

**United Kingdom Standards for Non-invasive Cardiac Imaging
Recommendations from the Imaging Council of the British Cardiovascular Society**

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1 **ABBREVIATIONS**

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3	BCS	-	British Cardiovascular Society
4	BSEcho	-	British Society of Echocardiography
5	BSCCT	-	British Society of Cardiac Computed Tomography
6	BSCMR	-	British Society of Cardiovascular Magnetic Resonance
7	BNCS	-	British Nuclear Cardiology Society
8	CCT	-	Cardiac computed tomography
9	CMR	-	Cardiovascular magnetic resonance
10	CPD	-	Continuing professional development
11	CQC	-	Care Quality Commission
12	CTCA	-	Computed tomography coronary angiography
13	Echo	-	Echocardiography
14	GMC	-	General Medical Council
15	MDM	-	Multi-disciplinary meeting
16	NICE	-	The National Institute for Health and Care Excellence
17	PACS	-	Picture archive and communication systems
18	PET	-	Positron emission tomography
19	RIS	-	Radiology information systems
20	RCR	-	Royal College of Radiologists
21	SPECT	-	Single photon emission computed tomography
22	TTE	-	Transthoracic echocardiography
23	TOE	-	Transoesophageal echocardiography

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1 **Introduction**

2 Heart and circulatory diseases affect more than seven million people in the UK. Furthermore, they
3 cause 170,000 deaths each year, which equates to more than a quarter of all deaths. The resulting
4 annual healthcare costs amount to £9 billion. The ageing and increasing population together with
5 improved survival rates from heart and circulatory diseases mean that the importance and impact of
6 these conditions will only rise in the future[1].

7 Non-invasive cardiac imaging is a critical element of contemporary cardiology practice. Progressive
8 improvements in technology over the last 20 years have increased diagnostic accuracy in all
9 modalities and led to the incorporation of non-invasive imaging into many standard cardiac clinical
10 care pathways. Cardiac imaging tests are requested by a variety of healthcare practitioners and
11 performed in a range of settings from the most advanced hospitals to local health centres. Imaging is
12 used to detect the presence and consequences of cardiovascular disease, as well as to monitor the
13 response to therapies. For example, non-invasive imaging through computed tomography coronary
14 angiography (CTCA) has largely replaced invasive coronary angiography as first-line testing for
15 stable chest pain of possible cardiac origin. The field is fast-moving: increasing microprocessor speed
16 and the use of artificial intelligence is likely to see further rapid evolution in the next decade.

17 The previous UK national imaging strategy statement which brought together all of the non-invasive
18 imaging modalities was published in 2010. At that time, CTCA was not a fully mature technology
19 nor was cardiovascular magnetic resonance (CMR) widely used in mainstream clinical practice.

20 The changes in practice and resulting large increases in demand for advanced cardiac imaging since
21 the document's publication have highlighted a number of issues and challenges relating to cardiac
22 imaging in the UK which include:

- 23 ● Wide geographic inequalities in provision
- 24 ● Disparate clinical delivery settings
- 25 ● National variability in infrastructure
- 26 ● Multiple overlapping indications
- 27 ● Multiple approaches to training and competence assessment

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29 For the purposes of this document, non-invasive imaging modalities are divided into four –
30 echocardiography, cardiac computed tomography (CCT), nuclear imaging, and CMR – on the basis
31 of their underlying technology (Figure 1).
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33 The purpose of this document is to collate contemporary standards developed by the modality-
34 specific professional organisations which make up the British Cardiovascular Society (BCS) Imaging
35 Council, bringing together common and essential recommendations. The development process has
36 been inclusive and iterative. Imaging societies (representing both cardiology and radiology) reviewed
37 and agreed on the initial structure. A writing group representing the four specialist societies (BSEcho,
38 BSCMR, BSCCT, BNCS) generated an initial set of standard headings. Modality-specific content
39 was generated by each society. The writing group then divided this content into common themes and
40 modality-specific guidance. Finally, a panel of senior clinical, NHS and patient representatives
41 reviewed and critiqued the document for applicability. The final document therefore represents a
42 position, which has been generated inclusively, presents rigorous standards, is applicable to clinical

1 practice and deliverable.

2 This document will be of value to a variety of healthcare professionals including

- 3 ● Imaging departments who wish to ensure that they are meeting contemporary best practice
- 4 standards.
- 5 ● NHS or other Health Care Providers that wish to evaluate the quality of the services they
- 6 provide.
- 7 ● Regulatory bodies, which in the UK include the [Care Quality Commission](#) (CQC)[2], and
- 8 initiatives like [Getting It Right First Time](#) (GIRFT)[3], which evaluate a service against an
- 9 agreed set of standards.
- 10 ● Commissioners and other purchasers of services, who wish to ensure that purchased services
- 11 are properly configured and meet agreed professional standards.
- 12 ● Service users, i.e., patients, and their relatives.

13 These standards are applicable directly to departments within the United Kingdom, and although

14 there are many differences between UK practice and practice elsewhere in the world (outlined in

15 Table 1), we believe many of the standards are applicable to health care systems in general are not

16 limited by national boundaries.

17 **TABLE 1: How imaging in the United Kingdom (UK) differs from other countries.**

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Domain	UK Imaging	EU and the Americas
Reimbursement	Primarily state-funded (NHS)	Primarily insurance or direct to patient
Workforce	Fewer imaging cardiologists and specialist radiologists	More imaging cardiologist and specialist radiologists
Credentialing	Optional accreditation	Board certification
Protocols and guidelines	Nationally government derived NICE guidelines	European Society or American College clinical guidelines
CMR	Highly developed integration into clinical care	Patchy integration into clinical care
Echocardiography	Physiologist / clinical scientist primary reporter	Physician / Cardiologist primary reporter
Cardiac CT	Nationally mandated NICE CG95 for new onset chest pain	Clinical guideline-based pathways to a variety of imaging techniques
Nuclear cardiology	Low level of cardiology involvement / predominantly radiology driven	Greater cardiology involvement

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1 **Cardiovascular Imaging Modalities**

3 ***Echocardiography***

4 Echocardiography (echo) uses ultrasound to create two-dimensional (2D) and three-dimensional (3D)
5 images of the heart (and aorta), which can be used to assess anatomy, function, and blood flow.
6 Images are most commonly non invasively - transthoracic echo (TTE). Higher definition images can
7 be acquired by the insertion of an echo probe into the oesophagus, transoesophageal echo (TOE).
8 Echo machines range from high-end equipment, which has all current echo capabilities through to
9 simple hand-held devices, which are limited to the acquisition of moving images and assessment of
10 blood flow. This diversity makes clinical standards critically important to ensure consistent quality
11 services.

12 Echocardiography has the advantage over other cardiac imaging techniques of high spatial and
13 temporal resolution, which means that it can visualise small and fast-moving structures. It is,
14 therefore, widely used to assess ventricular and heart valve function, with other tests of cardiac
15 function, notably CMR, reserved to answer questions concerning cardiac structure or function, which
16 are unresolved by echo. Machines are highly portable, so imaging can be delivered in virtually any
17 healthcare setting, whether hospital-based or in the community. Hand-held echo devices facilitate
18 emergency bedside scanning for rapid diagnosis or exclusion of conditions such as cardiac tamponade
19 and severe left ventricular systolic dysfunction. Echocardiography does not involve the use of
20 ionising radiation.

21 Echocardiography is limited by low quality images in a minority of scans due to poor acoustic
22 windows (related either to the chest wall, soft tissue, or lung tissue interfering with the ultrasound
23 beam). This means that there is a higher degree of variability in image quality between studies than
24 with other imaging modalities in some cases.

26 ***Cardiac computed tomography (CCT)***

27 Technological developments in detector design and micro-processing have transformed the clinical
28 applications of CCT. The technique uses contrast-enhanced ECG-gated CT scanning to depict the
29 heart and its related structures (including the aorta) motion-free with a high degree of geometric
30 accuracy. CTCA cannot only visualise severe coronary artery obstruction, it is also capable of
31 detecting early stage, non-obstructive atheromatous disease. CCT image quality is susceptible to
32 artefacts related to irregular heart rhythms and respiration, and it is less accurate in patients with
33 heavily calcified coronary arteries.

