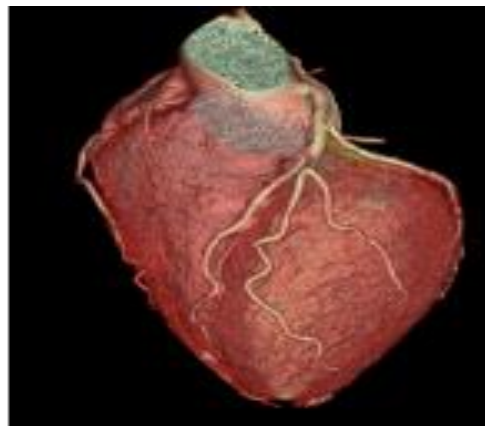
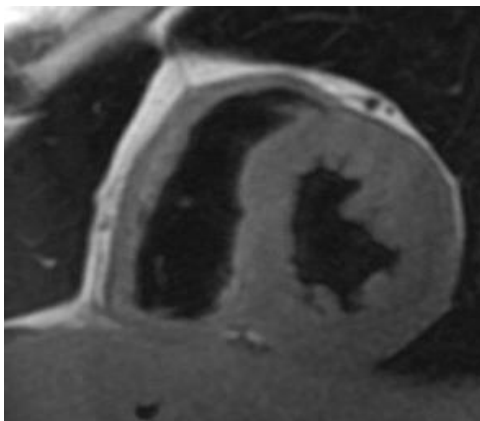
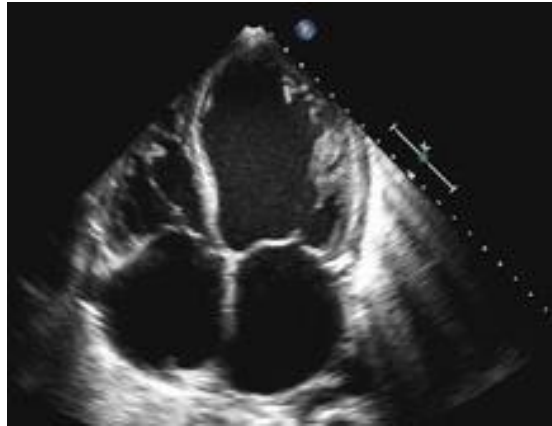
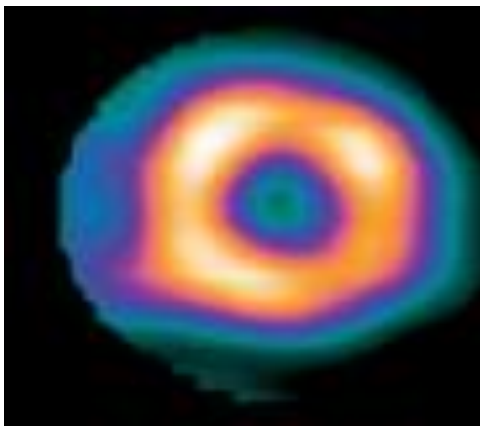


# DHSSPS Review of Imaging Services

## Cardiology Workstream

on behalf of the DHSSPS Radiology Imaging Review Board and the  
NI Diagnostics and Imaging Clinical Advisory group, Cardiology  
Clinical Network



May 2016

## **Preface**

As noted in the introduction to this document, the findings presented necessarily relate to a particular point in time. This is of particular relevance to staffing numbers reported, population estimates of need, and to clinical guidance on imaging investigation use. Since the report was written there have been changes in each of these areas, and as anticipated in the document, the NICE guidelines for imaging use in chest pain evaluation have been revised. While the overarching recommendations remain valid, some of the detail contained in the body of the report will require updating and revision. Indeed, one of the benefits of the structures proposed in this report is that they provide the flexibility to respond to the ever changing landscape of innovation in clinical and imaging protocols.

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## **Introduction**

This document has been drafted with the input of many individuals, groups and organisations who are listed in the appendix. In producing this report the input in particular of the Clinical Advisory Group on Cardiac Imaging and Diagnostics has been crucial. This document forms part of an overall strategic review of imaging services within Northern Ireland set in train by the Health Minister in 2014. The purpose of this report is to detail the current situation in Northern Ireland cardiac imaging, report the capacity of and demands on the system for investigations, set this in an evidence based context of projected and guideline recommended provision, explore the implications of this for the service across the province, and finally scope out possible future trends in imaging need, technology and usage. The report considers the major imaging modalities in turn with the exception of those tests which are largely interchangeable in the functional imaging field, which are reviewed together. Invasive cardiology imaging investigations, transoesophageal echocardiography, and paediatric imaging are outwith the scope of this report and therefore are not dealt with in a significant way in this document. The cardiac magnetic resonance and transthoracic echocardiography services have recently been the subject of extensive reviews. The sections on these imaging modalities are therefore relatively brief detailing the main findings and outlining how the services will look. The situation for the functional imaging tests (stress echocardiography and cardiac SPECT) and cardiac CT imaging are less defined and so more extensive proposals are made in this document. Review of these services coincided with advice from NICE on utilisation of these modalities and so the review in these areas is within the context of the NICE guidance. The report also reviews and gives guidance on generic imaging issues in as much as they impact on cardiology, with emphasis on scanner and departmental infrastructure, archiving and information technology provision, and both medical and non-medical staffing. The latter is an area of future challenge due to recent changes in training.

## **Executive summary**

In this report imaging modalities are generally considered separately though their complementary nature is emphasised, especially for the functional or anatomical tests for coronary disease. Cardiac imaging investigations may also be considered as those appropriate for delivery close to patients within each trust area (in this report sometimes termed 'level 2'), and those more specialised regional services where a hub and spoke or centralised model will be more appropriate due to consideration of equipment, infrastructure and staff expertise ('level 3').

Cardiac magnetic resonance (CMR) imaging is the archetypal level 3 investigation as a large proportion of the scan requests are from tertiary centralised services such as inherited heart disease and adult congenital heart disease. In terms of the likely number of studies required a model based on current demand plus change in waiting list gives a similar requirement as one based on population estimates suggested by the national society (BSCMR). For this reason adoption of the new hub and spoke model with scan numbers estimated using the above demand equation is recommended. Such infrastructure is now in place and funded, and such a service is expected to emerge within the next year, pending a slight change in staffing level.

Predicting and modelling the need for transthoracic echocardiography is very difficult due the very disparate number of referral sources, changes within any of which will materially change echo demand. The current method of estimating demand based on current delivery plus change in waiting list has advantage as it is sensitive to change from any source. However in theory this method can be problematic as it does not take into account the appropriateness of the studies requested. At the present time however, the level of demand predicted for this model is largely in line with numbers observed across various NHS regions (as per the NHS atlas), and so it is recommended that this method continues at the present time.

The situation for functional imaging (predominantly stress echocardiography and cardiac SPECT imaging) is more complex. The level of functional imaging varies

substantially between trust areas, both in terms of the tests available and the demand recorded. The use of a similar method to estimate demand as that successful for CMR and transthoracic echocardiography therefore is not applicable. A number of models for provision of functional tests have been published, and it is clear that there is significant variation from these in most trusts areas. Furthermore the equipment infrastructure and the staffing levels and experience vary widely between trusts and furthermore in those trusts with services, they remain vulnerable and dependent on a small number of individuals only. Various models are reviewed in this report and a conservative but deliverable model based on NICE guidance is proposed. The delivery of this model will depend on improved staffing numbers and expertise. It is recommended that there is diversification in the tests available so that should pressure on any one vulnerable service become excessive, the delivery of functional imaging as a whole is not jeopardised.

The situation with cardiac computed tomographic imaging (cardiac CT) and specifically CT coronary angiography is even more variable. Two trusts have established, though incompletely funded, services. Two other trusts have recently started services, and one trust delivers cardiac CT on an unplanned basis. No national body has made recommendations on the appropriate level of activity, though calculations can be done based on NICE guidance which would cover around half of the potential numbers expected. Further, none of the estimates really take into account the issue that functional and anatomical tests may be interchangeable in a relatively sizeable cohort of diagnostic patients at low and low/intermediate risk of having coronary disease. A recommendation for the provision of cardiac CT services is made based on NICE guidance. This will be the part of the recommendations requiring the greatest investment in infrastructure and staffing. CT imaging should be available for patients in all trusts, though the method for providing this could be open to negotiation.

While both functional (mainly stress echo or cardiac nuclear imaging) and anatomical imaging (cardiac CT) should be available for patients in each trust area, it is the case that there is overlap in indication and appropriateness between functional and CT imaging in a cohort of patients. It is therefore further recommended that the overall need for these 2 modalities is combined and that implementation takes place in a flexible way, with the overall provision divided between the modalities in a proportion

that reflects patient characteristics, local infrastructure and local staffing levels and expertise. This will further offset the issues of the (presently) low levels of CT availability, and the vulnerability of functional services to staffing issues.

The issues around imaging archiving and sharing, and report availability are complex. Trusts have developed imaging reporting and storage systems locally as services have developed. Not only is there no uniform method for storing or viewing reports within NI, but even within trusts there are several systems in use. This document recommends that cardiac imaging reports be made uniformly available via the NI Electronic Care Record, and acknowledges progress in this direction already (including CMR and some transthoracic echocardiography). Image archiving and viewing should similarly be uniform across NI, and a direct link to NIPACS for cardiac images is recommended. This would have to be delivered in the context of an NI wide review of PACS systems which would be supported by this report.

While recommendations for the future sustainable provision of imaging services are given in this report the short term issue of the legacy backlog will remain. A solution to this problem is required, and this report recommends that this is discussed with individual services within each trust to identify the best short term solution to the issue; this does not preclude a regional approach where appropriate and feasible. There are significant challenges in finding solutions in some areas due to lack of suitably training medical and non-medical staff.

The development of imaging services and infrastructure within other areas is relevant to cardiology, and changes in cardiology imaging may also have implications for radiology and other specialties. We recommend the formation of an overarching imaging board with representation from all the major groups involved in this departmental review process, together with any other relevant stakeholders. All relevant groups will then be aware of any major infrastructural and service developments and their implications for each group can be properly assessed. In addition new technologies can regularly be reviewed within the appropriate multidisciplinary team.

The Imaging Board would also have an overarching view of manpower/staffing issues within the imaging community. In terms of cardiology issues have been identified with the subspecialty expertise of cardiology trainees and prospective new

consultants. Recently there have been adequate numbers of trainees with experience in basic transthoracic echocardiography, and in cross sectional imaging including cardiac CT and CMR. However expertise in advanced transthoracic echo and in particular in the functional imaging areas of stress echo and cardiac SPECT are relatively less. In order to service these relatively vulnerable services in the future, more experience in stress echo and nuclear investigations is recommended for imaging trainees.

Similar but more serious issues have been identified within the clinical physiology workforce. The change in career pathway with a potential move to the graduation of more generically trained graduates and more pressure for on the job training via the Modernising Scientific Careers pathway has seriously jeopardised the future workforce for transthoracic echocardiography. This report recommends urgent engagement with the department, board and all other relevant stakeholders to explore ways forward, and acknowledges that this work has begun both locally and nationally. The provision of a postgraduate pathway in this area should be given consideration. Recommendations following a review in England should be considered a Northern Ireland context.

Finally, it should be noted that this report was compiled over a period of 18 months. Some of the data may have changed slightly over this time. This has several implications. First, staffing levels and the local populations within each trust/LCG area will change over time. For this reason those estimates of scan numbers based on population will need to be recalculated when implementation occurs to take into account the population at that time. Second, the proposed requirements for chest pain imaging (CT and functional) represent a partial implementation of the NICE guidance; the move towards a fuller implementation should be considered once the present plan has become established. Finally, the NICE guidance for assessment of chest pain is currently under review and significant changes are likely as a result of evidence available since the initial determination (and alluded to in various places in this report). For that reason the full implementation alluded to above should be influenced by the new iteration of the guidance when it becomes available.



## Key findings and recommendations

- The recently proposed hub and spoke model for CMR provision should be implemented and the commissioning estimates reviewed on yearly basis.
- The recently locally agreed model for echo provision should be implemented and the commissioning estimates reviewed on a yearly basis. Changes in work patterns should be considered should BSE guidance on work practices or the imaging dataset be reviewed.
- A substantial backlog of CMR and echocardiography patients remains despite the proposals for improved recurrent funding. Addressing this is challenging given the lack of spare infrastructure and staff capacity. Local and regional discussions should take place, and have begun, to identify the best way to address this issue.
- Chest pain imaging should move from a predominant strategy of exercise stress testing first to a more balanced model with appropriate early use of cardiac imaging tests as a first line.
- Functional imaging provision is patchy across NI and some services are vulnerable, depending on a small number of individuals. The complementary anatomical cardiac CT service is patchy and poorly developed at present. Neither service could cope with the demands of increased imaging in chest pain as proposed above.
- Estimates of required activity have been developed for overall functional and anatomical imaging combined, and should be implemented for each trust/LCG area in a proportion decided at local level. This will require expansion of both functional and anatomical imaging, with particular deficits in the area of cardiac CT.
- LCGs, trusts and cardiology commissioners should discuss the CT requirements with radiology to maximise the use of scanners and staff.
- PET imaging will likely also have a place to play in other cardiac diseases including cardiac sarcoidosis, prosthetic valve endocarditis, and pacemaker

infections. The HSC should begin to plan a regional service which offers FDG PET imaging for cases of suspected device or prosthetic valve endocarditis.

