BSCI Guidance for Cardiovascular CT training (Radiology)

Core training

This document outlines the details of the BSCI recommendations for core training and should be read in conjunction with, and as an adjunct to, the 2010 radiology curriculum. This document offers more detail on the recommended experience, knowledge and behaviours that will allow trainees to demonstrate acquisition of the required competencies. It is acknowledged that most hospitals currently performing cardiovascular CT in the UK only do one or two cardiac CT lists a week, making a definitive time requirement to gain the experience below problematic, particularly in the short term.

To gain core competence in cardiovascular CT it is recommended that trainees will need the following knowledge and experience:

a) Interpreting Contrast CT coronary angiograms

Ideally approximately 50 CT coronary angiograms should be interpreted, including both retrospectively and prospectively ECG gated studies. The case mix may additionally include studies involving the assessment of the following:

1) Stent and graft cases
2) Coronary Calcium Scoring (Non-contrast studies*)
3) Left ventricular function assessment (retrospectively gated studies)
4) Simple congenital heart disease
5) Coronary artery anomalies
6) Valvular pathology
7) Aortic pathology including dilatation and coarctation
8) Pericardial disease
9) Pulmonary venous anatomy
10) Cardiac tumours

*May be part of CT coronary angiogram study

b) **A basic understanding of current cardiovascular CT technology and practice:**

1) Cardiovascular CT capabilities (64 -320 detector technology, Dual Source, FLASH technology)
2) Cardiovascular CT indications and contraindications
3) Radiation safety (including IR(ME)R guidelines)

4) Cardiovascular CT procedure (acquisition parameters, prospective and retrospective ECG gated protocols)
5) Cardiovascular CT imaging protocols
6) Cardiovascular CT post-processing
7) Cardiovascular CT interpretation in clinical context
8) Cardiovascular CT limitations

Recommended learning methods include:

1) RITI modules
2) Self-directed learning - including dedicated computer programs with fifty cardiac CT cases fulfilling the above requirements
3) Dedicated teaching (e.g. tuition by radiologists and cardiologists)
4) Hospital meetings (e.g. departmental teaching, journal review, grand round presentations, study days, conferences, cardiac radiology meetings)
5) Local or national postgraduate education
6) Apprenticeship learning
7) In-house specialist teaching material.

Core training - additional Recommendations:

Although not mandatory, core trainees should consider attendance at one or more of the meetings outlined below (BSCI recommended meetings), particularly for those considering undertaking higher training. Additionally BSCI recommends certain courses, self-directed learning resources, online reading and books (see below, BSCI recommended courses).

Higher training (Levels 1 and 2)

Higher radiology training in cardiovascular CT aims to give trainees competence to independently report cardiovascular CT studies (level 1) and to run a Cardiovascular CT programme (level 2). This is the equivalent of the internationally defined SCCT level 2 and 3 clinical competence respectively, as described in the ACC Cardiovascular CT training document (http://www.scct.org/dgs/Cocats.pdf). To achieve this level of competence trainees need a much more detailed knowledge of the subject of cardiovascular CT and, importantly, other cardiovascular imaging modalities. This extends to both the role of Cardiovascular CT in the management of a

wide range of heart disease and also the technical aspects of how to obtain high quality information for all the different indications and how to process and report the scans.

The subspecialty training requirements are outlined here and mirror the international guidelines for training in Cardiac CT available at http://www.scct.org/dgs/Cocats.pdf:

To gain advanced competence in cardiovascular CT, trainees having **completed core specialty training** are likely to require the following:

a) For Level 1

1) 2 months equivalent full time cardiac CT training
2) Protocol involvement at time of CT acquisition of around 35 studies and supervised reporting of around 150 scans
3) Evidence of competence using workplace based assessments.

b) For Level 2

1) 6 months experience devoted purely to cardiovascular CT training (in a high volume cardiovascular CT centre)
2) 6 months additional experience concurrent with other cardiovascular imaging training
3) Protocol involvement at time of acquisition of around 100 studies. Supervised reporting of around 300 studies of which primary reporting of at least 100 studies
4) Evidence of competence using workplace based assessments.