34 CCT has been adopted by the National Institute for Health and Care Excellence (NICE)[4] as the
35 entry investigation for the detection of coronary artery disease in stable patients. This has resulted in
36 challenges for national implementation, with a shortage in both appropriate CT scanners and the
37 personnel to operate them.

39 ***Nuclear cardiology***

40 Nuclear cardiology is a group of investigations, which uses radio-isotopes to elucidate different
41 aspects of heart function. The method of imaging can be divided into “conventional” single photon
42 emission computed tomography (SPECT), and positron emission tomography (PET). SPECT has a
43 long history and strong evidence base for the investigation of coronary artery disease, while PET is
44 becoming an important part of the management of a range of cardiac diseases. Specific clinical
45 applications of these investigations include the detection of myocardial infarction and/or inducible

1 myocardial hypoperfusion/ischaemia, assessment of left ventricular function (less relevant these days
 2 following the widespread availability of echo and increasing availability of CMR), and the detection
 3 of myocardial inflammation. All nuclear cardiology techniques expose patients to ionising radiation
 4 and they lack spatial resolution when compared to other imaging techniques.

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 6 **Cardiovascular magnetic resonance (CMR)**

7 CMR is an advanced form of magnetic resonance imaging, which utilises ECG-gated image
 8 acquisition to minimise cardiac motion blurring. It allows the assessment of cardiac anatomy,
 9 function and viability of the myocardium. It is unique amongst imaging techniques in its ability to
 10 provide detailed information about tissue composition. CMR can be used to detect inflammation,
 11 fibrosis, infarction, inducible hypoperfusion/ischaemia, and to assess congenital heart disease, heart
 12 valve dysfunction and the presence of inherited myocardial diseases. Access to CMR is increasing,
 13 but it remains a relatively specialist technique so the funding streams (in England) are through
 14 specialised commissioning. While there is currently a limited number of centres which have the
 15 infrastructure and caseload to deliver CMR to an acceptable quality, improvements in technology
 16 should help to enable its wider dissemination.

17
 18 **TABLE 2: Advantages of different imaging modalities.**

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	Echocardiography	Cardiac CT	Nuclear Imaging	CMR
Portability	++	not	not	not
Patient ease	+++	++	++	+
Access	+++	++	+ / ++	limited, but increasing
Radiation	none	++	+++	none
Cost	£	££	££	£££
Some unique features	<ul style="list-style-type: none"> - High temporal and spatial resolution - easily employable in peri-operative setting - Limited by image quality - Mature technique 	<ul style="list-style-type: none"> - High spatial resolution - Isotropic datasets (3D) - Excellent blood tissue interface - Tissue discrimination 	<ul style="list-style-type: none"> - Tissue tracers can be used for a wide variety of indications. - Mature technique 	<ul style="list-style-type: none"> - Scar imaging - Detection of iron - Quantification size and function - Tissue discrimination

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 21 **Cardiac imaging – integration into the patient journey**

22 There is extensive overlap between modalities in their ability to answer the same clinical questions,
 23 for example, whether or not there is inducible myocardial ischaemia. The selection of the most
 24 appropriate imaging technique is a balance between the specific functionality of the modality, the
 25 aptitude of the local service, availability, waiting times, radiation dose, and patient preference. It is
 26 important that the needs of the patient remain at the centre of the diagnostic journey and guide service
 27 development.

1 **Assuring quality across cardiac imaging modalities**

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3 Each imaging department and modality will adopt processes individualised to its local circumstances,
4 there are areas of commonality, which must form part of any quality framework. There is universal
5 agreement that quality assurance must be a central part of the operation of an imaging department
6 and that this should be reflected in the job planning of those concerned.

7 The essential components which all departments should be able to demonstrate are:

- 8
- 9 ● the attainment and demonstration of appropriate skills,
 - 10 ● continuing professional development (CPD) in order to maintain and enhance skills,
 - 11 ● audit and quality improvement,
 - 12 ● learning from discrepancy incidents and
 - 13 ● peer-to-peer evaluation (for example, systematic second over-read audit by second reporter).
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15 This document supports departments adopting an Imaging Quality Framework along the lines of the
16 originally developed process for echocardiography by the BSE and described as the [Echo Quality](#)
17 [Framework \(EQF, Figure 2\)\[5\]](#) This brings together many of these themes, and links them in a
18 continuous cycle aimed at improving all aspects of the service including echocardiographic imaging
19 quality, reproducibility, education and training and, customer (patient or referrer) satisfaction. The
20 EQF process is applicable to many imaging disciplines.

21
22 The RCR provides [comprehensive standards](#)[6] including the 2019 document on [Quality Standards](#)
23 [in Imaging \(QSI\)](#)[7], as well as guidelines for learning from events and discrepancy. QSI is
24 recognised by NHS England and the CQC. The 2020 Radiological Events and Learning Meetings
25 ([REALMs](#))[8] guideline provides a roadmap for how departments should learn from events, errors
26 and discrepancies, including outlining the frequency of meetings, and the expected rate of attendance
27 for individual radiologists. It mandates an anonymous discrepancy review process, as well as the
28 evaluation of the output of peer-to-peer evaluation processes (systematic over-reads). The role of the
29 chair of the meetings is clearly defined, and guidance is provided for the conduct of both the chair
30 and meetings in order to promote a “blame-free culture”. The process outlines the relationship
31 between [peer review](#)[9] and [duty of candour](#)[10], the latter being a GMC imperative, which may be
32 triggered as a result of peer-to-peer or discrepancy processes.

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34 **Credentialing of practitioners**

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36 In the UK all medical practitioners must comply with the overarching framework of the General
37 Medical Council ([GMC](#)) for specialty training (through the Joint Royal Colleges of Physicians
38 Training Board [JRCPTB][11] or the Royal College of Radiologists [[RCR](#)][12], according to
39 specialty) and with maintenance of professional standards through [revalidation](#).

40
41 Many bodies including the British Society of Echocardiography (BSE), the European Association of
42 Cardiovascular Imaging (EACVI), the British Society of Cardiovascular Imaging (BSCI)/British
43 Society of Cardiac Computed Tomography (BSCCT), and the Society for Cardiovascular Magnetic
44 Resonance (SCMR) offer accreditation in individual imaging modalities. Such accreditation is a

1 convenient way for an individual to demonstrate the achievement and maintenance of agreed
2 standards, but this should not be regarded as the only way to demonstrate competence or regarded as
3 mandatory for clinical practice in the field. The GMC is currently exploring the use of a
4 “credentialing” process in areas where there is a) a need to ensure patient protection which cannot be
5 met through other means; b) a demonstrable service need; c) feasibility of developing and maintaining
6 the credential; and d) support for the credential from a recognised authoritative body in the field[13].
7

1 **Section 1: General service requirements**

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3 This section describes requirements that are applicable to all four imaging modalities. Each imaging
4 modality has its own intrinsic characteristics (Table 2). More detailed and modality specific
5 recommendations are described in subsequent sections.
6

7 ***Indications***

- 8 ● A locally agreed list of common indications should be available with recommended diagnostic
9 pathways, which include imaging. A local system to ensure appropriate triage should be
10 available.

11 ***Access***

- 12 ● Timely access to appropriate diagnostic modalities should be available within an organisation
13 or else provided by a planned regional network solution. Where an investigation forms part
14 of an urgent or emergency care pathway, it should be available either on a seven-day per week
15 or 24-hour a day basis as required.