- Province wide access to cardiac imaging reports should be implemented via the Northern Ireland Electronic Care Record.
- Province wide access to cardiac imaging datasets should be implemented via a single integrated NI PACS solution.
- A research culture should be matched within departments by research capacity, with closer integration of clinical and research departments.
- Cardiology medical staff training should encourage trainees to gain experience in functional imaging techniques.
- Serious shortages are predicted nationally in Cardiac Physiology staff with particular impact expected in echocardiography. Funding and service delivery pressures exacerbate the lack of training opportunities to develop the postgraduate workforce into the senior echocardiographers of the future. Urgent discussions with all stake holders are recommended, and recommendations of the NHS England review in this area should be considered for applicability to Northern Ireland.
- It is recommended that an overarching Imaging Board should be constituted to review speciality and overall service development in imaging.
- Imaging departments should develop and work towards the standards of the appropriate accreditation models.

## **Section 1: Cardiac Magnetic Resonance imaging (CMR)**

### **1. Initial position**

#### **Background**

Cardiac magnetic resonance (CMR) imaging is an important modality for the investigation of patients with complex cardiac conditions, particularly those with genetic, inherited, inflammatory, infiltrative and ischaemic cardiac disorders. Guidelines on its application in these areas have been published in European and American guideline documents, including Appropriate Use Criteria. Unique strengths include the cross-sectional nature of the images, and the ability to acquire in a multimodality fashion to include anatomical, functional, flow, volumetric, non-invasive angiography and tissue characteristics in a single study. CMR is particularly suited for the long term follow up of these and other diseases, as it does not utilise ionising radiation, and therefore is particularly safe when used recurrently or in younger patients. CMR imaging is relatively expensive and intensive of consultant and radiographer time.

A service was started almost 10 years ago in Belfast City Hospital, and subsequently has been developed into a clinical service based in the Mater Hospital Belfast. The current service is delivered on an NHS scanner staffed by Alliance Medical and supervised by NHS consultants under special agreement with the NHS.

This document details the current situation in respect of imaging of adults and older children; the issue of imaging younger children will be addressed through the paediatric imaging workstream.

#### **Activity**

The small service proved in BCH was subsumed into the Mater service within the last 18 months and so the vast majority of CMR in Northern Ireland is delivered via this regional service. A small number of scans have been carried out in other centres but no commissioned service exists in any other site. All regional CMR referrals are collated in Belfast for organisation of imaging.

As the recognised indications for CMR imaging have grown, so demand has increased at a rapid rate. The figure below details referrals received over the last 7 years. The annual rate of increase averages around 28% for last 4 years to 2014, though anecdotally it may be slightly less in the current calendar year. As well as new cardiology patients being referred, there has in addition been some ‘catch-up’ as those patients already in the system requiring imaging according to recent guidelines are being referred as they are seen; subsequently a significant backlog of cases has been generated.

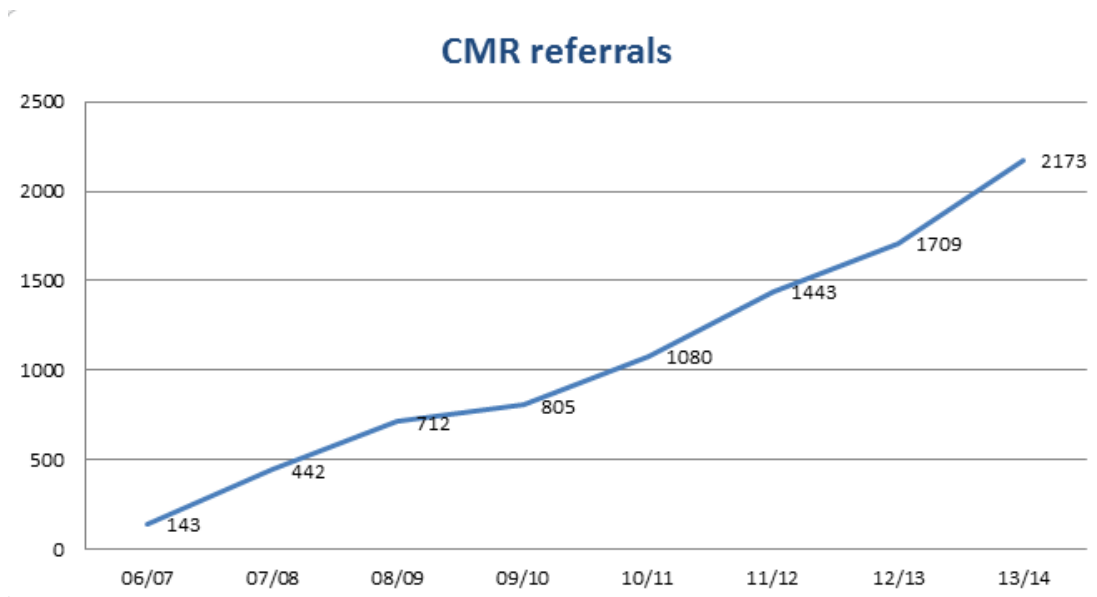


Figure 1: Number of CMR scans per financial year, 2006-2014.

The graph below indicates the number of patients scanned per calendar year up to end of 2012. A rapid rise in imaging numbers is noted, though the numbers requested still significantly outstrip supply.

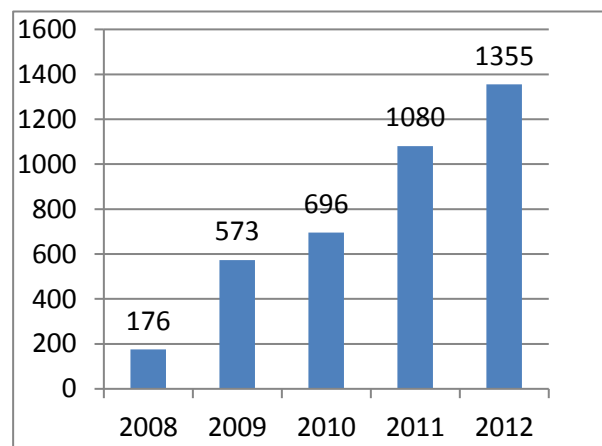


Figure 2: Number of CMR scans performed per year 2008-12.

Scans were delivered across several clinical sessions by 3 BHSCT consultants, 1 NHSCT consultant, and one consultant paediatric cardiologist (RBHSC), as below:

CMR imaging slots	No of Scans per week	No of scans per anum	Number and Type of sessions
Monday	2	84	1 session - complex cases made up of Paediatric and Adult Congenital
Wednesday am *	3	126	1 sessions * previously scanned BCH
Wednesday pm & eve	8	336	2 sessions
Thursday	4	168	1 session
Friday (a.m.)	4	168	1 session
Friday (p.m.) *	3	126	1 session - normal scans carried out by NHSCT Consultant*
<b>Total</b>	24	1008	8 sessions @ 1.5 PA's per session

Table 1: Weekly CMR sessions in Mater regional CMR service

The consequence of these data is that a large backlog of cases has built up, as detailed below:

Weeks	0-3	3-6	6-9	9-13	13-21	21-26	>26
No	82	47	53	84	218	113	68

Table 2: Number of patients waiting for imaging by length of wait in weeks.

The large number of scans outstripped the current funded scan provision to a very large extent. CMR activity was relatively high compared to the recurrently funded number of scans due to backstop funding which recognised the important place of the technique in clinical guidelines. Before review the funding situation was as follows:

- 321 scans recurrently funded legacy SBA
- 1000-1300 scans backstop (WLI)

As a result of the apparently continuously rising demand and the limit in supply, a review of need was carried out, using recognised planning assumptions based on the most up to date guidelines from the appropriate UK Specialty societies.

## 2. Estimating the need and proposing a new service

### Estimation of numbers of scans

Estimation of the overall need for CMR imaging is difficult for several reasons. The CMR service is still maturing, the evidence base for the value of the technique is continuing to expand, new technical advances are constantly becoming available, and not all suitable patients from some areas have yet been imaged, making it difficult to reach a 'steady state' level of need. For example following the significant expansion of the adult congenital heart disease service within the last 2 years, several new patients were identified who required CMR imaging, leading to a temporary rise in referrals. In order to deal with these uncertainties, it was decided to model the service needs using nationally produced estimates from the British Society of Cardiovascular Magnetic Resonance imaging (BSCMR) guidance\*.

Estimation of need was carried out assuming a total NI population of 1.8 million with a suitable reduction for children of around one third, giving a target population of 1.1-1.2 million adult population (depending on age cut off); paediatric CMR will be considered separately. The guidance gives an overall figure and also expected figures for some of the subspecialty areas which are the biggest users of CMR, including scans for patients with inherited cardiac disease, adult congenital heart disease (ACHD), ischaemic heart disease (IHD) and others.

<b>Disease area</b>	<b>Scans/million/yr</b>	<b>Scans/yr NI</b>	
Inherited	520	604	
ACHD	100	116	
Others	455	528	
IHD (all)	1200 *	1392	
<b>TOTAL</b>	<b>2275</b>	<b>2640</b>	<i>*IHD (viability) 400</i>

Table 3: Suggested CMR numbers per main indication as BSCMR guidance; includes perfusion studies for IHD patients.

The figure for IHD comprises patients being studied for myocardial viability and also those having functional imaging by stress CMR perfusion. In NI we noted that there is already a reasonably large number of functional scans being delivered by nuclear cardiology (SPECT) and stress echocardiography techniques, and so the number proposed would likely be an overestimate of need. For this reason, the proposed number per million allocated to IHD was reduced from 1200 to 600. The estimated need for functional imaging is presented later in this report, and it is suggested that for reasons of availability, local access, logistics and cost, the majority is carried out by SPECT or stress echocardiography. This results in a revised number of scans as detailed below:

Disease area	Scans/million/yr	Scans/yr NI
Inherited	520	604
ACHD	100	116
Others	455	528
IHD	600 *	696
<b>TOTAL</b>	<b>1675</b>	<b>1944</b>

*Table 4: Suggested CMR numbers per main indication as BSCMR guidance; includes reduced IHD numbers due to reduction in perfusion studies*

As there was a large amount of additional work being carried out under non recurrent backstop/waiting list funding, a significant number of CMR studies have been performed annually. To model the requirements in an alternative fashion, the need was estimated using the formula current activity + change in waiting list. The data are given below, and show that this method gives very similar figures to the BSCMR recommended figure (1881 v 1944 per annum).

	WL end March 13	WL end March 14	Change in WL	13/14 Activity	14/15 Demand
<b>Cardiac MRI</b>	530	724	194	1687	1881

*Table 5: CMR demand modelled using activity plus change in waiting list.*

We considered that there was still potentially a small backlog of suitable patients and some variation in the provision of alternative perfusion imaging available across NI, and decided on a final number of around 2050 scans in total.

## **Estimation around scanners and staff**

At the time of assessment, the vast majority of CMR imaging was carried out in BHSCT as detailed previously. The consolidation of the service on the Mater site improved the efficiency of the service with better management of urgent scans and flexibility in terms of consultant cover. However this arrangement also has problems. The Mater scanner is not managed by cardiology, and a small number of sessions are required for other general imaging, including occasional emergencies on the Mater site. In addition the large number of waiting list sessions required to deliver the activity detailed above meant that all sessions on the scanner were already filled. Additional activity was already being delivered at weekends and in the evening. In order to deliver the activity proposed in the above estimates (around 2050) the capacity, and indeed any growth in activity following the annual review of numbers, on the Mater site would be stretched. Delivering the entire service on a single scanner has other potential vulnerabilities in terms of possible unexpected scanner breakdowns. In order to offset these issues, improve the resilience of the service, and improve local access for the less complex studies another solution was proposed.

### **3. Meeting the gap and configuring the service model**

The proposal to recurrently fund a CMR service based on internationally accepted indications and delivering around 2050 scans annually was agreed and a delivery plan developed, taking into account the staffing and infrastructure issues identified above.

During the review period suitable 1.5T MRI scanners with cardiac packages were in fact in the process of being installed into radiology departments in 2 trusts in NI. In addition the regional revascularisation group was defining the staffing requirements for the NI primary angioplasty service. In order to provide clinical cover for time spent by interventional cardiologists delivering the primary PCI service, additional cardiology consultant posts were created as part of the process. There were profiled to fit with the development of the new CMR service. It was therefore decided that the best way of delivering the scans, as well as maximising local access, was for a 'hub



and spoke' service. The proposal was made to have the hub service in BHSCT; this would provide general cardiac scans for most of the east of the province, as well as delivering specialist scans in inherited cardiac diseases and adult congenital heart disease, both highly complex services already based in BHSCT for the whole of the province. Additional sessions delivering less complex standard clinical cardiac imaging would then be performed on the 2 new MRI scanners in NHSCT (Antrim Hospital) and WHSCT (South Western Acute Hospital). A cardiologist with suitable experience was already in place in SWAH, and a new cardiology appointment with suitable experience was recruited to NHSCT. The final sessional arrangements would therefore be:

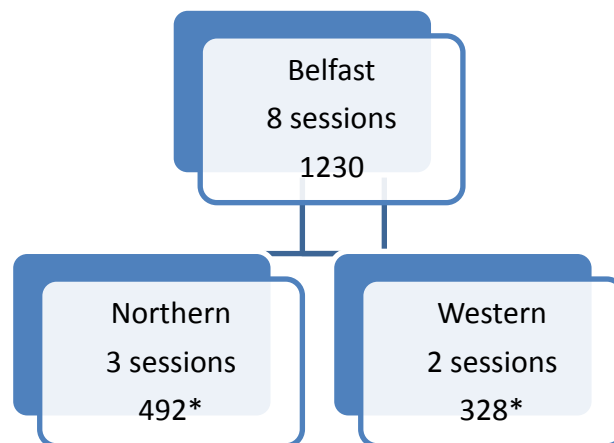


Figure 3: Proposed level of CMR activity in Northern Ireland in the hub and spoke model. The level of activity using this model would be 2050 scans/annum closely aligned to the estimates above.

