T2 weighted turbo spin echo (TSE) sequences with/without fat saturation.
- Single shot black blood prepared TSE sequences (e.g. half-fourier acquisition single shot (HASTE)).
- Phase contrast flow/velocity sequences with quantification.
- Large vessel angiography.
- Late gadolinium enhancement imaging.

Recommended:

- Real-time cine sequence.
- Perfusion sequences.
- T1 / T2 mapping.
- Alternative late enhancement sequences (3D, phase sensitive inversion recovery (PSIR), inversion recovery prepared SSFP (IR_SSFP)).
- 3D whole heart.
- Other sequences (Short Tau Inversion Recovery (STIR), tagging, coronary sequence, cardiac iron/T2*).

Specialist software for analysis

Minimum:

- Volumetric quantification of left and right ventricular volumes and mass.
- Quantification of velocity and flow.

Additional software may include:

- Complex 3D angiographic reconstruction, perfusion.
- Late enhancement quantification.
- LV analysis with long axis function, tagging analysis.
- T1/T2/T2* mapping displays.
- Quantitative perfusion maps.

Other equipment

- Resuscitation facilities (including defibrillation/oxygen/suction).
- An emergency trolley with specific drugs to deal with potential reactions to IV contrast media and stressors.

- MR safe wheelchair and trolley.
- MR compatible monitoring equipment such as: non-invasive blood pressure and saturation of peripheral oxygen (SpO2) monitoring equipment.
- MR compatible power injectors and infusion pumps.
- Phantom/s for magnet calibration and quality control.

Replacement Cycle / Servicing

BSCMR recommends replacement of MR scanners over 10 years old, in line with the NHS England and NHS Improvement report from November 2019 "Transforming imaging services in England: a national strategy for imaging networks" *https://improvement.nhs.uk/documents/6119/Transforming_imaging_services.pdf*

On page 13 this states: "Beyond this age equipment is less efficient and prone to breakdown" Current guidance from the Biomedical Engineering Advisory Group (BEAG) recommends such equipment should be replaced at 7 years.

A service contract should be in place for the scanner(s), with at least an annual service.

Workforce descriptors and credentialing / job planning / education and training

Workforce Descriptors

A CMR unit should have:

- A nominated Director/Clinical Lead with appropriate training accreditation and Continuing Medical Education/ Continuing Professional Development, who is on the UK Specialist Register for Cardiology, Radiology, Nuclear Medicine or who is subspecialty accredited in CMR.
- A nominated lead CMR Radiographer, ideally dedicated to this role. The position should offer enough time and support to ensure quality clinical care is delivered to patients in a safe and effective environment with appropriate clinical governance. They will also be responsible for (or delegating) equipment management and maintenance.
- Appropriately trained medical and technical staff to deliver the service; these will be familiar with the local rules and procedures for safe working practice in the MR environment.
- Arrangements for scientific and technical input from a medical physics expert appropriately trained in CMR methods.
- Arrangements for appropriate staff development, (education, training, accreditation, continuing professional development (CPD), revalidation).
- Current or planned (within 3 years) total activity sufficient to maintain individual accreditation.
- See also information below regarding national CMR activity.

Credentialing / training

CMR is an expanding and fast developing field. Therefore, training of staff and maintenance of up-to-date CMR practice is an important part of delivering a quality service. The main certification bodies are SCMR and the European Association of Cardiovascular Imaging (EACVI). EACVI also administer a credentialing examination in CMR, as does the Certification Board of Cardiovascular Magnetic Resonance (CBCMR) in the USA. Certification in CMR is stated at level 1, 2, and 3. The requirements for these levels are provided at: *https://scmr.org/page/Training*

Level 1 certification involves only an awareness of CMR techniques and is not appropriate for the independent performance of CMR. Level 2 indicates independent competency in a centre headed by a lead (level 3, or advanced) practitioner.

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Individual training, accreditation and CPD

Technologists:

- At least 6 months of full-time experience in CMR (at a centre performing >300 CMR cases/year) or 12 months of training if the facility performs between 50-300 CMR exams per year.
- At least 30 hours of CMR-related coursework.
- Coursework must be completed at a standard commensurate with undergraduate study, ideally in accredited CME/CEU programs, or accredited CMR training programs. Recognised registered MRI Technologists may be exempt from these requirements upon successful documentation of previous work.

Physicians:

The Director of the CMR lab must:

- Hold one of: SCMR or EACVI Level 3 accreditation, completed advanced modules (formerly known as sub-specialty training) in CMR, and/or subspecialty degree (advanced modules) in cardiac radiology or equivalent;
- Be a consultant with a certificate of completion of training in cardiology or radiology, who is on the UK Specialist Register and is revalidated/licensed to practice in the UK.

Other CMR consultants within a centre should hold at least level 2 accreditation / equivalent competency.

CMR training

BSCMR supports the UK higher specialist training curricula in cardiology and radiology which include modules in CMR. This should be completed to level 1 for all trainees, level 2 for those intending to perform CMR, and level 3 for those planning to lead a CMR unit.