16 ***Equipment***

- 17 ● All equipment used for cardiac imaging purposes should be set-up appropriately for cardiac
18 work including availability of necessary hardware and software modifications.
- 19 ● Imaging equipment typically has a 7-10-year lifespan. There should be a defined replacement
20 cycle, ideally with a planned seven-year replacement schedule, and no device should be in
21 use for more than 10 years.
- 22 ● There should be appropriate arrangements for the timely servicing and care of all equipment.
23 For equipment essential to out-of-hours diagnosis, service contracts should include the
24 potential for weekend repair.
- 25 ● Software for reviewing and reporting cardiac imaging studies such as Radiology Information
26 Systems (RIS) and Picture Archive and Communication Systems ([PACS](#))[14], etc., should be
27 integrated so that imaging and associated reports for other modalities can be referenced (e.g.,
28 echo images and reports should be available when reporting CMR scans).
- 29 ● The organisational imaging solution should permit the viewing of primary images in any area
30 where clinical decisions incorporating the imaging are being made, (e.g multidisciplinary
31 team meetings (MDMs)[15].
- 32 ● Reporting solutions, including tools for quantification of cardiac imaging studies, should be
33 integrated into a seamless reporting workflow (i.e., they should not require separate
34 workstations and image transfers), and the results of functional evaluations, etc., should be
35 transferable into RIS/PACS and the electronic patient record.

36 37 ***Workforce descriptors***

- 38
39 ● Healthcare professionals undertaking and/or reporting cardiac imaging should be able to
40 demonstrate appropriate training and maintenance of knowledge and skills through regular
41 practice and validated CPD.
- 42 ● There should be an agreed expectation regarding the number of cases performed during an
43 imaging session. This should be individualised according to the complexity of cases
44 encountered within the relevant unit.

- There are no statutory board examinations in imaging in the UK. For some practitioners, especially cardiologists, accreditation and revalidation is the basis for demonstrating competence. Radiologists may cover many organ systems and continuing competence in the cardiac imaging modality should be part of their CPD, and their annual appraisal and five-yearly revalidation processes.
- There should be a designated clinical lead for the service who ensures a system is in place for reviewing requests and reports, audit, quality control, protocols for imaging and urgent clinical review in response to abnormal findings.

Departmental clinical standards

- There should be a standard operating procedure (SOP) against which all aspects of service delivery can be compared and audited.
- The management of the department should be governed by written documentation, which, at a minimum, should include staff training, emergency procedures, radiation protection, and escalation (according to local rules).
- There should be an agreed and verifiable audit program. Suggested audit topics include the eight ‘best practices’ relating to radiation exposure identified by the International Atomic Energy Agency and their radiation-related quality index (QI) indicating the number of best practices used by a laboratory[16], satisfactory stressing, downstream testing, and correlative imaging.
- A clear system for ensuring the appropriateness of imaging referrals should be in place.
- A clear system for the escalation of important clinical findings should be in place.
- MDMs form an essential part of the delivery of patient care and of the quality assurance process within an imaging service. MDMs are a forum for the communication of imaging findings, clinical interaction, innovation, good practice, and CPD. MDM preparation and participation requires appropriate job planning. Documents from the [BCS](#) and the [RCR](#) describe the requirements for consultant imaging specialists and imaging departments to maximise the benefit to patients of imaging discussed at MDMs[15].
- There should be a “Learning from Discrepancies Meeting” (LDM). LDMs play a crucial role in clinical governance. Alongside other related processes, and as part of a quality assurance programme, the LDM facilitates improvement in the quality of service delivery, is an important source of shared learning, and contributes to improved patient safety.

Imaging department management meetings

These operational meetings should review:

- Capacity, activity and demand statistics
- Workforce and staffing
- Clinical governance
- Patient and user feedback
- Strategy and issues to escalate
- Radiation protection

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Radiation Protection

- It is important that the administered radiation activity for each individual exposure is optimised to obtain optimum diagnostic information with the lowest dose. The Ionising Radiation (Medical Exposures) Regulations 2017 - IR(ME)R 2017 - requires that employers regularly review, and make available to operators, diagnostic reference levels (DRLs).
- All procedures should be undertaken in accordance with departmental written protocols. Local DRLs should be specified in the written protocols.
- National DRLs for exposures used during SPECT and PET/CT imaging have been published and are available online[17].
- All staff involved in the organisation and administration of investigations, which utilise ionising radiation should be familiar with Departmental Local Rules and SOPs.

Infection Control

- Services in conjunction with local infection control departments should be able to demonstrate appropriate measures are in place to prevent person-to-person transmission of disease or other healthcare related infection.

Reporting (including Teleradiology)

- All images should be reported in accordance with agreed local protocols and standards by competent staff, who are working within their defined scope of practice.
- There should be an agreed approach in collaboration with radiology to the review and reporting of extracardiac findings where a cardiologist is the primary reporter.
- Where Imaging is delivered by an extra-organisational providers, clinically agreed protocols should be in place for the conduct and reporting (including any teleradiology arrangements).
- The NHS Constitution pledges that patients (in England) should wait no longer than six weeks for a diagnostic test. Pathways should be developed which meet this standard.
- Imaging for more urgent clinical indications (for instance, diagnostics for patients seen in a rapid access chest pain clinic) should be delivered by pathways, which are individualised to the relevant (two-week, in this case) time scale.
- Departments should have key performance indicators (KPIs) for the turn-around of reports, which are structured around the urgency, the referral source, and/or the type of investigation.
- Teleradiology (remote review and reporting) is an increasing part of normal processes of all cardiac imaging departments. It provides a high degree of flexibility and can improve departmental robustness and clinician wellbeing. There should be an agreed schedule including appropriate equipment, monitor resolution (which will vary between modalities), processor and internet speeds. Reporting remotely should be performed to the same standards as departmental reporting.

Data management

- All departments must have an electronic report database with facilities for storing and retrieving images and reports. Standards regarding imaging databases can be found at in the [RCR standards for confidentiality and RIS and PACS](#) [18] and the RCR [Standards for the](#)

1 [communication of radiological reports](#)[19]

- 2 ● Compliance with guidance and legislation on patient confidentiality must be fully observed
3 ([\[20\]](#)[\[21\]](#)[\[22\]](#)[\[23\]](#)).
- 4 ● All departments should ensure that their data/image management and storage is compliant
5 with General Data Protection Regulations ([GDPR](#)).
- 6 ● There should be GDPR-compliant methods for the secure transfer of primary clinical imaging
7 data (usually DICOM files) between institutions.

8 9 ***Strategic considerations for delivery and service development***

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11 When one of a number of different imaging modalities could reasonably be utilised in a clinical
12 pathway in accordance with best practice, the imaging modality used should be determined by local
13 availability and expertise. With increasing cost pressures across the NHS, the economic and resource
14 impact of local practices should be considered when setting up or reviewing local services and/or
15 patient pathways. Periodically national and best practice guidance will change with major
16 implications for service configuration. A recent example of how such considerations impact national
17 and local services can be seen in the implementation of the NICE guidelines for “Recent-onset chest
18 pain of suspected cardiac origin: assessment and diagnosis”[24] and the [associated resource impact](#)
19 [analysis](#)[25]. Where such challenges exist or develop these should be assessed and resolved at a
20 cardiac network level taking into account existing skills and services and allowing strategic,
21 integrated service development.

22 23 ***Providing a comprehensive patient-centred service***

24
25 Many units or hospitals will not provide all cardiac imaging modalities. When the required imaging
26 modality is not provided by the local hospital, it should be available to patients as part of a network-
27 wide imaging strategy. Robust referral pathways should form part of the network arrangements.
28 Patient involvement in the design of investigative pathways should be actively encouraged. There
29 should be robust methods to receive and respond to patient comments, complaints and suggestions.
30 Departments should be compliant with the [NHS national complaints policy](#)[26].