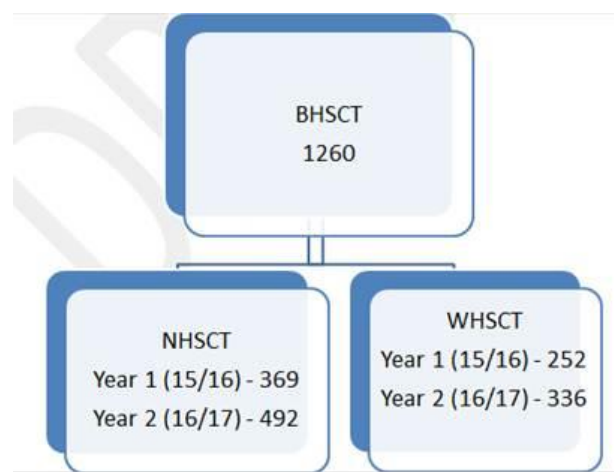


Figure 4: Draft proposed activity for the hub and spoke model for 2015/16 and 2016/7 based on current activity and waiting list data. These figures are liable to change. The additional numbers in 2016/7 reflect the increased number of patients scanned per session (see below).

A hub and spoke model has been designed to ensure uniformity of image quality and access across NI, in a fashion compatible with the best quality standards of the BSCMR guidance.

Each session in BHST would comprise 4 patients except for a small number of complex congenital cases where 2 or 3 could be carried out in the time available. It was agreed that the sessions in NHST and WHST should deliver 3 scans per session for the first year while staff were undergoing training, and then move up to 4 scans/session thereafter.

Radiography staff were already recruited to run the general radiology component of the scanners, and so would also perform the cardiac scans. A program of training has been set in place with visits to suitable training courses and to the hub in Belfast for some weeks prior to launch of the local services. It is also anticipated that the lead cardiologist (see below) will visit the regional service on start up to aid with setting up protocols and image quality.

### **Service components and standards**

The following components and related standards have been built into the system, based mainly on nationally and internationally agreed guidelines and policy statements:

- Equipment /scanner to published standards (SCMR, BSCMR, NICE).  
Initially 1.5T technology with regular review and reassessment at elective replacement
- Scanning sequences and protocols agreed province wide.  
Scanners should have as a minimum full standard cardiac sequences to cover the main cardiac indications including T1 and T2 weighted anatomical imaging, cine imaging (SSFP based sequences), flow mapping (mainly phase contrast method), non-invasive contrast angiography and delayed contrast enhancement imaging (post gadolinium delayed enhancement sequences using inversion recovery method). These are based on the internationally agreed SCMR protocols.

- Staffing levels.
  - Level 3 director of service (based in BHSCT)
  - 2 staff at all times for scanning
  - Minimum 1 doctor if stress
  - MRI safety and BLS training
- Referrals
  - Vetted centrally by level 3 lead clinician
  - Considered against indications agreed during commissioning (ESC document below)
  - Triaged to urgent/routine and hub/spoke
- Reporting
  - Reporter trainee at level 2 or above
  - Level 3 physician available to discuss cases
  - Link ups if not the case or sole operator
- Regional audit/discrepancy meetings at least 3 times per year
- Scan volumes per centre
  - Minimum 300 cases / yr within 3 years for spoke
  - Minimum 500 cases / yr for training centres/hub
- Scan volumes per consultant operator
  - Level 2 - 20hrs coursework, 100 scans/2yrs
  - Level 3 - 40hrs coursework, 200 scans/2yrs

Radiography staff were already recruited to run the general radiology component of the scanners, and so would also perform the cardiac scans. A program of training has been set in place with visits to suitable training courses and to the hub in Belfast for some weeks prior to launch of the local services. It is also anticipated that the lead cardiologist (see below) will visit the spoke services on start up to aid with setting up protocols and image quality.

At the time of writing, recurrent IPTs had been received by the Board from BHSCT, WHSCT and NHSCT and recurrent funding allocations had been identified to achieve the regional demand volume.

## Key documents:

Clinical Role of Magnetic Resonance in Cardiovascular Disease: A scientific statement of the European Society of Cardiology - *EHJ* 1998;19:19-39.

ACC Appropriateness criteria for CMR Hendel R.C., Patel M.R., Kramer C.M.; ACCF/ACR/SCCT/SCMR/ASNC/NASCI/SCAI/SIR 2006 appropriateness criteria for cardiac computed tomography and cardiac magnetic resonance imaging: a report of the American College of Cardiology Foundation Quality Strategic Directions Committee Appropriateness Criteria Working Group, American College of Radiology, Society of Cardiovascular Computed Tomography, Society for Cardiovascular Magnetic Resonance, American Society of Nuclear Cardiology, North American Society for Cardiac Imaging, Society for Cardiovascular Angiography and Interventions, and Society of Interventional Radiology. *J Am Coll Cardiol.* 48 2006:1475-1497

Delivering Cardiovascular Magnetic Resonance in the UK: BSCMR/BSCI guidelines 2010. (available at [www.BSCMR.org](http://www.BSCMR.org))

## **Section 2: Transthoracic Echocardiography**

### **1. Current situation**

#### **Background**

Transthoracic echocardiography is a non-invasive ultrasound based imaging investigation and represents the most common of the cardiac imaging investigations. It gives detailed information on cardiac structure and function, including valvular and haemodynamic function. For this reason there are a very wide range of indications, and taken together with its safety and portability, it is an increasingly commonly requested test. This review relates to transthoracic echocardiography performed by cardiac physiology departments embedded within cardiology departments. Such a department provides imaging for many inpatient and outpatient services within the NHS. Scans carried out in other settings are not considered as they represent only a tiny number of the overall scans performed, are carried out in small numbers in many differing locations, and are not recorded in an overall registry. However such numbers are too small to materially alter the demand for or supply of transthoracic cardiology services.

In contrast to the CMR service which receives almost exclusively referrals from cardiologists, many other clinical specialties refer large numbers of patients for echocardiography, including for example medical, preoperative and oncology patients. As such, assessment of future demand is very difficult as novel interventions and drugs introduced into a seemingly non related specialty may require cardiac monitoring or screening, and a new unforeseen demand on the service will arise.

This review also does not include stress echocardiography, which is considered elsewhere under functional imaging investigations, and transoesophageal echocardiography which is a specialist service generally undertaken in limited locations and with comparatively smaller numbers.

## Current situation-demand

There is a general growth in the demand for echocardiography across NI, and indeed across the UK which has been relatively consistent over the last several years. There are several reasons for the growth, some of which include increasing indications related to monitoring new drugs (e.g trastuzumab for breast cancer), increasing recognition of heart failure due to an ageing population and screening using NTproBNP, improved management of valvular heart disease, improved survival in patients with congenital heart disease, and the development of clinical pathways in which the imaging is embedded (including electronic referrals).

The numbers of scans carried out by clinical cardiac physiology departments, which as noted perform the vast majority of studies, are shown on a per trust basis over the last 4 years in the figures following.

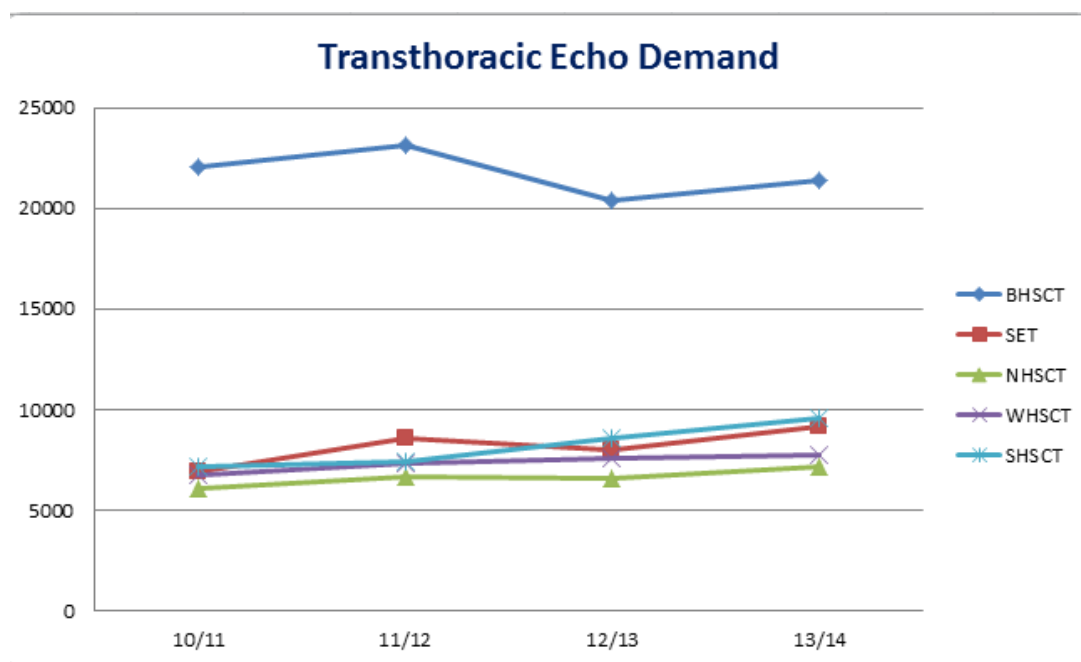


Figure 5: Transthoracic echocardiography demand (y axis, number) divided by trust in the years 2010/11 to 2013/14.

## Current situation-activity

The numbers of echo studies carried out by trust are detailed below, and speak to the increasing demand and hence worsening waiting list pressures. The increase over the last year is clear in each trust area. While there was slight variation in Belfast Trust numbers there is an overall clear rise year on year in all trust areas. In

addition a large backlog in elective activity was identified, with several hundred patients waiting more than 9 weeks.

	BHSCT	SET	NHSCT	WHSCT	SHSCT
10/11	22045	6937	6062	6712	7194
11/12	23122	8613	6702	7369	7400
12/13	20414	8004	6613	7541	8575
13/14	21353	9138	7172	7748	9552
growth (n=)	939	1134	559	207	977
% growth	4.6	14.2	8.5	2.7	11.4

Table 6: Numbers of transthoracic echocardiograms performed per trust from 2010/11 to 2013/14 with growth in numbers and percentages in the lower 2 rows

## 2. Estimating the need and proposing a new service

In developing a plan to deliver echocardiography addressing the demand, a capacity/demand exercise was undertaken both at a regional and a local level. There is not a clear standard guideline number of echocardiograms required per unit population due to the many variable factors influencing demand referred to above. Due to the complex factors underlying the trends it was decided to model demand using the formula:

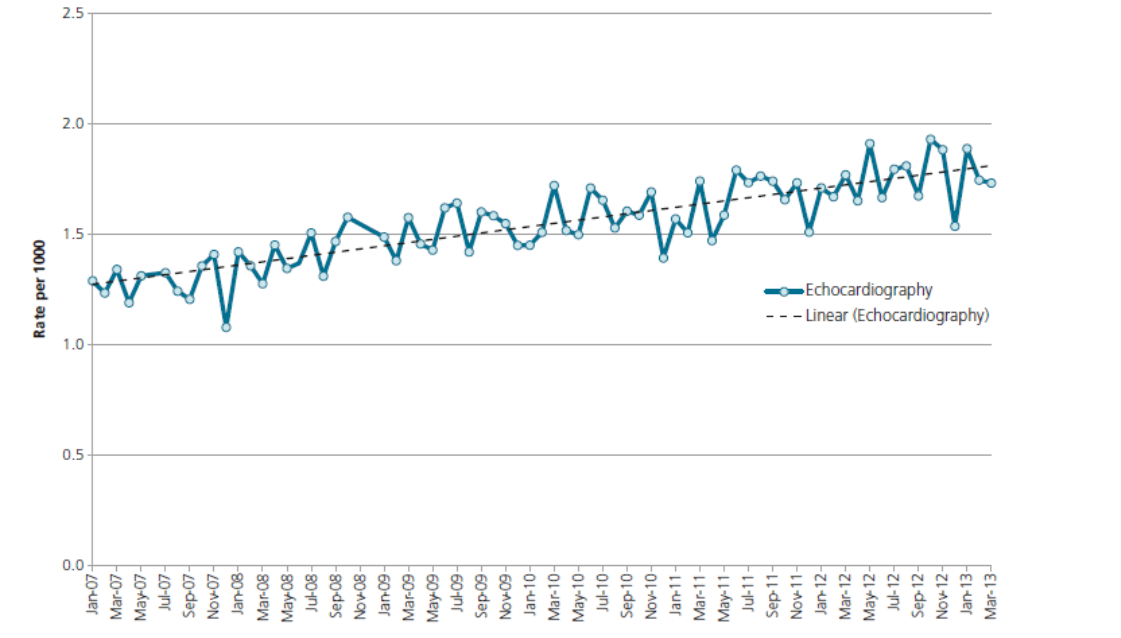
$$\text{Demand} = \text{activity} + \text{change in waiting list}$$

This formula would be applied on an annual basis using the end of year figures from the current and past years to calculate the required number of studies carried out. An annual calculation using the most current figures was felt to be appropriate as using averaged or historical figures would clearly underestimate the number of scans required due to the trend of increasing use of this service.