Achievement of CMR training should be based on an assessment of competency, and not merely time spent in training (although this is also important). Minimum scan numbers are just that – a minimum to ensure a basic level of broad experience, and are not a substitute for competency assessment.

BSCMR recommends that for advanced modules/specialist training, at least half of such training should be done in a high volume (>500 cases per year) centre.

Revalidation and CPD:

The CMR physician will be required to maintain competence including revalidation. For level 2 and 3 accreditation, the SCMR requirements are currently:

- Level 2: 20 hours of coursework and primary interpretation of 100 cases every two years.
- Level 3: 40 hours of coursework and primary interpretation of 200 cases every two years.

Departmental quality approval

The quality assurance programme will be defined in a written policy with regular audit of all policies and procedures. Radiographers/technologists and medical physics staff will be fully involved in this process with appropriate analysis and monitoring of the data obtained. Guidance relating the quality control measures has been provided by the Institute of Physics and Engineering in Medicine (IPEM) Report 80: Quality Control in Magnetic Resonance Imaging. 2002
http://www.ipem.ac.uk/ipem_public/article.asp?aid=634.pdf

A written policy will be in place for CMR equipment image quality testing. Signal and geometric parameters should be monitored. Information will be provided by the MR safety advisor or medical physics expert in MRI.

For units performing myocardial T1/T2 mapping, a phantom should be used for quality control, in line with the SCMR consensus statement.[5]

The unit must have an effective framework for the safe use of the MR equipment. Detailed guidance is available in the MHRA Device Bulletin, DB2007, Dec 2007: Safety Guidelines for Magnetic Resonance Imaging Equipment in Clinical Use, Section 5.3.3. These guidelines cover all aspects of safety including unit design and maintenance.

Each unit should have a specified MR responsible person (in most cases the director or the superintendent radiographer of the unit) who is in charge of MR safety.

Minimum number of scans for a CMR centre

CMR requires a high degree of operator input and expertise during scanning. The diverse nature of clinical indications and findings in clinical context means that CMR reporting benefits from minimum numbers to maintain quality and competency, even in trained staff. BSCMR recommends that institutional CMR numbers are

- a minimum of 300 clinical cases per annum.
- 500 clinical cases per annum for training centres.

Centres performing under 500 cases per year can undertake level 1 (core) training, and some advanced modules/sub-specialty training – but the advanced sub-speciality trainee will require additional experience at an accredited training centre for at least one year (half of their advanced modules / sub-specialty training).

If a centre is performing <300 cases per year, BSCMR recommends:

- Robust plans to achieve this minimum standard within 3 years. The unit should have a formal link with a high volume centre to ensure consistent quality until such time as 300 scans per annum are being performed. This will include access to joint reporting facilities, participating in CMR audit and governance meetings and may include scanning/reporting sessions at the high volume centre.
- If 300 cases per year cannot be achieved within 3 years, the centre stops CMR scanning and transfers the activity to a high volume centre.
- Less than 300 cases per year is acceptable for a site where an established CMR team (performing >300 cases/year) conduct outreach lists.

The national requirement for the number of CMR scans should also be considered when planning / expanding CMR services – see national commissioning service standards document.[6]

Patient / staff safety / emergency procedures / escalation – modality-specific risks

The main element of staff and patient safety specific to CMR is the area of magnet safety, referred to above and covered in detail in the Medicines and Healthcare products Regulatory Agency (MHRA) guidance: *Safety Guidelines for Magnetic Resonance Imaging Equipment in Clinical Use. Relevant safety information for users of magnetic resonance imaging (MRI) equipment in clinical use.* v4.2 March 2015
https://www.gov.uk/government/publications/safety-guidelines-for-magnetic-resonance-imaging-equipment-in-clinical-use
Robust training and safety protocols around the magnet are mandatory.

Patient safety

At least 2 members of staff will be present during scanning, both of whom will be trained in magnet safety, and at least one of whom will be appropriately trained in CMR scanning. For stress imaging, at least one available member of staff will be medically trained and up-to-date to deal with potential complications (including a valid Advanced Life Support or Immediate Life Support qualification).

RF exposure for many routine clinical CMR scans will fall within a higher level scanning mode ('first level' controlled scanning), which is usually defined as a specific absorption rate (SAR) of >2W/kg for whole body scanning, averaged over 6 minutes. Most scanners are limited to 4W/kg (within level 1 controlled mode). All scans incurring an experimental mode of exposure (i.e. above controlled mode scanning) – usually >4W/kg - must have ethical approval from the local institutional ethics committee.

Scanning pregnant patients will be considered on a risk/benefit basis. There are no known risks to the foetus or mother from MRI scanning, but data are limited.