1 Section 2: Echocardiography

2 2.1 Principal indications

3 Due to its availability, portability and widespread availability, the indications for TTE are broad and
4 the threshold for requesting the investigation is low. For principal indications see Table 3 and Figure
5 3:
6

TABLE 3: Principal Indications for Echocardiography	Notes
Breathlessness of potential cardiac origin.	
TTE is the first-line imaging test for the investigation and monitoring of a wide range of chronic diseases (including but not limited to heart valve disease, congenital heart disease, inherited and acquired heart muscle disease, and monitoring of ventricular function during chemotherapy treatment).	
Point of care haemodynamic assessment in the critically-ill patient.	
Stress echocardiography (either pharmacological or exercise) to detect ischaemia and to evaluate structural heart abnormalities such as valve disease and heart muscle disease.	
TOE is used to obtain high-resolution cardiac images. It is particularly valuable for assessing the mechanism and severity of mitral regurgitation, for diagnosing infective endocarditis and its complications such as abscess formation, for diagnosing and planning interventions for congenital heart disease, for guiding percutaneous structural cardiac interventions, and for monitoring ventricular function during major surgery.	
A comprehensive list of indications for echocardiography can be found online[27].	

7

8 2.2 Appropriateness and recognition of risk

- 9 ● Echocardiography does not involve the use of ionising radiation so it is frequently the first
10 choice investigation for the assessment of cardiac structure and function.
- 11 ● 16% of all echocardiograms performed are inappropriate[28]. A triage system should
12 therefore be in place in order to ensure adherence to appropriateness criteria[29].
- 13 ● Due to the national shortage of sonographers means the scans can be performed by relatively
14 junior cardiology trainees or other professionals which constitutes a risk from errors in image
15 interpretation and reporting. [30]
- 16 ● These risks should be mitigated through the provision of appropriate clinical supervision,
17 teaching, and training for all staff groups acquiring and reporting echo images.

18 TTE is non-invasive and the procedure itself is not associated. Stress echo is also non-invasive. It is
19 associated with a very low risk of ischaemia-related complications. By contrast, TOE is invasive and
20 carries a 1 in 1,000 risk of serious oesophageal traumatic injury[31].

21

22 2.3 Access to investigation and timeliness

- 23 ● Where a hospital has an acute medical take, echocardiography should be available 24 hours a

1 day[3,32].

- 2 ● This poses a significant challenge and organisations should mitigate this risk by investment
3 in training, diversification of roles, and by working in collaboration to provide network
4 solutions [33]
- 5 ● The challenges posed by remote communities may also require cooperation across healthcare
6 organisations at a regional level, particularly when advanced imaging (TOE and stress) forms
7 a core element of patient pathways which are recommended in guidelines from national bodies
8 such as NICE or the Scottish Intercollegiate Guidelines Network (SIGN)[34].

10 ***2.4 Equipment specification and replacement cycles***

- 11 ● Echocardiography machines must be equipped with the appropriate phased-array transducers
12 and cardiac-specific imaging software. Stand-alone continuous wave Doppler and tissue
13 Doppler capability are also recommended for all Doppler capable devices.
- 14 ● 3D capability is recommended on at least one machine in the department.
- 15 ● An echo machine can normally be used for a maximum of 2500 studies per year, but this
16 figure may be lower if it is used for a significant number of ward-based or complex studies.
- 17 ● Elective replacement planning should be at five years with no machine in regular clinical use
18 being over 10 years old.
- 19 ● Appropriate couches are required to facilitate patient positioning for the acquisition of high-
20 quality images.

21 Full recommendations for equipping an echocardiography department can be found in the BSE's
22 description of its process for [British Society of Echocardiography departmental accreditation in
23 echocardiography](#) .

26 ***2.5 Workforce descriptors, accreditation, job planning, and education and training***

27 All echo departments should have a designated Head of Department (HoD). The HoD may be either
28 a specialist registered medical practitioner or a specialist healthcare scientist. A cardiologist lead
29 should be on the GMC's Specialist Register for cardiology and should preferably hold individual
30 TTE [BSE/EACVI](#) accreditation (or equivalent).

31
32 A healthcare scientist lead must hold similar accreditation and be graded band 7 or above. They
33 should spend at least five sessions per week performing activities directly related to
34 echocardiography.

35
36 Any sonographer or cardiac scientist who performs and reports studies unsupervised should have
37 individual TTE [BSE/EACVI](#) accreditation (or equivalent) and will usually be graded band 6 or above.

38
39 Sonographers or cardiac scientists should have access to study leave and related funding to undertake
40 CPD activities in order to maintain and enhance their echo skills.

42 ***2.6 Departmental quality approval***

- 43 ● All echo departments should have a verifiable process for ensuring on-going quality assurance.

1 Furthermore, processes should be in place that encourage staff engagement with quality
2 assurance and which improve patient care through feedback mechanisms.

- 3
- 4 ● Demonstrating adherence to appropriate quality standards is best achieved by a department
5 completing the process for [British Society of Echocardiography departmental accreditation in
6 echocardiography](#)[35].

7

8 ***2.7 Echocardiography reporting recommendations***

- 9
- 10 ● All studies should be performed using an agreed minimum dataset (usually the [BSE minimum
11 standards dataset](#)).
 - 12 ● The average time required to undertake and report a comprehensive echo, however, is about 45
13 minutes. Sufficient time should be allocated in elective echo lists to enable the recording and
14 reporting of an echo study in accordance with BSE standards.
 - 15 ● Focused studies may be appropriate in some circumstances (e.g., a level 1 emergency
16 echocardiogram study, interval follow-up studies (which should still be performed in line with
17 the [BSE minimum standards dataset](#)), but the goals and scopes of such studies should be agreed
18 in advance and be auditable.
 - 19 ● Reports for routine studies should be issued within 24 hours of the examination.
 - 20 ● A full or preliminary report should be issued within one hour for urgent or inpatient studies.
 - 21 ● There should be agreed permissions stating which staff members can report echo studies and
22 who can sign off reports.
 - 23 ● A standard echo-specific electronic format must be established for reports. Furthermore, reports
24 should be readily retrievable from the electronic archive and integrated into the electronic
25 patient record.

26

27 ***2.8 Integrating organisational echo services and interdependencies***

28

29 Improvements in echocardiogram technology have been accompanied by expanded indications for
30 echo and by its increased use as a point-of-care test in the assessment of acutely unwell patients. In
31 addition, TOE is performed during cardiac surgery, during percutaneous cardiac interventions, and
32 in guiding treatment on the intensive care unit. This has led to the dissemination of echo skills from
33 cardiac scientists and cardiologists to cardiac surgeons, anaesthetists, intensive care specialists, and
34 emergency care physicians.

- 35
- 36 ● The relationships between cardiology imaging and intervention, intensive care, emergency
37 medicine, pharmacy, audit departments, research and manufacturers should be clearly mapped
38 and available for review.
 - 39 ● The same standards of equipment and training are applied in these different environments and
40 staff groups, respectively. Some of these issues have been addressed in detail through the BSE
41 Level-1 Individual Accreditation process and the joint BSE/Intensive Care Society Emergency
42 echocardiography departmental accreditation standards[35].
 - 43 ● Echocardiography should be delivered collaboratively, supported by the principal echo
44 department within the organisation.
 - 45 ● Accredited echocardiographers are core attendees at Valve and Structural Heart Disease

1 MDMs. Their attendance at these meetings should be recorded.
2

3 **2.9 Super-specialist echocardiography services**

4 There is a variety of super-specialist echocardiography services, including specialist TOE, stress
5 echocardiography, and echocardiography for congenital heart disease in children and adults. These
6 fall outside the scope of this document, but the applicable standards have been published by the BSE.
7 These services are often provided for a wide clinical network, and engagement with the network
8 around appropriate configuration is essential.
9

10 **2.10 Echocardiography-specific risks**

- 11 ● Echocardiography should be performed in an environment, which is suitable for maintaining
12 patient dignity and for the acquisition of high-quality images. This should include appropriate
13 privacy, space, and lighting.
- 14 ● Additional space is required to perform TOE and stress echo compared with TTE.
- 15 ● A standard TTE is not formally considered to be an intimate examination, nevertheless, its
16 performance requires patient sensitivity and all departments should have an approved
17 chaperone policy.
- 18 ● There should be awareness of health and safety issues, especially relating to back and eye
19 problems amongst staff, and adequate liaison with [occupational health and risk management](#)
20 [departments](#)[36].
21