While no formal guideline target number of investigations has been proposed by national bodies, some form of benchmarking of the above estimation is desirable. This pattern of growth is very similar to activity elsewhere in the UK, as shown in the graph below (reproduced from the NHS Atlas of variation) representing variation in

procedures throughout the NHS. A growth in commissioned activity of 43% over 6 years reported within the English NHS is similar to that suggested by recent NI data.

**Figure 28.1: Rate of echocardiography activity commissioned per 1000 population from January 2007 to March 2013<sup>3</sup>**



*Figure 6: Rate of echocardiography activity commissioned per 1000 population from January 2007 to March 2013.*

### Service components and model

Using the formula above, SBAs have been set and agreed for each trust area, with the final figure towards the upper end of the range noted in the NHS atlas of diagnostic services. Based on the 13/14 demand, recurrent gaps were identified as detailed below. IPTs have been drafted as required and SBAs have now been agreed with the 5 trust areas.

The data also show the significant problem with study backlogs. While WHSCT and SEHSCT have no significant waits beyond 9 weeks, other trusts between them have large numbers, and current estimates are of around 3000 patients waiting beyond the 9 week target. There is a current shortage in clinical physiology staff capable of performing echocardiography on a UK wide basis which is discussed elsewhere in this document. Unfortunately there are therefore limited non recurrent options due to required BSE accreditation to scan and report autonomously.



	NHSCT	WHSCT	SHSCT	SET	BHSCT	NI
<b>SBA</b>	6,219	8,010	8,370	10,360	21,738	54,697
<b>13/14 demand</b>	7,172	7,748	9,552	9,183	21,353	55,008
<b>Variance</b>	-953	262	-1,182	1,177	385	-311

	NHSCT	WHSCT	SHSCT	SET	BHSCT
<b>&gt; 9 week waits end July 14</b>	688	7	30	86	828
<b>% variance against SBA</b>	0%	-5%	5%	-4%	-2%

Table 7: SBA levels and variances across NI Trusts for echocardiography 2013/4.

### 3. Meeting the gap and defining the service model

The above discussion defines how the problem will be addressed. The organisation of echo services is devolved to each trust area; SBAs have been agreed with each trust and resources for staffing shortfalls are being sought or have been provided.

As well as the need for additional staffing, equipment will be needed as numbers of scans increase. The number of staff, the time for performing studies and reporting, and appropriate time for training have been factored into the new proposal using the British Society of Echocardiography standards document. In particular the standards will include:

- Each echo will be carried out to the standard of the BSE minimum transthoracic dataset, with additional imaging as clinically indicated.
- Each echo machine will perform a maximum of 2500 scans per year, and fewer if there are complex studies or significant numbers of ward-based studies.
- Each physiologist will undertake no more than 1800 studies per year, and fewer for those in training or those at a senior level supervising trainees.
- A standard study takes 45 minutes; more complex studies around 60 minutes.

These developments are a major step forward, though there are still challenges to the adequate delivery of these services. The time allowed per study and the volume of studies per echocardiographer remain challenging as the minimum BSE dataset is frequently not all that is required for studies (for example TAVI patients, strain imaging for chemotherapy patients). In addition the anecdotally large number of impatient studies being reported by all departments is skewing the workload with urgent inpatient studies required for patient management or discharge having a negative effect on outpatient waiting times. In the medium term training of new staff is also very problematic due to a variety of factors which are discussed in the workforce section. The final issue is that of the echocardiography backlog detailed previously. The recurrent funding will help with capacity going forward but fails to deal with the extensive backlog; the aforementioned staffing problems limit the non-recurrent options for dealing with this backlog.

### **Key documents**

British Society of Echocardiography: Standards for transthoracic echocardiography

British Society of Echocardiography: Transthoracic echocardiography minimum dataset (available from British Society of Echocardiography at [www.bsecho.org](http://www.bsecho.org))

## **Section 3: Functional imaging and cardiac computed tomography**

### **Background**

The National Institute for Health and Care excellence (NICE) published guidance on the pathways for management of chest pain in 2010. Embedded within these was guidance for the use of functional imaging and cardiac CT imaging, and the recommendation that standard functional testing with exercise ECG stress should end. In this section of the report we detail the current use of such imaging in NI, model the implications of NICE and make recommendations about moving forward. While the NICE document gives helpful advice for stable chest pain populations, the tests in question are also useful for a variety of other clinical scenarios, and in making the recommendations we have sought to model these in addition. Finally recent research evidence suggests that the very rigid guidance on the suitability of each investigation for patients at particular levels of pre-test likelihood should be relaxed, and to this end some advice about the interchangeability of the various investigations is given. This advice is therefore based on NICE and Professional Body guidance and current practice / pathways in Northern Ireland. This guidance covers patients who present for medical help to either primary or secondary care. It covers predominantly stable presentations.

### **1. Initial position**

The functional and anatomical tests discussed in this section are used for the diagnosis and management of ischaemic heart disease (heart attack, angina, acute coronary syndromes) and in particular in the assessment of patients with chest pain for the above conditions. Chest pain is a common symptom, accounting for about 1% of GP visits and 5% of A&E department visits. Combined hospital and primary care data produce an incidence of cardiac chest pain of 6.5 per 1,000 general population per annum. This is supported by data from the Regional NI Rapid Access Chest Pain Clinic (RACPC) snapshot audit which estimated attendances to the RACPC service alone at 8400 for NI per year (5000pmp) in 2009. Population-based questionnaire

studies show about 20% of adults reporting chest pain over the course of a year. This reflects the chronicity of ischaemic heart disease but also low consultation rates, particularly in those without a diagnosis of cardiac disease. The incidence of chest pain consultations increases with age and is more common for men.

Cardiac disease accounts for only 8-18% of all cases of chest pain and the majority of chest pain seen in primary care is due to more benign conditions, e.g. gastro-oesophageal reflux disease (GORD), muscle sprains, panic disorder or shingles. GORD is the most common cause of non-cardiac chest pain. One study found that 8% of those diagnosed clinically within primary care had a diagnosis of ischaemic heart disease, 83% were excluded as non cardiac-based and in 9% there was diagnostic uncertainty. About 17% were referred for further assessment.

It is as a result of these differing presentations that it is important to provide rapid and timely investigation in order to ensure that patients access the correct treatment pathway. The newer non invasive diagnostic tests can be divided into structural or functional. Structural tests include invasive coronary angiography or non invasive computed tomographic (CT) coronary angiography. These tests are anatomical and show the shape of the arteries and the chambers of the heart and demonstrate any narrowing present in the coronary arteries; however, the functional consequence of the narrowing (in terms of blood flow reduction and the production of chest pain) is not directly assessed. Functional tests in contrast assess blood flow to the heart during stress and so indicate the functional significance of any narrowing present; this may be by directly assessing perfusion (nuclear tests such as cardiac SPECT) or by noting how the reduced blood flow reduces cardiac muscle contraction (Dobutamine stress echo; DSE). There is currently no significant stress CMR service provided in NI, though it is recognized by NICE as a suitable investigation. It is unlikely that it will provide a large contribution to the functional investigation requirements given the pressures on CMR for other indications (see section above). However, recent provision of modern MRI scanners in some LCG areas may allow a service to be developed. When and if it is available, it could replace some of the functional tests for intermediate likelihood patients. It is assumed in this document therefore that chest pain is due to coronary artery narrowing with reduced blood flow (i.e. angina) if either (i) a structural test shows a severe coronary narrowing such that

blood flow will clearly be compromised as a result or (ii) a functional test shows that myocardial blood flow has been compromised. In some cases either test may be equivocal, and under this circumstance additional testing will be required.

Current stable chest pain services are organised around the RACPC, with some patients also being investigated via cardiology outpatient clinics. The vast majority of patients currently undergo exercise stress testing (EST) for diagnosis and assessment of chest pain. The NICE document recommends that this test is withdrawn from diagnostic use and replaced by imaging investigations. Estimating this need will be the focus of the following modelling.

The current activity and demand are hard to estimate. There are several signals that demand is increasing. Firstly, cardiac outpatient referrals have been increasing in general, and some patients will come to imaging via this route. The number of new cardiac referrals to secondary care clinics are shown below; this includes all patients and not just those with chest pain.

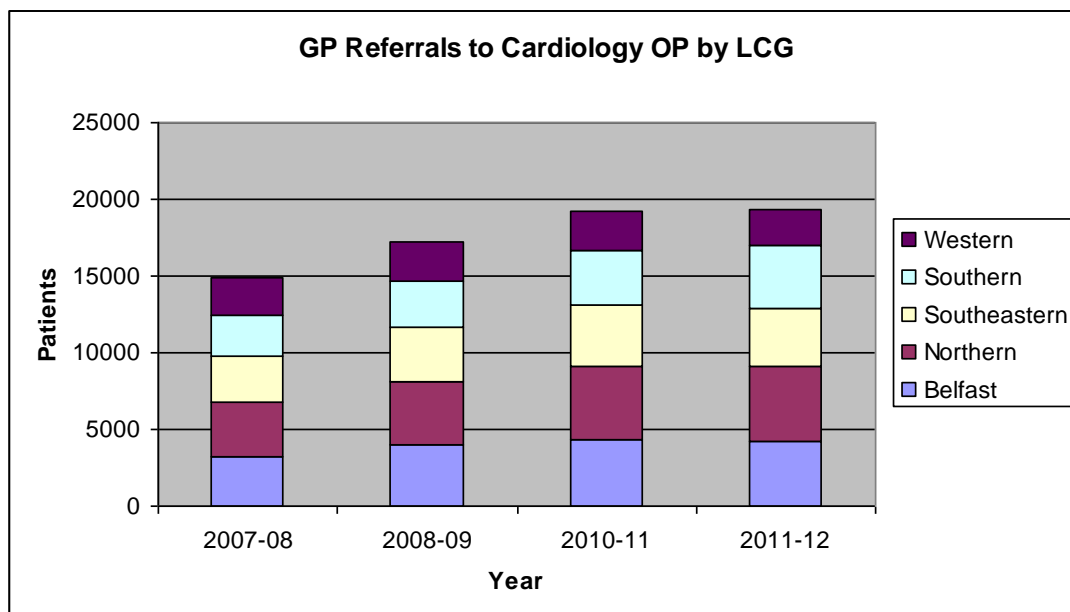


Figure 7: GP referrals to cardiology outpatient clinics 2007-12; all causes.

The numbers coming through RACPCs are also substantial. Based on the 2009 regional audit, the numbers per year at that stage were around 5000pmp or approximately 8400 patients annually province wide. Further data extrapolated from the RACPC snapshot audit showed that around 92-3% of attendees did have an

EST performed, and that 26% of attendees required a further imaging investigation to reach a diagnosis, as shown below.

	Current
Treadmill	7812 (93%)
Imaging	2186 (26%)

This imaging activity forms only part of the overall demand for functional imaging however. For example, demand for myocardial perfusion imaging (MPI) by SPECT is shown below. Clearly RACPC is only one of many routes of referral for this functional test. It can be seen that overall demand regionally has been growing over the last 3 years. Regional data suggest a reduction in activity in BHSCT about 2 years ago matched by an increase of activity in NHSCT over the same time period, reflecting an increase in imaging capacity for NHSCT patients within their own trust area.