The case mix should ideally include:

- coronary artery disease (CT coronary angiography with and without stents)
- coronary artery disease (Coronary Artery Bypass Grafts)
- coronary artery anomalies
- left ventricular function assessment (global and regional function)
- aortic, mitral, tricuspid and pulmonary valve pathology
- aortic pathology including dilatation and coarctation
- simple and complex congenital heart disease
- pericardial abnormalities
- cardiac mass/tumour
- right ventricular function assessment

- pulmonary venous anatomy
- coronary sinus anatomy
- myocardial perfusion (first pass studies)
- detection of myocardial infarction (late pass studies)

Practical knowledge gained should include the following:

a) A detailed understanding of the types of protocol available, the strengths and limitations of each and the parameters which must be optimised for each protocol. These should be allied with an understanding of the physics of Cardiovascular CT and ionising radiation and how these impinge on the clinical process. This should include an understanding of:
   - Indications and risk factors that might increase the likelihood of adverse reactions to contrast media
   - Radiation exposure factors
   - CT scan collimation (slice thickness)
   - CT scan temporal resolution (scan time per slice)
   - Table speed (pitch)
   - Field of view
   - Window and level view settings
   - Algorithms used for reconstruction
   - Contrast media
   - Presence and cause of artifacts
   - Post-processing techniques and image manipulation on work stations
   - Total radiation dose to the patient

b) Clinical role. Higher/ advanced trainees need adequate exposure to all aspects of provision of a clinical Cardiovascular CT service. This would include:
   - Vetting of referrals for appropriateness and consideration of ionising radiation safety.
   - Organising Cardiovascular CT lists
   - Liaising with other members of the radiology and cardiology teams.
   - Overseeing Cardiovascular CT lists
   - Report on scans with supervision.
   - Retain a close involvement with the clinical activities of the department, including audit and other quality assurance programmes.

- Close involvement with combined cardiology/imaging meetings, presenting Cardiovascular CT cases.
- On-call commitment should be adequate to meet continuing training requirements.

c) Cardiac CT research presented at regional/national meetings or published in peer reviewed journals

Additional desirable achievements include:

a) a higher degree involving Cardiovascular CT
b) BSCI/SCCT Level 2/3 Accreditation

Recommended learning methods include:

a) Completion of RITI modules
b) Self directed learning (e.g. textbooks, journals and internet sources)
c) Dedicated teaching by consultant staff (e.g. period of tuition by radiologist or cardiologist)
d) Hospital meetings (e.g. surgical conferences, cardiac radiology meetings)
e) Local postgraduate education (e.g. departmental teaching, journal review, grand round presentations)
f) Foundation courses and study days
g) Attendance (or presentation of research) at regional, national and international conferences)
h) Reflective commentary about anonymised patients in the portfolio of educational achievements
i) Apprenticeship learning (experiential learning)
j) Participation in research and audit supervised by consultant trainer
k) Participation in teaching
l) Participation in management
m) Use of in-house specialist teaching material

Assessment Methods

Workplace-based assessments have been introduced to allow a more structured approach to assessing trainees' competency. Below are outlined recommendations for the Cardiovascular CT component of higher/advanced cardiac imaging training. Both DOPS (directly observed procedural skill) and Mini-IPX (image interpretation exercise) are recommended and examples of suggested WBAs are provided. These should be used in conjunction with maintenance of a logbook and be part of the educational supervisor's assessment and report.

The assessors of WBAs should ideally be consultants running a Cardiovascular CT service and preferably be Level 3 SCCT/BSCI accredited. Approximately 6-8 of each type of assessment should be performed per year. It is envisaged that the time required for a DOPS is the duration of the scan plus 10 minutes for discussion and analysis. A Mini-IPX should take around 20 minutes (15min assessment, 5 min feedback).

a) DOPS

These assess the ability to correctly perform a technical procedure. Reference is made to the SCCT guidelines for performance of coronary computed tomographic angiography. It is important that trainees develop a portfolio of DOPS to demonstrate their competence, as cardiovascular CT should be regarded as a procedure with many technical factors for the supervising practitioner to focus on. Whilst in some cases this may be limited by local practice, trainees should consider training opportunities in other CT centres to maximise their exposure to a broad range of clinical scenarios. The DOPS should be documented in the standard format on the trainee's e-portfolio. Suggested DOPS and areas for assessment within these include the following:

1) DOPS: CT coronary angiography

a) Interacts appropriately with patient
b) Able to position patient within CT scanner with due regard to safety and comfort
c) Appropriate use of pharmacological agents to achieve appropriate heart rate (Aware of alternatives and contraindications to pharmacological agents)
d) Appropriate use of prospective or retrospective protocol (age, rhythm dependent) and use of the lowest reasonable radiation dose
e) Correctly times contrast bolus
f) Able to post process and interpret images (Axial, VR, MIPS, MPR)
g) Able to interpret and report images appropriate to the clinical context

2) DOPS: CT Calcium score

a) Interacts appropriately with patient
b) Able to position patient within CT scanner with due regard to safety and comfort
c) Appropriate acquisition plane
d) Appropriate use of correct protocol with low radiation dose to the patient
e) Able to post-process and interpret images
f) Understands clinical implications of result

3) DOPS: Coronary Artery Bypass Graft Assessment

a) Interacts appropriately with patient
b) Able to position patient within CT scanner with due regard to safety and comfort
c) Appropriate adjustment to acquisition plane (extended coverage)
d) Appropriate use of pharmacological agents to achieve appropriate heart rate (aware of alternatives and contraindications to pharmacological agents)
e) Appropriate use of prospective or retrospective protocol (age, rhythm dependent) and awareness of factors to minimise the dose of radiation
f) Correctly times contrast bolus
g) Able to post process and interpret images (Axial, VR, MIPS, MPR)
h) Able to interpret and report images appropriate to the clinical context

4) DOPS: Global and regional LV function (usually part of CT coronary angiogram study)

a) Interacts appropriately with patient
b) Able to position patient within CT scanner with due regard to safety and comfort
c) Knowledge of the requirements for LV analysis (i.e. retrospectively gated or broad prospective gating including end systole and diastole)
d) Appropriate use of pharmacological agents to achieve appropriate heart rate and understanding of potential effect on global LV function.
e) Aware of alternatives and contraindications to pharmacological agents
f) Correctly times contrast bolus
g) Able to post process and interpret images (Axial, VR, MIPS, MPR, calculation of chamber volumes and ejection fraction)
h) Able to interpret and report images appropriate to the clinical context

5) DOPS: Basic Congenital Heart Disease (CHD)

a) Interacts appropriately with patient (especially if learning disabilities or paediatric)
b) Able to position patient within CT scanner with due regard to safety and comfort

c) Knowledge of the requirements for Adult CHD analysis (i.e. retrospectively gated or broad prospective gating including end-systole and diastole)
d) Appropriate use of pharmacological agents to achieve appropriate heart rate (Awareness of risks and limitations of pharmacological agents in congenital heart disease)
e) Appropriate use of additional or extended protocols to answer clinical question, while minimising the dose of radiation
f) Knowledge of correctly times contrast bolus particularly in patients with Fontan type circulation and awareness of issues in patients with right to left shunts.
g) Able to post process images (Axial, VR, MIPS, MPR)
h) Able to interpret and report images appropriate to the clinical context

b) Mini-IPX:

These test the ability to interpret the images and then to relate these findings to the appropriate clinical context. Suitable cases for mini-IPX include:

1) Coronary Calcium Scoring
2) CT Coronary Angiography – prospective and retrospective protocols
3) Resting Ventricular Function (Global and Regional)
4) Aortic disease
5) Pulmonary arterial disease and RV function
6) Ischaemic heart disease (Infarction)
7) Pericardial disease/cardiac masses
8) Non –Ischaemic Cardiomyopathy (including HCM and myocarditis)
9) Congenital Heart Disease
10) Use of cardiac CT in assisting electrophysiology procedures
11) Knowledge of extra-cardiac findings

It can be useful to discuss the clinical scenario, the clinical implications of the result and other possible cardiac imaging tests that may be of use in the context of image interpretation and analysis. It is expected that those trainees training to level 1 or 2 would be able to discuss the following on a case-by-case basis:

1) **Coronary Calcium Scoring**
   a) Understands the role for coronary calcium scoring as a screening tool

b) Understand strengths and limitations of coronary calcium scoring in asymptomatic patients and as part of a CT coronary angiography protocol for chest pain assessment with particular emphasis on national guidelines (e.g. NICE)

c) Understand effect of coronary calcium on luminal assessment in CT coronary angiography