22 Detailed safety standards for TOE and stress procedures fall outside the scope of this document.
23 However, national safety standards for invasive procedures (NatSSIPs) should be followed.
24 Furthermore, local policies should comply not just with the requirements for imaging, but incorporate
25 appropriate SOPs for the following areas

- 26 ● Pharmacological stress
- 27 ● Ultrasound contrast administration
- 28 ● Probe decontamination (TTE and TOE)
- 29 ● Safe sedation
- 30 ● Advanced life support
- 31 ● Management of complications arising from TOE.
32

33 **2.11 Echocardiography-specific audit and governance**

- 34 ● Regular, ideally weekly, echo meetings, must be held to review unusual, challenging, or
35 otherwise difficult cases.
- 36 ● The [British Society of Echocardiography Echo Quality Framework](#)[5] provides a template for
37 the delivery of such meetings. Attendance should include cardiac scientists and consultant echo
38 specialists as a minimum. There must be an established process for issuing revised reports,
39 when relevant, following echo meeting discussions.
- 40 ● Additionally, departments are encouraged to participate in local and national audit processes.
- 41 ● An escalation policy for highlighting serious and unexpected findings should be in place.
42

43 **2.12 Challenges to the delivery of echocardiography**

44 Demand for echocardiography has increased as the indications for its use have expanded and become

1 better recognised. In combination with well-documented shortages in cardiac scientists and an aging
2 population amongst whom conditions, which require echo, such as valve disease and heart failure,
3 are more prevalent, this has led to problems in the delivery of echo in a timely manner for some
4 patients.
5 This problem may be compounded in some regions by long travel times, which have been linked to
6 low uptake of diagnostic testing in cancer screening programs. These challenges are associated with
7 inequalities in access to healthcare in rural communities.
8 Where gaps in provision occur, a network approach to service delivery is recommended, with
9 institutions working across organisational boundaries to provide the required services.
10 Remote review and telemedicine solutions may help to bridge some of these gaps, but the governance
11 around such solutions must be clearly described.
12

1 Section 3: Cardiac computed tomography

2 **3.1 Principal indications.** For principle indications see Table 4 and Figure 4:

3

Table 4: Principal Indications for Cardiac CT	Notes
<i>To evaluate the coronary arteries</i> (by CTCA): Stable chest pain with typical or atypical angina, or non-anginal chest pain with ST changes or Q-waves on the resting 12-lead ECG.	NICE CG95 [37]
As an alternative to invasive coronary angiography prior to heart valve surgery in patients unlikely to require adjunctive coronary artery bypass grafting (CABG).	ESC [38]
To assess the functional significance of coronary artery stenoses (by estimating fractional flow reserve).	NICE MTG32 [39]
To evaluate the thoracic aorta: For possible trauma, acute aortic syndrome, aortic dilation, planning and follow-up of aortic intervention.	
To evaluate structural heart disease: Prior to intervention for structural heart disease, such as trans-catheter aortic valve implantation (TAVI).	ESC [38]
Before and after surgery/intervention in patients with congenital heart disease.	
Assessment of aortic stenosis when echocardiographic parameters are discordant.	ESC [38]

4

5

6 **3.2 Appropriateness and recognition of risk**

7 Cardiac CT is non-invasive (but for the requirement for a venous cannula for the administration of x-
8 ray contrast) and very safe.

9 Cardiac CT involves a relatively low dose of ionising radiation (which is similar to the dose from
10 invasive coronary angiography[40]). Cardiac CT may be considered appropriate:

- 11
- 12 ● If it is likely to provide an accurate diagnosis;
 - 13 ● If it is likely to identify patients who may benefit from specific interventions (such as medical
14 therapy or myocardial revascularisation) or guide delivery of therapy (such as TAVI);
 - If it is likely to provide information relating to prognosis.

15 All requests should be triaged for appropriateness and priority according to an locally agreed set of
16 indications.

17

18 **3.3 Access and timeliness**

19 There should be 24-hour, seven day a week access to emergency motion-free CT imaging of the
20 thoracic aorta for patients with suspected aortic trauma or acute aortic syndrome.

21 Provision of cardiac CT for structural heart disease and coronary artery evaluation is required within
22 working hours.

23 Provision of CTCA services as per [NICE CG95 \(2016\)](#)[37] represents a significant challenge both in
24 workforce and equipment terms. However services at a network level need to be configured to deliver
25 investigation and report within 2 weeks.

26

1 **3.4 Equipment specification and replacement cycles**

2 The minimum technical requirements for cardiac CT imaging can be provided by a general purpose
3 CT scanner which has a detector array of at least 64 rows and which has been ‘cardiac enabled’ with
4 ECG-gating ([Safe Practice](#))[41]. However, more advanced CT technology should be available, or at
5 least accessible through local arrangements on a regional basis, when imaging patients who are
6 difficult to scan (for example those with arrhythmias) and when planning provision of large volume
7 CTCA services ([NICE DG3](#))[42].

8 The life of a cardiac CT scanner is around seven years, according to manufacturers’ maintenance
9 recommendations. Life expectancy is, however, influenced by scan volumes. A program which
10 prospectively plans scanner replacement around this expected lifespan should be in place[43].
11

12 ***Specialist analysis software***

13 *Minimum requirements:*

- 14 ● Coronary artery calcium score calculation.
- 15 ● Coronary artery visualisation and stenosis quantification including automated centerline
16 extraction for the major epicardial coronary arteries.

17 *Additional software may include:*

- 18 ● Cardiac chamber volumetric and functional quantification.
- 19 ● Thoracic aorta assessment tools (for intervention planning, e.g., TAVI).
- 20 ● Myocardial perfusion assessment including quantitative perfusion maps.
- 21 ● Estimation of fractional flow reserve by CT (FFR_{CT}) for non-invasive assessment of the
22 functional significance of coronary artery stenoses ([NICE MTG32](#))[39].

23 *Other equipment*

- 24 ● Resuscitation facilities (including defibrillation/oxygen/suction).
- 25 ● An emergency trolley which includes the storage of drugs to treat reactions to contrast agents
26 and beta-blockers.
- 27 ● Monitoring equipment such as a non-invasive blood pressure machine and a pulse oximeter.
- 28 ● Phantoms for CT calibration and quality control.

29 30 **3.5 Workforce descriptors, accreditation, job planning, and education and training**

31 Clinicians who supervise and report cardiac CT scans (usually radiologists or cardiologists) should
32 be trained in cardiovascular CT to the equivalent of [BSCI/BSCCT](#) level 2 standard or higher[44].
33 Radiographers who perform cardiac CT should be competent to do so through sub-speciality training,
34 which can be delivered in-house, by manufacturers, and supplemented by online learning and by
35 attendance at dedicated study days ([Society of Radiographers](#))[45].

36 Guidance regarding the CPD needed for maintenance of skills and re-accreditation in cardiac CT is
37 available through the [BSCI/BSCCT](#)[44].

38 For job planning purposes, a programmed activity of direct clinical care delivering cardiac CT might
39 include the supervision and reporting of between 4-8 scans depending upon case-mix.
40

1 **3.6 Departmental quality approval**

2 There is currently no minimum requirement for departmental accreditation for cardiac CT, which will
3 normally be provided by general CT departments.

4 It is recommended that departments which undertake cardiac CT dedicate a minimum of one session
5 per week to cardiac scanning in order to justify the service and maintain competencies.

- 6 ● Regular (weekly) departmental cardiac imaging MDMs which include cardiac CT are
7 recommended.
- 8 ● Cross-modality review meetings and regional network meetings are recommended.
- 9 ● Quality assurance activities should include contributions to case review, participation in local
10 and national audit of radiation dose and downstream testing, discrepancy reporting, and
11 maintenance of CPD to enable re-accreditation and revalidation.