	Total Waits	Change in WL		Activity (inc WLI)		Demand (Activity +/- change in WL)
Mar 11	768					
Mar 12	693	+33	11/12	2544	11/12	2577
Mar 13	931	0	12/13	2302	12/13	2302
Mar 14	978	-29	13/14	2613	13/14	2584
<b>Dec 14</b>	1175	197	<b>14/15 Apr-Dec</b>	1808	<b>14/15 Apr-Dec (estimated)</b>	2673

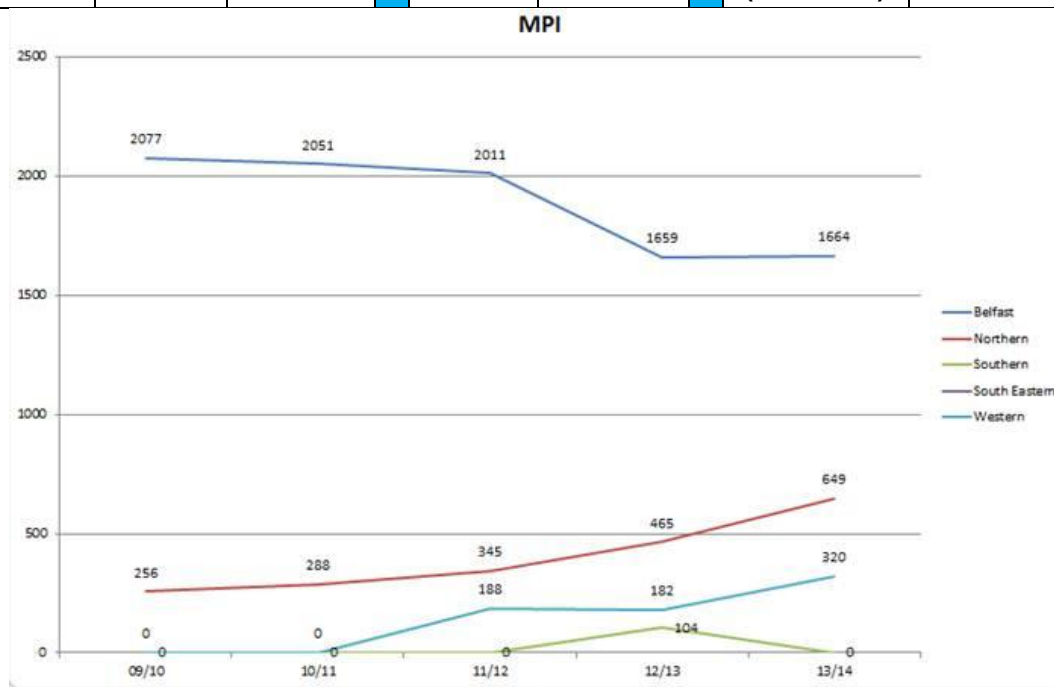


Figure 8: regional activity for myocardial perfusion imaging (MPI) by SPECT 2010-14.

The numbers for cardiac CT are smaller as the services across NI are more recently developed. A regional scoping exercise was carried out in 2014/5 and identified 5.5 imaging sessions per week dedicated to cardiac CT in NI. This comprised:

SEHSCT	1.5 sessions (Ulster/Downe)
WHSCT	3 sessions (mainly Tyrone County)
NHSCT	1 session (Antrim)

There have been changes in these numbers since the exercise reported. A further 2 sessions were commissioned within SHSCT and are delivered by a new appointment consultant radiologist. The BHSCT has no formally commissioned services. Gated cardiac CT imaging is carried out for anatomical problems, including TAVI, but no dedicated cardiac sessions are timetabled.

## **2. Estimating the need and proposing a new service**

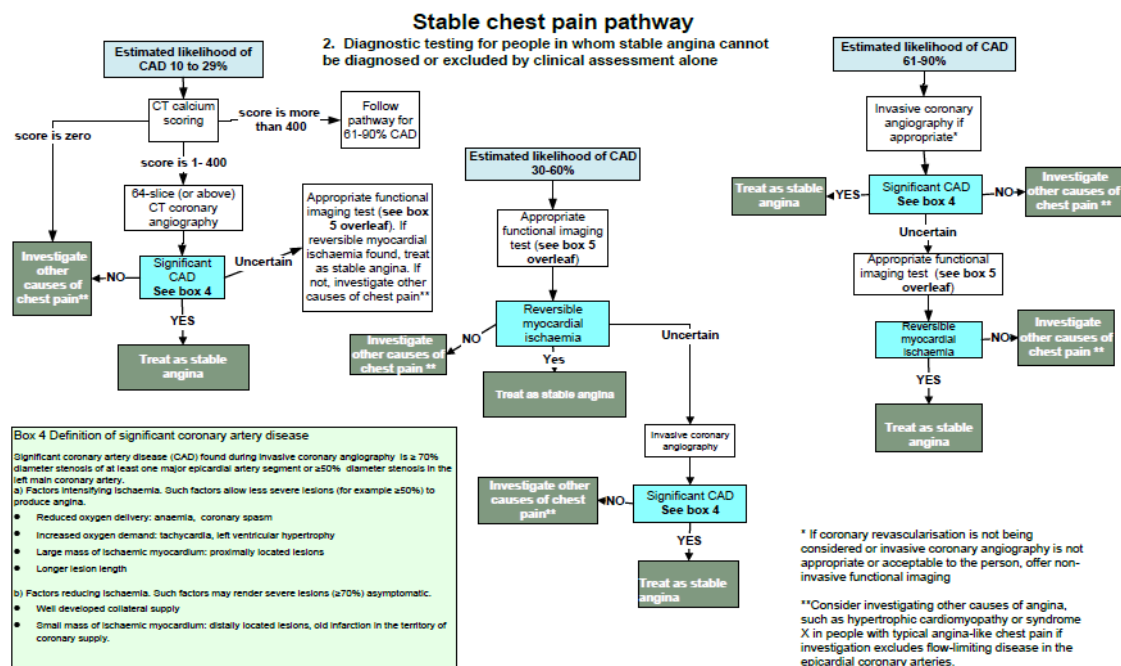
The need for functional and anatomical imaging cannot be modelled in a similar way to that used for transthoracic echo or CMR above as both services are underdeveloped across NI and have not been set up to deliver the NICE guidance. Further, modelling the need solely on NICE will be insufficient, as it deals only with stable chest pain syndromes and excludes the activity required to deal with the large variety of other IHD presentations and referral sources. In the following we have attempted to model the need based on a variety of methods including the NICE guidance, previous NICE guidance on nuclear cardiology only (NICE TA73), workforce planning statements from national societies, and other sources. Unfortunately the guidance for the number of functional tests did not take into account cardiac CT as it was at the time an immature technology, and there are indeed no formal guidelines for level of CT provision.

### **NICE CG95 and implications for imaging provision**

In March 2010 the National Institute of Clinical Excellence (NICE) issued Clinical Guideline 95 (*Assessment and Diagnosis of Recent Onset Chest Pain or Discomfort of Suspected Cardiac Origin*). This document recommended that EST be removed from the list of suitable investigations for new presentations with chest pain, and be

replaced by invasive or non-invasive imaging tests, selected by the pre-test likelihood of underlying CAD based on an assessment at the RACPC. This is described in the algorithm below.

## Proposed NICE guidance



National Institute for Health and Clinical Excellence, Clinical Guideline 95, 2010

Figure 9: NICE CG95 algorithm for imaging assessment of chest pain.

This should be applied for patients presenting with chest pain without a known history of coronary heart disease. The decision on what diagnostic test to perform should be based on the pre-test likelihood of risk, utilizing the findings of the simple tests, clinical examination and family history. This diagnostic test will be, depending on the presentation, either anatomical to look for obstructive coronary artery disease and/or functional testing for myocardial ischaemia.

The main change to current practices would be the use of calcium scoring and CT

National Institute of Health and Care Excellence (NICE) Clinical Guideline 95: *Assessment and Diagnosis of Recent Onset Chest Pain or Discomfort of Suspected Cardiac Origin*, 2010.



In low risk patients which are excellent at excluding significant coronary artery disease in this patient population. Those with intermediate pre-test likelihood (30-59% likelihood) should be referred for functional imaging. Those at higher risk should move directly to invasive coronary angiography.

NICE have suggested that the diagnostic performance of the exercise stress test has not the sufficient accuracy for patients with no prior history of coronary heart disease. As a result the NICE algorithm specifically excludes EST as a suitable test. Currently within Northern Ireland the majority of patients are assessed using this investigation, as indicated previously. Our own data shows that this continues to be a reasonable approach. In the NI RACPC snapshot audit, over 70% had an adequate diagnosis made using clinical assessment and EST without recourse to further investigation. Second, research data published after the NICE Guidance show that in some groups e.g. women able to exercise, a treadmill first approach (with imaging only for inconclusive or unsatisfactory treadmill tests) is equivalent to imaging first (Shaw LJ et al WOMEN Trial). Finally, in Northern Ireland there is neither the physical capacity on CT scanners nor sufficient clinical expertise to deliver on this guidance in its entirety. In this paper we propose a hybrid model with imaging for those patients most likely to benefit, and exercise testing for the rest. Full details of the hybrid pathway are in the appendix.

### **A hybrid investigation model for chest pain**

Based on the reasons outlined above, we propose a 'hybrid' model based on NICE but evolved from the current clinics based around EST. This hybrid model has been developed to maximize all available resources, although it is recognized that the NICE guidance should be the ultimate goal and that this model is only a direction of travel. If some services in trusts are able to exceed the 40% imaging target (see next section) suggested in the hybrid pathway then those arrangements should continue. The algorithms which detail the hybrid pathway are shown in the appendix. The hybrid model imaging estimates, as well as other modelling estimates are detailed below.

Shaw LJ et al. Comparative Effectiveness of Exercise Electrocardiography With or Without Myocardial Perfusion Single Photon Emission Computed Tomography in Women With Suspected Coronary Artery Disease (WOMEN trial). *Circulation* 2011, 124:1239-1249:

In essence the hybrid model will move some patients from EST first to imaging investigation first. The following table demonstrates the capacity requirements of the Northern Ireland hybrid model and the NICE guidance for new presentations for stable angina. The data are for 2009 RACPC attendance of 8400 patients.

	Current	NICE (2009 figures)	HYBRID (2009 figures)
Treadmill	7812 (93%)	0 (0%)	5040 (60%)
Imaging	2186 (26%)	8400 (100%)	3360 (40%)

*Table 8: Numbers and proportions of patients expected to undergo each test by NICE or new hybrid protocol.*

NICE CG 95 assumes that all patients move to an imaging investigation (invasive or non-invasive). In the NI hybrid model the 40% of patients will move directly to imaging without first having EST. The number was estimated using data on the outcome of exercise stress testing from the RACPC audit, and also the likely groups from the literature previously noted to have a suboptimal diagnostic result from EST techniques. These patients are those most likely to have an unhelpful EST. The breakdown is as follows:-

Percentage	Reason
8%	Unable to exercise
5%	ECG changes that negate interpretation.
19%	Inconclusive treadmill expected or previously
8%	Other clinical reasons ( AF etc)
40%	

*Table 9: reasons for inability to complete adequate exercise stress test*

The capacity requirements for cardiac imaging can be thought of in totality for all indications in cardiology, just for the RACPC chest pain patients as per the NICE model, or just for RACPC chest pain patients based on the NI hybrid model above. Modelling data are available for certain of these scenarios and not others, and differences between the data generated must therefore be recognised.

The following non-invasive capacity for cardiac CT and functional imaging (cardiac SPECT, stress echocardiography, and occasionally stress CMR) relates to all cardiology referrals for the diagnosis of both stable potential chest pain and other

more acute indications. These are population based models and so do not specifically separate out those scans done for the RACPC. Numbers refer to number of patients and not number of scans (some investigations require 2 scans e.g. stress/rest perfusion, calcium score/CT angiography). Further the data do not take into account regional referral patterns which would further influence the figures.

### **Modelling for functional imaging (cardiac SPECT and DSE)**

The volumes highlighted in the following paragraph shows four levels of demand based on the three major papers published since 2003. When originally carried out last year, the estimates for all papers were made for 2013 as this was the last year for which full data on imaging capacity was available. Assuming that commissioning occurs as a result of this paper, the estimates will be updated for 2016 or the appropriate year of implementation.

**Paper 1:** Based on the report from the British Cardiovascular Society Working Group 2007<sup>1</sup>

This paper, produced in 2007 showed current activity and projections of need in 2010 and 2020. Functional tests were divided into stress echo and nuclear imaging; however for the purpose of this paper the overall demand was totalled as which of these is used to provide functional information is dependent on local facilities and consultant expertise. The table below shows the required volumes identified based on the local Northern Ireland population (1.81 million).

Functional Investigation	2007 (actual estimate)	2010	2020*
Nuclear	2000pmp	3600 pmp	7200 pmp
Stress Echo	165 pmp	2000 pmp	4000 pmp
Total	2165pmp	5600pmp	11200pmp
For NI (1.81 million)	3918	10136	20272

*Table 10: Estimated numbers of SPECT scans using BCS paper 2007. \*The NI population will be higher by 2020 which will affect the total volume.*

<sup>1</sup> A H Gershlick, M de Belder, J Chambers, et al. Role of non-invasive imaging in the management of coronary artery disease: an assessment of likely change over the next 10 years. A report from the British Cardiovascular Society Working Group. *Heart* 2007;93:423-431.

Interpolating for 2013 (6680pmp) gives a figure of around 12097 studies for NI for all coronary disease indications assuming linear growth from 2010 to 2020. The data do not include CMR perfusion imaging, though currently this is a very small proportion of perfusion imaging in NI. It could however replace some of the nuclear or stress echo examinations should appropriate facility and expertise be available.

**Paper 2:** Based on NICE TA73 2003<sup>2</sup> with British Nuclear Cardiology Society survey uplift

A previous NICE determination<sup>2</sup> advised on the use of nuclear cardiology SPECT procedures in all aspects of the management of patients with coronary artery disease. Calculations based on the NICE 2003 target of 4000/million gives a demand of 7240 scans for 2003. This guideline referred to nuclear imaging only. Assuming that it refers to all functional imaging needs, then the figure could be used for both SPECT and stress echo with the proportion of each to be determined by availability and expertise locally, as above. The British Nuclear Cardiology Society surveys from the early 1990s to 2004 have shown a fairly constant growth rate for cardiac scanning of about 12.5%/yr. This growth rate has been added for the 10 years since the 2003 to estimate a demand for 2013 (9000pmp) of around 16290 functional tests. Figures are given in the table at the end of this section for comparison.