2) CT Coronary Angiography – prospective vs. retrospective protocols

a) Understands the principles of prospective and retrospective gated Cardiovascular CT studies

b) Understands strengths and limitations of each approach e.g. Radiation dose reduction, loss of functional information, artefact analysis etc.

c) Awareness of vendor specific approached to prospective and retrospective data acquisition

3) CT Coronary Angiography vs. invasive angiography

a) Understands the strengths and limitations of CT Coronary angiography vs. invasive angiography

b) Understand differences in spatial and temporal resolution between CT Coronary Angiography and invasive coronary angiography

c) Understand basic invasive coronary angiography planes and the potential limitations of comparing both techniques

d) Understands role of plaque assessment for both techniques and standard tools for quantification of stenoses (i.e. QCA) and the limitations in comparing techniques

4) CT Coronary Angiography vs. functional cardiovascular imaging

a) Understands the strengths and limitations of CT Coronary angiography vs. alternative non-invasive functional tests e.g., MPS, DSE and Stress CMR

b) Knowledge of the strengths and weakness of each test in assessing ischaemic heart disease.

c) Understanding of arguments between anatomical and functional imaging for ischaemic heart disease, including plaque vulnerability

d) Able to correctly interpret resting LV function data in conjunction with CT coronary angiography

e) Able to correctly interpret Early/Late Pass enhancement data

f) Able to write an appropriate, cogent report that is relevant to the clinical problem

5) Resting Ventricular Function (Global and Regional):

a) Able to correctly assess global LV function

b) Able to correctly describe regional wall motion using standard terminology i.e. hypokinesis, akinesis, dyskinesis.

c) Constructs report using the AHA 17 segment model

d) Able to correctly calculate LV volumes

e) Ability to use at least one analysis package, and awareness of problem areas (eg apical slices, basal slice and mitral valve in-plane motion)

f) Able to correctly interpret volumetric data

g) Uses appropriate reference ranges (for imaging and analysis used)

h) Able to write an appropriate and cogent report that is relevant to the clinical problem

6) **Aortic disease**

a) Understands the role of cardiac CT in the diagnosis and follow-up of aortic disease

b) Able to appropriately assess aortic size

c) Aware of other imaging modalities used in the assessment of aortic disease (MRI / invasive angiography) and their relative strengths and weaknesses

d) Knowledge of the role of cardiac CT in the assessment of patients undergoing aortic interventions (TAVI, aortic stents)

e) Able to write an appropriate and cogent report that is relevant to the clinical problem

7) **Pulmonary arterial disease and RV function**

a) Understands the role of cardiac CT in assessment of pulmonary disease

b) Awareness of other imaging modalities used in the assessment of pulmonary vascular disease (MR and nuclear techniques) and their relative strengths and weaknesses

c) Knowledge of pulmonary arterial and venous anatomy

d) Able to calculate RV size and function

e) Able to write an appropriate and cogent report that is relevant to the clinical problem

8) **Ischaemic heart disease (Infarction)**

a) Knowledge of how myocardial infarction can be assessed by CT (e.g. wall motion abnormalities, wall thinning, "late enhancement"

b) Understands importance of reporting cardiac wall abnormalities even on prospective scans with no functional information.

c) Able to write an appropriate and cogent report that is relevant to the clinical problem

9) **Pericardial disease/cardiac masses**

a) Able to determine an appropriate differential diagnosis

b) Knowledge of pericardial anatomy and disease processes

c) Knowledge of masses found in the heart

d) Able to write an appropriate and cogent report that is relevant to the clinical problem

10) Non –Ischaemic Cardiomyopathy (including HCM and myocarditis)

a) Knowledge of how cardiomyopathy can be diagnosed by CT
b) Knowledge of other complementary imaging techniques used to assess patients with cardiomyopathy (CMR, echo) and their relative strengths and weaknesses
c) Able to write an appropriate and cogent report that is relevant to the clinical problem

11) Congenital Heart Disease

a) Understanding and appropriate use of sequential analysis for congenital heart disease cases
b) Appropriate calculation of LV and RV volumes (as appropriate)
c) Appropriate awareness of surgical procedures and the assessment of post operative cases
d) Able to write an appropriate and cogent report that is relevant to the clinical problem