12 13 **3.7 Cardiac computed tomography reporting recommendations**

14
15 No specific UK reporting guidelines exist. It is recommended, however, that reporting is undertaken
16 according to standardised local policies.

17 The Society of Cardiovascular Computed Tomography (SCCT) provides a reporting system in the
18 form of '[CAD-RADS](#)'[46], which can be particularly useful for audit and follow-up purposes.

19 Approved reports should be available within 24 hours for out-patients and on the same-day as the
20 study for urgent in-patient scans.

21 There should be an established discrepancy reporting process.

22
23 The dose length product (DLP), which allows an estimate of the radiation dose, should be included
24 in the report.

25 26 **3.8 Interdependencies with other services**

27 The relationships between radiology, cardiology imaging and intervention, medical physics,
28 pharmacy, audit departments, research and manufacturers should be clearly mapped and available for
29 review.

30 In particular there should be a well-described process for the review and reporting of non-cardiac
31 findings.

32 Accredited cardiac CT experts are core attendees at Structural Heart Disease MDMs. Their attendance
33 at these meetings should be recorded.

34 35 **3.9 Super-specialist cardiac computed tomography services**

36 Super-specialised services, such as adult congenital heart disease services which require CT should
37 be provided as part of an agreed network process as all units will not have the required skill mix.

38 39 **3.10 Cardiac computed tomography-specific risks :**

40 IR(ME)R - 2017 governs the delivery of cardiac CT radiation doses according to the 'as low as
41 reasonably practicable' (ALARP) principle ([IRMER](#))[47]. Specific training of staff as to modes of
42 ECG-gating and the relevance in ensuring that scans comply with the ALARP principle is
43 recommended.

1 All staff involved in the delivery of cardiac CT should be trained in basic life support, with immediate
2 access to staff who are trained in advanced life support. Appropriate equipment to facilitate advanced
3 life support should be readily available. Cardiac CT staff should be familiar with the treatment of
4 anaphylaxis and have immediate access to the necessary drugs.

5 The potential risks of intravascular administration of contrast agents must be weighed against the
6 potential benefits. Withholding agents may deprive patients of the benefits of valuable diagnostic
7 information or necessary therapy. Further guidance can be found on dedicated guidelines on safe use
8 of contrast agents[48].

9 An agreed protocol to manage the risks of contrast induced nephrotoxicity should be in place.

10

11 ***3.11 Cardiac computed tomography-specific audit and governance***

12 For the safe practice of cardiac CT in adult patients in UK imaging departments:

- 13 ● There should be a contrast extravasation policy in place, which is supported by appropriate
14 patient literature.
- 15 ● Cardiac CT radiation doses should be audited regularly by means of the recorded DLP.
16 Centres are encouraged to submit these data to BSCI/BSCCT for their national dose audits.
- 17 ● Cardiac CT centres are encouraged to participate in local and national audit processes of
18 downstream testing.

19

20 ***3.12 Challenges to delivery of cardiac computed tomography***

21 It is estimated that 350,000 CTCAs are required per annum in the UK to deliver the NICE diagnostic
22 pathway for recent-onset, stable chest pain of possible cardiac origin, [NICE CG95](#)[37]. Provision for
23 the assessment of structural heart disease, aortic disease, etc., requires more capacity still.

24 The specific challenges include delivering cardiac CT services (CTCA services, specifically) in the
25 wake of [NICE CG95](#)[37] are outlined in ‘Challenges in delivering computed tomography coronary
26 angiography as the first-line test for stable chest pain’[49].

27

28

1 **Section 4: Nuclear cardiology**

2 **4.1 Principal indications:** For principle indications see Table 5 and Figure 5:

Table 5: Principal Indications for Nuclear Cardiology	Notes
Assessment of coronary artery disease, ischaemia and viability using myocardial perfusion scintigraphy / positron emission tomograph	
Assessment of left ventricular function in undergoing cardiotoxic cancer therapy (baseline and serial) where echocardiography is not appropriate using multigated acquisition (MUGA)/radionuclide ventriculography	
Investigating Infective endocarditis in special circumstances (e.g. uncertainty based around Duke criteria / indwelling medical devices)[50]	ESC 2015 [50]
Myocardial inflammation (especially sarcoidosis) using positron emission tomography	
Cardiac TTR amyloidosis using bone scintigraphy (particularly with 99mTc-DPD)[51]	ESC 2014 [51]

3

4 **4.2 Appropriateness and recognition of risk**

5

6 Nuclear cardiology investigations are non-invasive, but for the requirement for a venous cannula for
7 the administration of the appropriate radio-pharmaceutical and stressor agent. It is therefore very
8 safe.

9

10 Radiation doses differ between different nuclear cardiology and choices (where available) should be
11 made to keep the radiation dose as low as possible

12

13 All requests should be triaged for appropriateness and priority according to an locally agreed set of
14 indications. Choice of investigation and technique should be guided by patient characteristics.

15

- If it is likely to provide an accurate diagnosis;
- If it is likely to identify patients who may benefit from specific interventions (such as the needs for ischaemic revascularisation) or guide delivery of therapy (such as the removal of infected prosthetic material);If it is likely to provide information relating to prognosis.

19

20

21 **4.3 Access to investigation and timeliness**

22 Access to nuclear cardiology services should be available at a local and networked level.

23

- Where nuclear cardiology forms part of a diagnostic pathway (for instance for the evaluation of chest pain, diagnostic work-up for infective endocarditis, diagnosis of cardiac amyloidosis) it should be reliably delivered within the appropriate 2 week or 6 week time frame respectively.

27

- 1 ● Where this is not possible for an individual organisation a networked solution should be in
2 place.
- 3 ● Where nuclear cardiology forms part of an acute care pathway it should be available on a 7/7
4 basis.

6 **4.4 Equipment specification and replacement cycles**

7 Radiological equipment has a finite life-span, beyond which there is reduced image quality and
8 increasingly frequent malfunction[52].

- 9 ● Equipment replacement cycle should be no more than 10 years. (Operating costs for older
10 equipment are high when compared with newer equipment. Maintenance may not be possible
11 or provided for very old equipment.)
- 12 ● Every healthcare institution or authority should have a plan for rolling upgrade or replacement
13 of medical imaging equipment.
- 14 ● This plan should look forward a minimum of five years, and be updated on an annual basis.

16 **4.5 Workforce descriptors, accreditation, job planning, and education and training**

17 [ARSAC](#)[53] requires employers and practitioners to hold a licence for the administration of
18 radioactive substances for a specified purpose at any given medical radiological installation.

- 19 ● Each employer is required to hold a licence for each administration at each medical
20 radiological installation for the purpose of the administration of radioactive substances to
21 humans.
- 22 ● Every practitioner is required to hold a licence in order to justify the administration of
23 radioactive substances to humans.
- 24 ● The majority of licences are issued for five years.

25
26 At a medical radiological installation where administrations of radioactive substances are undertaken,
27 it is expected that there will be a multi-disciplinary team involved with service provision. This will
28 include practitioners, medical physics experts, radiopharmacists (if appropriate), and other healthcare
29 professionals (e.g., radiographers, technologists, and nursing staff) with appropriate training and
30 experience.

- 31
32 ● Practitioners are clinicians (nuclear medicine physicians, dual-accredited radiologists/nuclear
33 medicine physicians, radionuclide radiologists, and/or cardiologists).
- 34
35 ● Applicants for licences who have not undertaken any of these structured training programmes
36 are required to demonstrate equivalent training, experience and competence pertaining to the
37 procedures they wish to undertake (e.g., [EACVI/European Association of Nuclear Medicine](#)
38 [\(EANM\)](#)[54] or [American Certification Board for Nuclear Cardiology](#)[55]).
- 39
40 ● Practitioners who wish to justify exposures as part of a PET/CT service will require training
41 and experience additional to that required for conventional nuclear medicine procedures.
- 42
43 ● Practitioners are expected to undertake appropriate continuing medical education (CME)
44 associated with the procedures for which they are licensed as part of the appraisal and
45 revalidation processes, and to confirm this at the time of revalidation.