Patients with severe renal failure (eGFR <30ml/min), especially those on dialysis, have a small risk of nephrogenic systemic fibrosis (NSF) from gadolinium contrast. It is an exceptionally rare condition, so the risk is extremely low, but departments should have a defined procedure for managing patients with severe renal failure. In most cases, the benefit from CMR may outweigh the small risk from NSF, but a defined approach is required for these patients.

Emergency Procedures

Emergency procedures will be reviewed and audited at regular intervals (at least annually) :

- Cardiac arrest
- Fire / flooding
- Magnet quench
- Decreased oxygen level
- Power loss / loss of lighting

Reporting recommendations

All clinical CMR scans should have a report generated. Responsibility for CMR reports always lies with a consultant, who should sign/approve the report. However, reporting can be delegated by the consultant under the following conditions:

- A level 3 CMR accredited physician will be available to discuss cases when needed.
- The reporter is a trainee with level 2 or higher accreditation.

CMR reporting should be integrated with the clinical scenario and should conform to appropriate international standards (e.g. SCMR standardised reporting guidelines[7]) and/or adjusted to local UK needs.

CMR practitioners should participate in the clinical multidisciplinary team meetings where diagnostic and clinical information (including CMR) are discussed to inform patient management, in order to provide appropriate expertise in the interpretation of the CMR scans.

A CMR unit should have a clinical review meeting at least fortnightly, at which CMR scans can be reviewed and/or colleague advice sought. CMR practitioners reporting in isolation is discouraged. If only one reporting level 3 physician is present in a unit, that unit should have a formal link with a separate centre or reporting physician at least six times a year. Where a cardiologist/nuclear physician is reporting alone, radiology advice should be available to discuss extra-cardiac pathology; similarly expert cardiology advice should be available when radiologists report alone.

Reporting times

BSCMR recommends that inpatient CMR scans should be reported by the next working day, and outpatient scans should be reported ideally within 2 working days, and in any case within 2 weeks. Regular audit of reporting times is recommended as a quality performance indicator.

Interdependencies with other services

Cardiology/Radiology Interaction

Please see above under reporting.

Hub and Spoke

Lower volume centres (as defined above) should establish links with high volume CMR reference centres for reporting of more complex and/or borderline cases (e.g. some cardiomyopathy or myocarditis cases) with appropriate image transfer, and ideally joint CMR review sessions. This could be established as a "hub-and-spoke" model to reduce patient journeys to reference centres.

Super-specialist services

Adult Congenital Heart Disease (ACHD)

Patients with all but the simplest congenital heart disease should generally be imaged in a CMR centre with considerable experience of ACHD imaging, often in a designated ACHD centre. Patients with simple congenital heart disease (e.g. bicuspid aortic valve, straightforward coarctation) can be scanned locally if expertise permits. If a patient is found to have previously unrecognised complex congenital lesion(s) during a scan at a non-ACHD centre, the scan should be completed as far as possible, and further imaging performed if necessary in the future at an ACHD centre.

Data management – storage and transfer, image archiving, implementation of the General Data Protection Regulation (GDPR)

All images should be stored/archived in accordance with standard NHS approaches. This includes a suitable storage set-up including back-up archive, with appropriate access to clinicians, and security for data protection.

Access to the NHS IEP (Internet Exchange Portal) or other secure image transfer systems is strongly recommended.

Modality-specific incorporation of NICE pathways / interdependencies with other services

NICE Clinical Guideline (CG) 95: Chest pain of Recent Onset: Assessment and Diagnosis (2010 updated 2016) states:

1.3.4.4 For patients with confirmed CAD (for example, previous MI, revascularisation, previous angiography), offer non-invasive functional testing when there is uncertainty about whether chest pain is caused by myocardial ischaemia.

1.3.6.1 When offering non-invasive functional imaging for myocardial ischaemia use:

- myocardial perfusion scintigraphy with single photon emission computed tomography (MPS with SPECT) *or*
- stress echocardiography *or*
- first-pass contrast-enhanced magnetic resonance (MR) perfusion *or*
- MR imaging for stress-induced wall motion abnormalities.

Take account of locally available technology and expertise, the patient and their preferences, and any contraindications (for example, disabilities, frailty, limited ability to exercise) when deciding on the imaging method.

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Modality specific challenges to delivery (e.g rural areas / district general hospitals / Devolved Nations)

BSCI/BSCMR made a detailed projection of the likely need of CMR in the UK which was followed by NHSE 2013/4. In the original document the estimates are made by scan indication, but the overall estimate was that the CMR need is 2275 scans per million adults per year, approximately equivalent to 52 full time CMR magnets doing 2250 scans per year in the UK.

The BSCMR 2019 survey indicates that there are currently 82 active CMR units in the UK, but there is significant geographical variation in CMR-enabled magnets, CMR volume and waiting times for scans (www.bscmr.org/cmr-provision-in-the-uk).

Our recommendation is that every cardiology department should have access to a CMR service, and that the NHSE diagnostic target of 6 weeks from referral to scan performed should be used as the benchmark / key performance indicator across the UK.

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