12) **Use of cardiac CT in assisting electrophysiology procedures**

a) Understanding of the role Cardiac CT has in assisting EP procedures
b) Knowledge of pulmonary and cardiac venous anatomy
c) Able to produce appropriate constructions of the area of interest
d) Knowledge of CT image integration into EP labs
e) Able to write an appropriate and cogent report that is relevant to the clinical problem

13) Radiation dose in Cardiac CT and mechanisms to reduce exposure

a) Awareness of the importance of radiation safety and the risks involved in radiation exposure
b) Awareness of vendor specific mechanisms to reduce radiation exposure

14) **Knowledge of extra-cardiac findings**

a) Awareness of extra-cardiac structures scanned during cardiac CT
b) Knowledge of important extra-cardiac abnormalities that require further action
c) Understanding for the need for close radiological and Cardiological working
d) Able to write an appropriate and cogent report that is relevant to the clinical problem

BSCI Recommended Educational Resources

1) BSCI Recommended Meetings:

Although not mandatory, core trainees can consider attendance at one or more of the following, particularly if they are considering undertaking higher/advanced training: BSCI recommend that all radiology trainees attend the cardiovascular CT sessions at UKRC/RCR scientific meeting at least once in their training. Higher/advanced trainees would be expected to attend regular meetings both to remain aware of current advances in cardiovascular CT and also ideally to present their own presentations/research.

The BSCI annual meetings (see here for information)
The BCS annual meeting cardiovascular CT sessions (see here for information).
The UKRC annual meeting cardiovascular CT sessions (see here for information)
The ICNC annual meeting cardiovascular CT sessions (see here for information)
The SCCT annual meeting (see here for information)
The RSNA annual Meeting cardiovascular CT sessions (see here for information)
ESC meeting (see here for information)
There are a number of regional meetings (e.g. SW Imaging Network (SWINE)) and local meetings. See www.bsci.org.uk for details.

2) BSCI Recommended Courses

Trainee attendance at formal Cardiovascular CT courses is not mandatory, but for those interested, current courses can be found at here and here. The BSCI run an annual meeting on Cardiac CT in collaboration with the radiology and cardiology sections of the Royal Society of Medicine and details can be found here.

3) BSCI recommended Self-directed learning resources

Web resources include

1. **BSCI** education material
2. **SCCT**: http://www.scct.org/
3. **ESC**: http://www.escardio.org/communities/working-groups/nuclear-cardiology/pages/welcome.aspx

http://www.escardio.org/communities/Working-Groups/nuclear-cardiology/publications/report-cardiac-ct/Pages/cardiac-ct-review.aspx

4. **ASNC**: http://www.asnc.org/

4) BSCI suggested introductory online reading

a. Assessment of Coronary Artery Disease by Cardiac Computed Tomography

b. SCCT guidelines for performance of coronary computed tomographic angiography

c. SCCT guidelines for the interpretation and reporting of coronary computed tomographic angiography

d. ACCF/ACR/ SCCT/SCMR/ASNC/NASCI/SCAI/SIR 2006 Appropriateness Criteria for Cardiac Computed Tomography and Cardiac Magnetic Resonance Imaging

e. Consensus Update on the Appropriate Usage of Cardiac Computed Tomographic Angiography

f. Cardiac Drugs used in Cross-sectional Cardiac Imaging: what the Radiologist needs to know. Clin Radiol 2010;**65**: 677-684

g. Considerations When Starting A New Cardiac MDCT Service, Avoiding the Pitfalls. Clin Radiol 2008;**63**: 355-69

4.5 BSCI suggested introductory books

1. Cardiac CT Made Easy by Paul Schoenhagen, Arthur E. Stillman, and Richard D. White (Paperback - 8 Dec 2005)
2. Oxford Handbook of Cardiovascular CT (Paperback) by Ed Nicol, Jim Stirrup, Simon Padley and Andrew Kelion. (2011)
3. Multi-slice and Dual-source CT in Cardiac Imaging: Principles, Protocols, Indications, Outlook by Bernd M. Ohnesorge, Thomas G. Flohr, Christoph R. Becker, and Andreas Knez (Hardcover - 19 Oct 2006)
4. Cardiac CT Imaging by Matthew J. Budoff and Jerold S. Shinbane (Hardcover - 1 Jun 2010)

Appendix

BSCI Guidance for Cardiovascular CT training
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