- 1
- 2
- For job planning purposes, a programmed activity of direct clinical care delivering nuclear cardiology might include the supervision of eight stress tests and the reporting of between 8-10 scans[56].
- 3
- 4
- 5

6 **4.6 Departmental quality approval**

7 ARSAC requires employers to hold a licence for each administration at each medical radiological installation for the purpose of the administration of radioactive substances to humans.

8 There is no specific departmental accreditation available for nuclear cardiology, but departments should be able to provide evidence of engagement with broader accreditation. For example:

9 The British Nuclear Medicine Society ([BNMS organisational audit tool](#)[57]). It is suggested that nuclear medicine departments aim to complete the use of the audit tool twice in a five-year cycle.

10 The United Kingdom Accreditation Service is piloting assessments under its [Medical Physics and Clinical Engineering \(MPACE\)](#) scheme in the area of Nuclear Medicine[58].

11 **4.7 Nuclear cardiology-specific risks**

12 All forms of nuclear cardiology result in ionising radiation exposure to patients, and each medical radiation exposure must therefore be justified and the exposure should be as low as possible whilst maintaining diagnostic quality. Staff are at risk of exposure to ionising radiation in certain circumstances, exposure to ionising radiation therefore requires monitoring with staff protection governed by Occupational Health standards. All procedures should be undertaken in accordance with departmental written protocols. Local DRLs should be specified in the written protocols ([ARSAC Notes for Guidance](#))[59]. National DRL for CT exposures used as part of SPECT/CT and PET/CT procedures have been published and are available [online](#)[60].

13 **4.8 Nuclear cardiology reporting recommendations**

14 The American Society of Nuclear Cardiology has published guidelines for performing nuclear cardiology procedures, which includes recommendations regarding standardised reporting[61].

15 **4.9 Interdependencies with other services**

16 Nuclear medicine, and thereby nuclear cardiology, is a multidisciplinary specialty which involves nuclear medicine physicians, radiologists, cardiologists, medical physicists, radiopharmacists, nuclear medicine technologists and radiographers, and nurses. Availability of radiopharmaceuticals often is subject to local, national and international relationships.

17 It is recommended that practitioners should participate in coronary, endocarditis, and heart muscle disease MDMs.

18 **4.10 Super-specialist services**

19 Provision of certain aspects of nuclear cardiology is limited by resource constraints and minimum volume requirements, e.g. myocardial perfusion PET, fluorodeoxyglucose (FDG) PET/CT for infective endocarditis, and deoxythymidine (DPD) scintigraphy. Where these cannot be provided within a single organisation, a network solution or formal referral process to a suitable unit should be in place.

20 **4.11 Nuclear cardiology-specific audit and governance**

1 Nuclear cardiology departments should participate in regular external peer review, such as the [BNMS](#)
2 [Organisational Audit Programme](#)[62].

3 They should participate in local audit programmes. This should include both effectiveness audits
4 around clinical / prognostic accuracy and environmental audits.

5 It is recommended that departments should hold regular LDMs.

6

7 ***4.12 Challenges to delivery of nuclear cardiology imaging***

8 Nuclear medicine training is now part of the Clinical Radiology curriculum. Access to training centres
9 and recruitment remains a challenge. This, along with other issues, including reduced numbers of
10 trained staff coming to the UK from the European Union and retirements has led to a workforce
11 shortfall.

12 The future of radiopharmaceutical supply remains uncertain following the UK's exit from the EU.
13 Problems in the supply chain could significantly affect the provision of nuclear cardiology, however
14 this issue is not specific to nuclear cardiology.

15 Other challenges include: the advanced age of equipment throughout the UK and the ability to replace
16 and upgrade due to heterogeneity of replacement policies; continuing concerns about radiation
17 exposure and delivering ALARP; developing skill-sets to include independent nurse or physiologist
18 stressing through a PGD (Patient Group Directive)[63] and non-medical reporting and ensuring that
19 appropriate governance arrangements are in place to facilitate these developments.

20

21

1 **Section 5. Cardiovascular magnetic resonance imaging**

2 This is a concise summary of the full [British Society of CMR Clinical Standards Document 2022](#).

3

4 **5.1 Principal indications:** For principle indications see Table 6 and Figure 6:

5

Table 6: Principal Indications for CMR	Notes
Cardiac anatomy	
Quantification of ventricular volumes, function and mass	
Cardiomyopathies, myocarditis, cardiotoxicity, myocardial infiltration, fatty replacement and cardiac transplantation	
Cardiac flow and shunting	
Valvular heart disease	
Congenital heart disease	
Coronary artery disease (stress perfusion imaging)	
Myocardial infarction/viability	
Iron storage diseases	
Pericardial disease	
Cardiac tumours and paracardiac masses	
Aorta and thoracic great vessels (contrast and non-contrast angiography)	
Acquired vascular disease	

6

7 A concise guide to the categories of indication for CMR is included here; and are available as a set
8 of comprehensive indications [online](#)[64]and to the expert consensus panel document[65]:

9

10 **5.2 Appropriateness and recognition of risk**

11 In general, CMR is considered appropriate when it can provide additional information which has the
12 potential to alter the clinical diagnosis (including disease severity) and/or management of the patient.
13 CMR is often used after previous testing, such as echocardiography and/or coronary artery imaging,
14 whether by CTCA or invasive coronary angiography, when important clinical questions remain
15 unanswered or new clinical questions have arisen as a result of the initial test. It is not appropriate to
16 use CMR purely to confirm the findings from previously-used imaging modalities.

17 CMR is very safe. There are no known long term health risks from the high magnetic fields or
18 radiofrequency pulses used during testing. Precautions are, however, required regarding
19 ferromagnetic objects, which may cause injury to the patient, staff, and/or equipment if subject to the
20 high magnetic field in the MR scanner room. Some patients with certain types of implants or

1 embedded metal (e.g., shrapnel) may, therefore, need to be excluded from undergoing CMR scanning.
2 Patients with cardiac pacemakers/defibrillators may be scanned under the following
3 circumstances[66]:

- 4 ● The device and leads system are MR-conditional (i.e., safe to scan under certain conditions),
5 and appropriate programming of the device has occurred prior to the scan. Processes should
6 be in place to enable patients with MR conditional devices to be scanned in all MRI centres,
7 particularly if MR conditional devices are implanted in that centre. [These patients do not](#)
8 [require referral to specialist centres](#).
- 9 ● The device and leads system is not MR conditional ([‘legacy’ devices](#))[67] but the information
10 from the scan is crucial to the patient’s management and outweighs the risks of scanning. This
11 is a specialist area of practice, and in general is carried out in specific centres with the relevant
12 experience and expertise ([MRImyPacemaker.com](#))[68].

13 14 **5.3 Access and timeliness – expanding to 7/7 and 24/7 working**

15 CMR is not available in every hospital, as it requires specialist staff, equipment, expertise, and regular
16 practice to maintain skills. It is generally performed in larger hospitals with an established cardiac
17 centre (and should be accessible by every cardiothoracic surgical centre in the UK). Where CMR is
18 not available or its availability is limited, there should be a clear network pathway in place to deliver
19 the service,

20 CMR is most commonly performed as an outpatient service (~95% of scans). There are no clear
21 indications for emergency CMR as other cardiac imaging modalities, in particular echo, CT, and
22 invasive coronary angiography, are more appropriate in this setting. 24-hour provision is therefore
23 not required. Urgent inpatient scans should ideally be performed within 48 hours. Elective outpatient
24 scans should ideally be performed within 6 weeks but limited capacity in many areas means that
25 waiting times are often longer than this.