**Paper 3:** Based on NICE TA73 2003<sup>2</sup> without British Nuclear Cardiology Society survey uplift

This model uses the same 4000pmp NICE target from NICE TA 73 without uplift. Although numbers of functional tests should have increased from 2003, the provision of an anatomical service using cardiac CT will have the opposite effect of reducing scan requirements. Assuming that the uplift is negated by the increase in CT usage, the figure of 4/1000 is applied unchanged. This results in 7240 scans annually.

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<sup>2</sup> NICE Technology Appraisal Guidance No.73. Guidance on the use of Myocardial Perfusion Scintigraphy for The Diagnosis and Management of Angina and Myocardial Infarction. NICE, London, 2003

However the total number of scans required will then require an additional (potentially large) estimate of CT numbers. Furthermore, CT scans reporting an indeterminate degree of coronary stenosis will require functional imaging to determine the need for revascularisation and this would also require an increase in capacity. Numbers are summarised at the end of this section.

**Paper 4:** BCS workforce document 2005<sup>3</sup> with British Nuclear Cardiology Society survey uplift

This document estimated an annual need of 6000 nuclear scans pmp. It was suggested that the stress echo target would be similar. However to avoid overlap each was to be reduced by 40% giving 3600 pmp for each scan. This gives a demand for a total of 7200 scans pmp (either nuclear or DSE) for 2005. For the purpose of this paper the 12.5% annual uplift was added giving 14400 pmp (approx 26064 scans for 1.81million population) for 2013.

The required capacity volumes published in the 4 papers above have been entered in the table below, broken down by LCG area and method of estimation. This refers to all functional imaging capacity for the management of coronary disease, and includes within the figures those scans for the RACPC irrespective of whichever model is used.

It is unlikely that one technique will deliver all the functional imaging in each LCG and as previously mentioned it will be dependent on local facilities / capacity and Consultant expertise.

The below activity does not take account of the CT demand although there may be some overlap, depending on the risk profile of patients. For example an audit of BHSCT SPECT waiting list showed that around 20-25% of patients might have been suitable for cardiac CT based on the NICE criteria. The corollary is that a minority of CT patients require functional imaging to assess the significance of intermediate grade coronary stenoses, so the overall reduction in functional requirements would be less than that above. Recent papers mentioned later also indicate that CT and

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<sup>3</sup> Hackett D. Cardiac workforce requirements in the UK 2005. British Cardiac Society, 2005.

functional imaging will overlap in terms of appropriateness in a reasonable proportion of chest pain patients. The option based on paper 3 deliberately excludes an overlap and so likely a larger number of CT examinations would need to be added to the overall number of imaging tests for this scenario.

LCG Area	Population	Total Capacity Requirements (Paper 1, 6680pmp scans)	Total Capacity Requirements (Paper 2, 9000pmp scans)	Total Capacity Requirements (Paper 3, 4000pmp scans)	Total Capacity Requirements (Paper 4, 14400 pmp scans)
Belfast	348204	2326	3134	1393	5014
Northern	463297	3095	4170	1853	6671
SouthEastern	346911	2317	3122	1388	4996
Southern	358034	2392	3222	1432	5156
Western	294417	1967	2650	1178	4240
<b>TOTAL</b>	<b>1810863</b>	<b>12097</b>	<b>16298</b>	<b>7244</b>	<b>26077</b>

*Table 11: Number of functional imaging tests required per LCG area and overall based on 4 modelling assumptions. Numbers reflect 2-013 calculations as part of the Cardiology Network response to NICE CG 95.*

### **Modelling for cardiac CT imaging**

No professional body has yet made a statement on the requirements for cardiac CT for the UK. Further, unlike the models presented above, no serious document has yet projected the overall requirements for cardiac CT. It is discussed in very little detail in any of the above papers; this is because of the rapid increase in the applicability of cardiac CT over the last 5-10 years due to a sudden upgrade in the technical capability of scanners with the recent advent of multidetector spiral scanners. The following estimation is based on the NICE document and other estimations taken from what are considered to be appropriate uses for cardiac CT. In particular, there is increasing emphasis on using this investigation as a rule out test in low risk patients attending emergency departments or admitted to hospital with non classical chest pain presentations. The number of CT scans required for this emerging important indication is therefore currently unclear.

## **Paper 1: Modelling using NICE CG95 and local estimates**

Using the NICE chest pain algorithm all low risk RACPC patients should have cardiac CT. Using the figure alluded to in the introduction of 6.5/1000 population attendances at the RACPC, the figure for CT in a population of 1.8 million is 3510 scans/year assuming as before 30% of attendees are low risk and so merit CT as opposed to functional imaging. This figure does not include other indications for cardiac CT such as replacing traditional invasive angiography in valve patients and post CABG chest pain, as well as its use for triaging low risk chest pain admitted to hospital. There are no recommended activity levels for these indications, even though they are endorsed in appropriateness documents. In a 2007 report to the network<sup>6</sup>. I estimated some of these figures on a population basis using projections from Dr Stephen Green and assumptions about the proportion of invasive angiography which could be replaced by CT angiography.

In this model around 500 scans/ year were estimated for 2010 for valve and previous CABG purposes. The number of scans for inpatients is unclear. We assumed that many inpatient attendances could be avoided with better first time imaging at RACPCs, but that some proportion of low risk patients would still be admitted and may qualify for CT. A further rather small population of patients might require CT including in those with structural cardiac diseases when CMR was contraindicated, in aortic dissection and in endocarditis. If an arbitrary figure of 10% of the RACPC figure was assumed (around 350/year), then an overall figure of around 850 scans/year (about an additional 25% on top of the RACPC figure) would be added to the RACPC figure of 3510 giving a total of 4360 scans/year for NI. Assuming 5 scans / session the number of CT sessions required is also presented below.

The most recent BSCI document recommends 8 scans per session, but not all are for CT coronary angiography; a figure of 5 therefore seems reasonable but could be discussed depending on the capability of the relevant scanner.

Irrespective of this it can be appreciated that there is a large shortfall in CT provision within NI.

<b>LCG Area</b>	<b>Population</b>	<b>NI %</b>	<b>Cardiac CT RACPC/s table pain N=3510</b>	<b>Cardiac CT Other indications N=850</b>	<b>Total Capacity Requirements N=4360</b>	<b>Scan sessions per year based on 5 per session</b>
<b>Belfast</b>	348204	19.2	674	163	837	<b>167.5</b>
<b>Northern</b>	463297	25.6	899	218	1117	<b>223.5</b>
<b>Southeastern</b>	346911	19.1	670	162	832	<b>166.5</b>
<b>Southern</b>	358034	19.8	695	168	863	<b>172.5</b>
<b>Western</b>	294417	16.3	572	139	711	<b>142</b>
<b>TOTAL</b>	1810863	100%	3510	850	4360	<b>872</b>

Table 12: Estimated CT numbers by LCG area and overall (based on 2013 data as part of Network response to NICE CG 95).

### **Total functional and anatomical imaging requirements**

While the NICE approach of rigidly triaging patients to a particular imaging modality based on pre-test likelihood seems logical, recent research has cast doubt on this approach. This may be due to the fact that the pre-test likelihood tool (Diamond Forrester score) is inaccurate in low risk patients (Patterson, Heart 2015), leading to a degree of under investigation in some cohorts. Randomized trials of CT imaging versus standard care have tended to show benefit for imaging first strategies in Scottish (SCOT-HEART investigators, 2015) and in local populations (McKavanagh, 2015). Furthermore the PROMISE study showed that for many patients functional imaging with SPECT and anatomical imaging with CT are largely equivalent.

Therefore we propose to sum the numbers of patients requiring anatomical or functional imaging. Recognizing that the exact split between functional and anatomical approaches being equivalent in a substantial subgroup of referrals, it is reasonable

<sup>6</sup>Harbinson MT. Multidetector Computed Tomography (MDCT) coronary artery imaging - current role, future possibilities and estimate of service requirements. A report to the revascularization subgroup, Northern Ireland Cardiology Network. February 2007



to combine the numbers required into a total number of imaging tests; provided that both categories of investigation are available for each LCG/trust area, the exact split can then be determined at local level. For this calculation model 1 (the most up to date and the second most conservative) has been selected for functional imaging, and added to the CT model to provide an overall number of patients to be studied by LCG/trust area. These data are presented below:

LCG Area	Population	NI %	CT Total Capacity Requirements N=4360	Functional Total Capacity Requirements N=12097	Total imaging requirements
Belfast	348204	19.2	837	2326	3163
Northern	463297	25.6	1117	3095	4212
Southeastern	346911	19.1	832	2317	3149
Southern	358034	19.8	863	2392	3255
Western	294417	16.3	711	1967	2678
<b>TOTAL</b>	<b>1810863</b>	<b>100%</b>	<b>4360</b>	<b>12097</b>	<b>16457</b>

*Table 13: Final estimated number for combined functional anatomical testing in chest pain by LCG and overall.*

In developing the CT services close liaison with radiology is required to maximise efficient use of scanners and radiography staff. The number of cardiac capable CT scanners, the number of sessions used, the number of free sessions, and the scanner location was investigated as part of the review process and is available in the main radiology report. A later recommendation in this document is the formation of an Imaging Board to assess advances in imaging services in a more holistic and cross cutting way; this would likely benefit this cardiac CT service development.

SCOT-HEART investigators. CT coronary angiography in patients with suspected angina due to coronary heart disease (SCOT-HEART): an open-label, parallel-group, multicentre trial *Lancet* 2015; 385: 2383–91.

Patterson CM, Nair A, Ahmed N, et al. Clinical outcomes when applying NICE guidance for the investigation of recent-onset chest pain to a rapid-access chest pain clinic population. *Heart* 2015;101:113–118.

P McKavanagh, L Lusk, PA Ball, RM Verghis, AM Agus, TR Trinick, E Duly, GM Walls, M Stevenson, B James, A Hamilton, MT Harbinson, PM Donnelly. A comparison of Cardiac Computerised Tomography and Exercise Stress Electrocardiogram Test for the investigation of stable chest pain: the clinical Results of the CAPP Randomised Prospective Trial. *European Heart Journal – Cardiovascular Imaging* (2015) 16, 441–448

## **Summary**

The recent NICE guidance recommends the end of treadmill testing and a move to imaging investigations for the vast majority of patients attending RACPCs. It is recognized that this must be the “Gold standard” that we work towards; the hybrid solution detailed in this paper is proposed as an interim measure which addresses the fundamental change in emphasis of the NICE algorithm, but is realistic given the capacity constraints in both manpower and hardware. The numbers chosen, especially for functional imaging, are conservative, and may represent an under estimation of need. It is anticipated that if implemented this algorithm will result in around 60% of patients undergoing EST rather than over 90%, with the imaging investigations increasing from 25% to around 40%. For the purposes of calculation patients at low risk undergo cardiac CT and those at intermediate risk functional testing. There is an overlap in indications between the scan groups and the overall imaging capacity is more important than the exact number provided by each test, with the caveat that both functional and anatomical tests should be available in each LCG area. The balance between the two however should be flexible depending on local expertise. Each LCG should consider its response based on local expertise and availability of hardware.

In addition NICE CG 95 speaks to only part of the overall need for functional and anatomical testing, though undoubtedly one of the most important and larger sources of referral. The figures in this paper attempt to take into account overall needs rather than just those specific to the RACPC model and NICE CG95. The situation is further complicated by the fact that NICE recently announced a review of CG 95 and any proposed changes would obviously have to be considered when formulating the final plan for implementation.

## **Implications and issues for Implementation**

Unlike the situation with CMR and echocardiography these recommendations are considerably more complex to implement. First there is wide variation across trusts in the levels of functional and anatomical imaging taking place. As noted previously CT imaging is variably delivered across trust areas, with one having a very small

service. The majority of work is not recurrently funded. Similarly cardiac SPECT is delivered in only 3 trusts. Stress echo is available in a more widespread fashion but numbers are small in some cases. There is limited consultant expertise in some areas, especially functional imaging, and not all trusts have nuclear medicine departments making delivery of on-site cardiac SPECT problematic. Cardiac CT should be considered also in the light of the radiology workstream report and suitable cardiac capability should be incorporated onto new CT scanners. Similarly consultant numbers or work patterns will likely be impacted in both cardiology and radiology and this will need to be addressed on both a Trust and Regional basis. Some national bodies recommend dual cardiology/radiology input for cardiac CT and this of course will have significant staffing implications. If these recommendations are accepted, we would propose an implementation group is formed to scope out ways in which appropriate functional and anatomical services can be delivered for each trust area. It is expected that the ratio of functional to anatomical tests will vary within each trust area according to expertise and equipment availability, and indeed cross trust provision (including if required hub and spoke models) may be one possible outcome for some of the tests. However we propose that the overall number of investigations be guided by the current document. The numbers proposed, delivered, and local needs should be reviewed 2 years after implementation of this plan.