26 27 **5.4 Equipment specification and replacement cycles**

28 **Equipment specification**

29 ***MRI scanner***

- 30 ● A fully maintained, shared, or dedicated MRI scanner (minimum 1.5 Tesla) with cardiac
31 capability.
- 32 ● Sufficient magnet access to achieve minimum annual unit (see [NHS England National Service](#)
33 [specifications](#))[69]. ECG gating, patient monitoring (including BP, pulse oximetry), contrast
34 pump.
- 35 ● For a new CMR installation, the BSCMR recommends the following specifications:
- 36 ● Radiofrequency (RF) receiver: 16 or more RF channels (torso/body/cardiac receiver array
37 with multiple elements).
- 38 ● Minimum gradient specifications: 30mT/m, 150mT/m/msec.
- 39 ● Artefact resistant ECG hardware/software (e.g., vectorcardiogram).

40 Further details on cardiac specific sequences, specialist software for analysis, and other essential MR
41 compatible equipment can be found in BSCMR Standards Paper[70].
42

1 ***Replacement cycles***

2 BSCMR recommends replacement of MR scanners which are more than 10 years old, in line with the
3 [NHS England and NHS Improvement report from November 2019](#)[71]. Current guidance from the
4 Biomedical Engineering Advisory Group (BEAG) recommends such equipment should be replaced
5 after seven years[72].
6

7 ***5.5 Workforce descriptors, accreditation, job planning, and education and training***

8 A unit performing CMR should have:

- 9 ● A named director/clinical lead who is on the GMC’s Specialist Register for Cardiology,
10 Radiology, Nuclear Medicine, accredited in CMR, and able to demonstrate ongoing
11 appropriate CME/CPD in CMR.
- 12 ● A named lead CMR radiographer. Ideally this would be their main or only role. The position
13 should provide sufficient time to ensure that high-quality clinical care is delivered to patients
14 in a safe environment which is supported by appropriate clinical governance processes. The
15 post-holder will also be responsible for equipment management and maintenance.
- 16 ● Appropriately trained medical and technical staff to deliver the service. They will be familiar
17 with the local rules and procedures for safe working practice in the MR environment.
- 18 ● Arrangements for scientific and technical input from a medical physics expert who is trained
19 in CMR methods.
- 20 ● Arrangements for appropriate staff development, including education, training, accreditation,
21 CPD, and revalidation. Further details can be found at [BSCMR.org](#).
- 22 ● Current or planned (three-year) activity sufficient to [maintain individual accreditation](#)[69].

23 Further recommendations for departmental quality control and minimum numbers of scans for a CMR
24 centre can be found in BSCMR Standards Paper[70].
25

26 ***5.6. Departmental Quality assurance***

27 All CMR departments should have a verifiable process for ensuring on-going quality assurance.
28 Furthermore, processes should be in place that encourage staff engagement with quality assurance
29 and which improve patient care through feedback mechanisms.
30

31 ***5.7 Cardiovascular magnetic resonance imaging reporting recommendations***

32 All clinical CMR sessions should be supervised by a named consultant who is responsible for
33 generating a formal scan report.

34 CMR reporting should be integrated with the clinical scenario and should conform to appropriate
35 [international standards](#).

36 CMR practitioners should participate in clinical MDMs in which CMR imaging plays an important
37 part in informing patient management, in order to provide appropriate expertise in the interpretation
38 of the CMR scans. Such MDMs include heart muscle disease, MDMs, structural heart disease MDMs,
39 and valve MDMs.

40 A unit performing CMR should have a clinical review meeting at least fortnightly, at which CMR
41 scans can be reviewed and/or colleague advice sought.

42 CMR practitioners reporting in isolation is discouraged. Reporting physicians should have ready
43 access to appropriately skilled imaging peers for advice regarding complex or ambiguous scans.

1 The BSCMR recommends that inpatient CMR scans should be reported by the next working day, and
2 outpatient scans should ideally be reported within two working days.

3 4 **5.8 Interdependencies with other services**

5 Lower volume centres should establish links with high volume CMR reference centres for reporting
6 of more complex and/or borderline scans (e.g., some cardiomyopathy or myocarditis cases), with
7 arrangements for image transfer and joint CMR review sessions. This could be established as a “hub-
8 and-spoke” model to reduce patient journeys to reference centres.

9 10 **5.9 Super-specialist services**

11 **Adult congenital heart disease (ACHD).** Patients with simple congenital heart disease (e.g., bicuspid
12 aortic valve, straightforward coarctation) can be scanned locally if the relevant expertise is available.
13 All other ACHD patients should generally be imaged in a CMR centre which has specific experience
14 in ACHD imaging. This is often in a designated ACHD centre. If a patient is found to have previously
15 unrecognised complex congenital lesion(s) during a scan at a non-ACHD centre, the scan should be
16 completed as far as possible, and further imaging performed if necessary in the future at an ACHD
17 centre.

18 **Non MRI-conditional cardiac devices.** CMR in patients with older ‘legacy’ non MRI-conditional
19 cardiac devices should be performed in centres experienced in scanning such patients. This service is
20 generally provided on a regional basis.

21 22 **5.10. CMR-specific risks:**

23 The main element of staff and patient safety specific to CMR is the area of magnet safety, referred to
24 above and covered in detail elsewhere[73].

25 A set of standard operation procedures should be in place to ensure a safe environment and quality.
26 Robust training and safety protocols around the magnet are mandatory. Detailed guidance on patient
27 safety can be found in BSCMR Standards Paper[70].

28 Emergency procedures should be reviewed and audited at regular (at least annual) intervals, and
29 should cover cardiac arrest, fire and flooding, magnet quench, decreased oxygen level, and loss of
30 power and lighting.

31 Gadolinium-based contrast agents are remarkably safe, with a lower adverse event rate for both
32 allergic type reactions and nephrotoxicity than iodine-based contrast media [74]. The RCR
33 recommends the following in patients with chronic renal impairment (in alignment with the European
34 Medicines Agency)[75]:

- 35 - The EMEA suspended the linear agents thought to be highest risk from intravascular use.
- 36 - It previously concluded that cyclical products (those with lowest risk, called group II agents)
37 can be used for patients with severely reduced renal function when a contrast-enhanced MRI
38 scan is clearly the best method of examination.

39 A local protocol should be in place to manage care of patients with impaired renal function balancing
40 the risks of gadolinium induced complications and the clinical requirement for the investigation
41 reflecting these guidelines.

42 43 **5.11 MRI specific audit and governance**

44 CMR departments should participate regularly in local audit programmes, which should include both

1 effectiveness audits around clinical and prognostic accuracy audits.

2 3 **5.12 Challenges to delivery of cardiovascular magnetic resonance imaging**

4 The BSCMR recommends that every cardiology department has access to a CMR service, and that
5 the NHSE diagnostic target of six weeks from referral to availability of scan report should be used as
6 the benchmark KPI across the UK.

7 The BSCI/BSCMR made a detailed projection of the likely need for CMR in the UK which was
8 followed by [NHSE 2013/14](#)[69].

9 Access to CMR imaging is variable across the UK (BSCMR 2019 survey)[76]. The BSCMR is keen
10 to promote greater availability of CMR in every region of the UK, sufficient to meet the NHS England
11 six-week target for outpatient diagnostics.

12 13 14 **Section 6. Conclusion**

15 The major characteristics of high-quality, contemporary cardiac imaging services are described in
16 this document. Such departments should be able to demonstrate these qualities through their audit
17 and governance processes.

18
19 Further detailed recommendations regarding current national standards and position statements are
20 contained in the appendices. It is inevitable, however, that advances in technology such as storage
21 and processing power, together with new applications of precision medicine, artificial intelligence,
22 and virtual reality will fundamentally change the practice of non-invasive cardiac imaging over the
23 next decade. In light of this, we recommend that this document is reviewed in five years.

1	FIGURES:
2	Figure 1: The rich diversity of cardiac imaging - Overview of Cardiac Imaging
3	
4	Figure 2: Imaging Quality Framework (adapted from the BSE EQF (13))
5	
6	
7	Figure 3: Overview of Echocardiography
8	
9	Figure 4: Overview of Cardiac CT Imaging
10	
11	Figure 5: Overview of Nuclear Cardiology
12	
13	Figure 6: Overview of Cardiac Magnetic Resonance.
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