When developing new services, clear standards should be set. Advice on guidelines and standards for commissioning new services in cardiac CT, cardiac SPECT and stress echocardiography are available from the relevant professional bodies and are listed in the table below. For reasons of brevity these documents are not reproduced here in their entirety.

Coronary CT angiography service specification; A report of the British Society for Cardiovascular Imaging, 2013.

Cardiac imaging: a report of the National Imaging Board, 2010.

Commissioning a nuclear cardiology service: a BNCS/BNMS/BCS report.

BSE procedure guidelines for the clinical application of stress echocardiography, recommendations for performance and interpretation of

stress echocardiography: A report of the British Society of Echocardiography Policy Committee, 2004.

Standards for CT coronary angiography; Royal College of Radiologists, 2014.

*Table 14: Sources of information on commissioning standards for functional tests and cardiac CT*

## Section 4: IT infrastructure, equipment and medical physics

Several issues are important in an electronic strategy for cardiac imaging. These include image archiving, image viewing, scan scheduling, connectivity to ECR, ECG archiving, access to privately performed tests, and electronic requesting of investigations. There is great variation within each trust, and between trusts in how images are stored, reported, archived, and shared. Systems have tended to grow within each trust or hospital as an additional imaging technique is added, and as a consequence there is no central repository for reports. Within trusts this means that reports must be accessed from multiple information systems, and that reporting and imaging are often separate, so that the images and report must be considered through separate systems. An example within one trust area is given below.

Transthoracic echocardiography	Reports on 2 versions of CVIS and free standing software program. Images on 2 archiving systems.
Cardiac magnetic resonance imaging	Images and reports on one version of PACS.
Cardiac SPECT	Limited images only available on one PACS system. Reports on one version of CVIS.
Cardiac CT	Reports and images on 2 versions of PACS depending on site acquired.

*Table 15: Within one trust the following systems are in use*

The situation is further complicated as imaging carried out on such systems may be accessible only from within one trust, and so access to scans carried out in other hospitals or trust may not be possible. The group considered that 2 solutions should be considered to this problem, detailed below. In addition to this issue, the development of hub and spoke arrangements, and changing work patterns, make the traditional method of reporting at an imaging workstation within the imaging department increasingly challenging for some parts of the service. New solutions to this problem should also be considered in this section.

## **Improving access to reports**

The group considered that Northern Ireland wide access to cardiac imaging reports of whichever type should be implemented. A current process using the Northern Ireland Electronic Care Record (NIECR) is ongoing. Discussions have taken place with the NIECR group, and a cardiac subgroup is already convened. This has led to early successes with NI wide access to CMR reports of scans carried out in the hub center at the Mater. Within trusts, transthoracic echocardiogram reports are now also migrating to NIECR. The process began with the transfer of 40,000 reports within the WHSCT and has now moved on to other trust areas. This report recommends that this process be taken to its natural conclusion with implementation of province wide sharing of all cardiac imaging reports through NIECR. It is noted however that having reports adjacent to the images themselves is important, and it should be considered whether reports might also be migrated to the PACS solution. In addition to this, the ECR group is in the early stage of rolling out electronic referrals for radiology investigations, with the ability to check on the status of pending investigations. If this pilot is successful, we would recommend that it should also be considered for cardiology investigations. An alternative is to have full ordering and scheduling through an integrated RIS arrangement which should be carefully considered, particularly in the context of a Northern Ireland wide implementation of PACS. A pilot linking a cardiology RIS to ECR has recently started in one area.

## **Image viewing and archiving**

When PACS systems were being commissioned for radiology, cardiac imaging was in general not included in this process. Each trust is therefore purchasing individual archive storage ad hoc every 3-5 years when the existing archive has no further space. Data requirements are likely to be large. For example data from coronary procedures may vary from 100 MB up to 3 GB depending on the duration and complexity of the procedure. Echocardiogram studies are up to 800 MB in size and 3D TOE studies may average 1.5 GB per study. The requirements in some trusts are 1TB / month. In many trusts up to 50% of all data storage for non-radiology is consumed by cardiology. Each trust is negotiating with different vendors and support contracts with little comparison between trust prices. A single archive, centrally co-

ordinated would ensure safer data storage, ensure MDMs always have the data required, and would most likely be cheaper to run in a data warehouse

Ideally we recommend that all suitable cardiac imaging studies should be archived on an agreed NI wide PACS system and that province wide access to the images should be implemented. This aspiration is in line with that of the radiology workstream. We recognize the considerable challenges archiving all cardiac images on a single PACS platform would bring in the current context within NI, but support a move in this direction as proposed by the radiology workstream. Obviously the addition of cardiac images would have significant implications in terms of memory/storage requirements. Initial meetings between representatives of the NI Cardiac Network and the NIPACS team have taken place already, with the aim of including cardiology in future commissioning of PACS. A limited Interim agreement has been reached for cardiology to use NIPACs for storage and viewing of invasive angiography images required for decisions about cardiac surgery; this will prevent transfer of images from other Trusts to RVH Cardiac Surgery by DVD.

It is recommended that at the above changes include all cardiology images. In particular this would include images acquired in private institutions, and also ECG images which are acquired in a digital fashion but for which there is very patchy storage currently.

### **Reporting infrastructure**

Given the issues mentioned above in terms of hub and spoke services and consultant working on multiple sites, the issue of reporting is important. Some complex reports require direct manipulation and measurement of images on a workstation linked to the scanner and can only be done in the imaging department. However a considerable amount of other reporting could be done remotely via secure internet connections and PACS. We recommend that this type of reporting infrastructure is considered as services are being designed and is included when new services are commissioned.

The above points are well summarized in the joint BCS/SCST report on cardiac physiology services in England which makes the following recommendation in terms of IT infrastructure:

'With the rapid development of information technology (IT) innovations, the Review recommends that NHS England strengthens the IT and telecommunications infrastructure available across healthcare providers to support web based, secure archiving which will allow for the transfer of electronic images and data with patients as they meet care providers along their clinical pathway. This will improve the quality of the information available to clinicians, reduce the duplication of investigations, and facilitate timely and accurate diagnosis and the provision of effective treatment and care.' Ref: BCS/SCST Strategic review of cardiac physiology services in England: final report (May 2015)

We support this as an aspiration for Northern Ireland also.

### **Referral processes**

Note has been made of some electronic requesting moving to NIECR. The group supports the use of e-referral processes and within the last year has piloted the use of e-referral forms for echocardiography within a limited number of hospitals for heart failure related echocardiography. Expanding this to include relevant cardiac imaging investigations such as CT and CMR should be considered. Electronic booking and request management, including linkage through to NIECR, is recommended.

### **Equipment and medical physics**

The group acknowledges the important role medical physics experts play in the commissioning and acceptance of equipment and in helping ensure the quality and safety of imaging equipment and procedures. In addition we feel that medical physics input should be considered essential for service development and research work. The group recommends that specific medical physics time be included in all business cases for new equipment, and into plans for imaging services, based on levels of WTE staffing determined by the type of equipment and shape of the service, and agreed in advance with medical physics management. Some types of service require heavier medical physics input than others for regulatory reasons, such as nuclear cardiology for example, so an individual agreement for each type of service is appropriate.

Equipment chosen should be as cost effective and clinically effective as possible. Various options may be possible and the types of patients to be imaged should be



considered in this regard. For example the BCIS standards and guideline documents note that newer generation CT scanners allow more comprehensive assessment of certain types of patient than standard 64 detector CT scanners. In this particular example the additional information available from a more modern CT scanner could prevent a patient requiring a second test, but of course at the cost of a more expensive scanner. They then go on to provide some information for commissioners. Understanding the purpose and case mix of the service is therefore important. Newer equipment could have advantages in terms of image acquisition speed and radiation dose (for example solid state detector nuclear cameras), and these factors should also be taken into account when commissioning. Some benefits of newer equipment as proposed by the National Imaging Board may include:

- better, more detailed and more useful diagnostic information to target therapy more effectively
- more efficient rapid image acquisition, workflow, analysis and reporting
- rapid and widespread availability of results to clinicians
- replacing invasive procedures with non-invasive tests

*Figure 10: extract from National Imaging Board on newer equipment*

The National Imaging Board has also provided advice for commissioners around cardiac imaging services, and includes recommendations on minimum equipment specification and software applications for each modality. In addition the report details appropriate elective replacement dates for imaging equipment which are endorsed by this report.

Modality	Date
Echocardiography scanners	5 years
Cardiac SPECT cameras	7 years
[Cardiac] CT scanners	7 years
CMR scanners	7 years

*Table 16: Suggested elective replacement dates for scanning related equipment as proposed by the National Imaging Board*

#### Key documents

Ref: Cardiac imaging: A report from the National Imaging Board, 2010

E health and care strategy for Northern Ireland. HSCB, 2016.

## Section 5: Research in cardiology and cardiac imaging

Research and cardiac imaging are intimately linked in several ways. Currently there is interest in the search for 'imaging biomarkers' of disease, management response or prognosis. Additionally imaging is becoming part of the attempt to precisely characterise disease presentation in the individual patient in studies labelled as 'precision medicine'. Broad categories of studies might include:

- Cardiac imaging results may be part of the inclusion criteria to a study or may form the efficacy or safety endpoint.
- Research may test the use of existing cardiac imaging modalities to direct patient management or better predict prognosis.
- Cardiac imaging may be applied to new clinical situations, or advances in imaging technology may be tested in patient populations to determine their added value.
- Pure imaging research in terms of designing and trialing new imaging sequences, scans or analysis software may be undertaken

Whatever the situation it is clear that pressures on service delivery make research scans increasingly difficult, even if funding is available.

The absence of close integration between clinical and academic departments within the NHS in NI is a significant disadvantage with respect to much of the rest of the UK. The development of academic medical centres/campuses which directly link academia and clinical delivery in several large NHS centres facilitates research use of imaging and direct research imaging, and is also attractive to funders and industry. Finding a method to increase the flexibility in this relationship is crucial to delivering high quality imaging research with the NI NHS. In addition to these infrastructural issues, flexibility in terms of staff contracts and funding would be required to ensure that such an arrangement was feasible.

We recommend a small group comprising senior academics in interested areas and senior NHS clinicians and managers is convened to address these issues and

propose a way forward. Research culture should be emphasized in imaging departments so that the artificial divide between routine clinical imaging and innovation and research is ended. Jointly staffed departments allow earlier introduction of technical and clinical innovation and ensure that clinical care, staff development and research success are closely aligned.

The recent publication of the Northern Ireland Research and Development strategy, and of the Research for All document by the Royal College of Physicians of London, should help provide impetus in this area.

### **Key documents**

Research for all. Royal College of Physicians of London, 2016.

Research for better health and social care. A strategy for better health and social care research and development in Northern Ireland 2016 - 2025. DHSSPSNI, 2016.

## Section 6: Workforce report

### Medical

The BCS workforce annual report indicates that there were 41 consultant cardiologists (39.2 WTE) in Northern Ireland at end 2013. Consultant expertise in cardiac imaging generally in NI has generally come from this cardiology pool but in fact several subspecialties may be trained in cardiovascular imaging, as detailed below.

Echocardiography	cardiology
Nuclear cardiology	cardiology nuclear medicine nuclear medicine radiology
Cardiac CT:	Cardiology radiology
Cardiac MRI:	Cardiology radiology

*Table 17: possible specialty backgrounds in each imaging modality*

Within Northern Ireland echocardiography and virtually all CMR is cardiology delivered. The majority of cardiac nuclear medicine (SPECT) is cardiology delivered though some services have radiology/nuclear medicine input. Cardiac CT is mainly cardiology, but as well as radiology reporting in some services there are also joint reporting sessions. Recently additional cardiac CT sessions have started in the southern trust with radiology supervision. The arrangement for joint reporting is recommended by several bodies, including nationally through the BSCI.

As detailed above the various modalities have varying levels of resilience in terms of staffing. Within each trust area there is generally one cardiologist responsible for each of the available imaging modalities, and often they will be responsible for more than one. Echocardiography tends to be mainly physiologist led in terms of reporting, and only complex echo such as stress studies and TOE have consultant reporting. The exception is BHSCT where for example there are 3 adult and 1 paediatric CMR reporters, though the large nuclear cardiology service relies on a single consultant and associate specialist. Approximate consultant numbers are as follows:

Trust	BHSCT	NHSCT	SEHSCT	WHSCT	SHSCT
<b>CMR</b>	3+1*	2	[2]**	0	0
<b>Cardiac CT</b>	1***	2	2	2	[0]****
<b>Nuclear</b>	1 +1*****	1	0	2	1
<b>Stress echo</b>	3	1	1	2	1

\*Plus one paediatric CMR consultant reporter

\*\* Only a small noncommissioned service is delivered

\*\*\*Consultant expertise but no service

\*\*\*\*As noted previously post unfilled

\*\*\*\*\*Plus associate specialist

These figures have increased since the imaging report data collection commenced, and there are now additional cardiac CT reporting sessions in the South-eastern and Southern trusts. These data should be revisited when implementation is being considered.

The figures indicate that (i) there is considerable variation between trusts in terms of overall numbers (ii) there is variation between trusts in terms of spread of testing available (iii) some areas are vulnerable with small numbers of reporters. These figures also speak to the commissioning of functional and anatomical tests referred to above, and shows how there must be variation within each trust as to the overall split of these tests locally. The main issue is that many imaging services are delivered by a single consultant within each trust, and so such services may be considered at risk or certainly vulnerable. In recent years there have been several consultant appointments in cardiac cross sectional imaging (CT and CMR) and transthoracic echocardiography, but few with experience in nuclear cardiology or stress echocardiography.

The correct number of cardiologists and other doctors including radiologists required to deliver imaging services are less clear. The number depends partly on the activity planned but also on how it is spread between modalities. For example the differing split between functional and CT imaging will change numbers significantly, especially if a dual reporting mechanism is required for cardiac CT. No up to date guideline figures are available. The BCS guideline document was published in 2005 when CMR and in particular cardiac CT were immature technologies and estimation of

future provision was very difficult; this was acknowledged in the report at the time. The figures suggested were:

Area	FTE/per million population	FTE/Northern Ireland 1.8m
Echocardiography	14.5-24.9	26.1-44.8
Nuclear cardiology	3.7-5.1	6.7-9.2

*Table 18: suggested consultant numbers for imaging tests*

*Source: Cardiac workforce requirements in the UK. Hackett D for BCS.2005.*

These numbers seem high especially for echocardiography, though this includes all aspects including standard transthoracic studies, stress echo, and TOE, and takes into account that consultants also have to deliver other clinical sessions. The numbers for CT and CMR were added into all other imaging and are not reproduced here as they were heavily caveated in the report. Nonetheless even accepting that the echo figure is excessive, there remains a significant shortfall in consultant numbers in some areas, compared with the numbers reported in post at present.

Cardiology trainees can select from 5 subspecialty areas towards the end of training, with imaging one possible selection. Within this, imaging training is delivered in a modular fashion with trainees selecting those modalities they wish train in. Recommended training curricula in each modality have been drawn up by the relevant specialist society. Due to this modular arrangement and trainee choice, some imaging areas may be under represented among the body of cardiology trainees. Most trainees undertake basic transthoracic echocardiography training through the BSE. However among senior cardiac imaging trainees, there is limited expertise in high level nuclear cardiology and stress echocardiography. This clearly has implications for the future of cardiac imaging services. The shortage in consultant radiologists is detailed in the main radiology report. It is noteworthy that already an increase in training numbers has been proposed as a result of the main radiology report. Currently these posts have not been designated to any particular subspecialty but the increase in numbers does allow for more trainees in cardiothoracic radiology. It is not possible to quantify this at present.

Some solutions to these problems can be proposed, though many of these are partly implemented already:

- Consultant appointments can be made strategically both within trusts and across NI as a whole, targeting not just imaging expertise but specific subspecialty imaging experience in the areas of deficit (of course this happens to an extent already, and if trainees have selected not to take train in these areas this may be problematic).
- Cardiology [or radiology] training numbers can be developed with specific subspecialty profiles so that enough trainees are channeled into each area.
- More formalized subspecialty training in the latter years can be provided.

### **Non-medical workforce**

Before considering this issue in detail it should be noted that there is and should be a direct link between medical and non-medical workforce for new consultant appointments. New consultant appointments cannot deliver additional imaging services without the appropriate departmental resource and if imaging expertise does not exist within the non-medical workforce within that site, the value of the appointment is lost. Imaging consultant appointments therefore need to be linked to appropriate equipment and non-medical staffing.

As the largest imaging investigation by an order of magnitude in cardiology, echocardiography is of prime importance in staffing. This is where the bulk of cardiac physiologist (CP) staffing is invested in terms of imaging tests. Indeed as well as performing the scans, the majority of echocardiograms are also reported by CP staff suitably accredited as recommended by the BSE.

There are current pressures in maintaining adequate staffing levels within cardiac Physiology, and with various changes in training and pressures on departments, these are likely to worsen. Professional bodies have recently warned of a 'crisis' in workforce for echocardiography (and to some extent in physiologist led device management also). High attrition rates in staffing are reported across the UK. The new structure under which physiologists will work is discussed below.

## **New structures-Modernising Scientific Careers workstream**

Modernising Scientific Careers, led by the Chief Scientific Officer, is a key work programme within the Department of Health designed to ensure flexibility, sustainability and modern career pathways for healthcare scientists, fit to address the needs of future NHS. It provides career frameworks for education and training of healthcare scientists. The BSE has been involved in the development of curricula for both Practitioner Training Programme (PTP) and Scientist Training Programme (STP). The MSC programme's stated aim was to "avoid the risk of career dead ends" and "provide a set of education and training standards for the whole of healthcare science that can be owned by the professionals who developed them." [From BSE website].

The model is that physiologists graduate with their primary degree and then undergo postgraduate training in the health service. It is at that point that they attain the skills required to become an echocardiographer and attain BSE accreditation (or equivalent qualifications in pacing for example). This postgraduate training will produce 'healthcare scientists' able to deliver these complex services for the NHS. There are several barriers to this model, which may be particularly problematic in Northern Ireland. For echocardiography, the area with the greatest need, these are detailed below:

- There is little time for training of undergraduate students in the hospital setting due to the very tight time demands placed on echocardiographers working to the BSE template. Additional imaging requirements above the minimum BSE dataset are commonly required which leaves little time for any training function.
- In addition to the lack of training time, there is insufficient financial provision within the trusts to deliver this advanced postgraduate training.
- No formal postgraduate training programme has been developed or funded within NI and so the infrastructure to deliver training for the next generation of echocardiographers is compromised.



As well as impacting on training these issues also prevent the development of the enhanced cardiac physiologist role which would enhance the delivery of many services within trusts.

These issues have been recognized NHS wide, and have been extensively considered by the BCS and SCST in a comprehensive report about the state of the service in England. Many of these findings are pertinent to Northern Ireland. Some of the main recommendations are reproduced below, and it is recommended that these are explored in the Northern Ireland context.

<b>Recommendation</b>	
7	The Review recommends that urgent action is taken to address the considerable shortfall in the current cardiac physiology workforce at all levels across the career framework. The current workforce is inadequate to meet current demand, with marked variations in access to cardiac physiology investigations and significant waiting lists in some areas; and, in addition, it will be inadequate to meet future demands if the proposed service changes and resulting efficiency gains outlined above are not implemented alongside an expansion in the workforce.
8	To offset the strategic workforce risks, NHS England and Health Education England (HEE) will need to: <ul style="list-style-type: none"> <li>• ensure the service can implement the full efficiency-gain service model, including the primary care strategy;</li> <li>• recruit and retain its cardiac physiology trainees, including controlling the current 20% attrition rate;</li> <li>• ensure the current level of post-graduate training places is maintained to maximise the benefits of the expanded graduate training programme;</li> <li>• determine the future role of the lead cardiac physiologist with medical colleagues, in the light of the review of post-graduate medical education and training, and expand the current level of higher training in cardiac physiology accordingly;</li> <li>• work with NHS Trusts and NHS Employers to develop local staffing strategies to address the projected assistants' shortfall and their training needs.</li> </ul>
9	Developing the workforce to meet current demand is not enough; the expansion of the workforce should be informed by a functional analysis of the role requirements of delivering emerging and innovative models of cardiac physiology service delivery. The Review recommends that NHS England and Health Education England both extend the current roles of consultant cardiac scientists into advanced practice and also promote the Modernising Scientific Careers (MSC) education and training models (Higher Specialist Scientist Training (HSST) and Accredited Specialist Scientific Expertise (ASSE) programme) as a standardised accredited training route to facilitate the development of this expertise in a planned way.
10	The Review recommends that Health Education England and Local Education and Training Boards (LETBs) understand the volume of uplift needed in the Scientist Training Programme (STP) and HSST programme to meet the demand for an increased highly skilled workforce. Both HEE and LETBs should make a case for additional funding for training places, and privilege the funding of both STP and

	HSST programmes for cardiac physiologists, to both fill current workforce gaps and meet workforce needs for the future.
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*Table 19: Selected recommendations from Strategic review of cardiac physiology services in England: final report. BCS/SCST, 2015.*

In this section we recommend that early discussions between the various stakeholders including the SCST, the department, HSB and trusts are formalized so that many of the recommendations in the report can be assessed in a local context, and appropriate remediation of the situation recommended.

#### Interim solutions

During the writing of the report the DHSSPSNI has agreed to fund additional training for up to 30 physiology students. The majority of these will likely be assigned to cardiology. In addition Prof Young the Chief Scientific Adviser at the DHSSPSNI is planning to call a Modernising Scientific Careers working group in keeping with the above recommendation.

#### **Key documents**

Recommendations from Strategic review of cardiac physiology services in England: final report. BCS/SCST, 2015.

Cardiac workforce requirements in the UK. Hackett D for BCS. 2005.

## **Section 7: Overarching service organization and oversight**

### **Imaging Board**

The above complex issues in medical and non-medical workforce have implications for other imaging and clinical areas. Further the development of some services above such as cardiac CT and nuclear cardiology for example have significant ramifications for specialties outside cardiology. The IT infrastructural issues are also province and specialty wide issues. For this reason some sort of overarching body to share information and provide oversight to these cross cutting projects would be most welcome. As part of the report we would recommend the instigation of an Imaging Board with membership from the various medical specialties as well as all relevant staff and stakeholders from the review process. This group should be constituted to review major changes in any imaging area to ensure that the implications of such changes are recognized across the healthcare system as a whole. The group would also be ideally placed to drive forward and oversee those cross cutting issues such as IT infrastructure change.

### **Accreditation**

Professional bodies have published standards for personal and departmental accreditation in most of the cardiac imaging specialties. While for example the BSE has clear standards for departmental accreditation, other specialty groups such as BNCS do not as yet have formal accreditation process, though quality standards have been published. It is recommended that departments should work towards these, recognizing that the volume of work and working practices may not allow direct engagement with the requirements in all cases.

## **Section 8: Future trends in cardiac imaging**

In this report the current guideline uses and standards for services are presented and the implications for development are detailed. However it is likely that there will be substantial changes in imaging technology, indications, and clinical use over the next 5-10 years. In this section we anticipate some of those changes and recommend that these areas are reviewed regularly to determine when advances have reached the point that clinical application is feasible and able to favourably impact on patient care.

### **Echocardiography**

Cardiac ultrasound is a mature technology and so step changes in imaging are unlikely over the next 5-10 years. Some current trends however are likely to come to the fore. Increasingly accurate methods for detecting left ventricular dysfunction, such as deformation imaging, are gaining in evidence, and it is likely that such measures will soon make it in to guideline acquisition datasets. This is already the case for some subspecialty areas such as cardio-oncology. Other new scan parameters are likely to be introduced over this time scale also.

The second trend may be that of miniaturisation. Small portable devices already exist, and some predict a move to virtual ultrasound stethoscopy as a routine part of the clinical examination. Clear research evidence of a definite positive effect on clinical outcomes is awaited.

The final area in echocardiography where change is expected is that of the role of the echocardiographer; such staff already have an important role in acquiring and reporting studies, and an expanded role could be foreseen in running for example stress echocardiography sessions or echo led valve clinics. Such models have started to appear in the literature and could be adapted to our own situation. Of course this is dependent on staffing which as detailed later is likely to be problematic in the future.

## **CMR imaging**

Technological advances are occurring at a fast rate in the field of CMR and some new scan sequences (e.g. T1 mapping by ShMOLLI) will soon be ready for widespread clinical application. T1 mapping is a technique which allows estimation of the interstitial volume / diffuse disease in the myocardium. Contrast and non-contrast scans are possible providing slightly different information. Many studies have appeared in the last 5 years detailing the diagnostic advantage of detecting such changes in terms of diffuse fibrosis or infiltration in diseases such as amyloidosis and other causes of apparent ventricular hypertrophy. The data are likely to reach the point within the next 5 years that such techniques will become embedded in imaging protocols for such diseases. It is important that any new MRI scanners are equipped with the ability to measure this parameter. Due to the stringent hardware requirements for accurate T1 mapping it is expensive to add these sequences to current scanners, and so this sequence should be enabled in all newly purchased scanners.

Other sequences likely to become clinically important are T2 mapping for myocardial oedema and feature tracking for regional wall motion and the equivalent of myocardial deformation imaging.

Given the rapid pace of change in CMR it is likely that new sequences and innovations will come to the fore relatively quickly and scan guidelines should be reviewed on a regular basis.

## **Cardiac CT imaging**

In recent years there have been big advances in the speed of scanning, in scan resolution and more recently in advanced algorithms for radiation dose reduction. While some changes may occur in these areas in the future, much of this technology is now available for clinical use, especially in new scanners. Current research efforts are centring on improved assessment of coronary stenosis beyond degree of narrowing. For example attempts to interrogate the characteristics of plaque are moving forward and may bring benefit in the future. More compelling are attempts to derive functional information from cardiac CT. These have largely been in 2 areas. A small number of reports are detailing perfusion imaging during CT and reporting

alterations in myocardial tissue characteristics (in HU). Infarct detection can be done in a similar fashion to delayed gadolinium contrast enhancement with CMR, but of more interest are sequences detailing stress and rest perfusion. This technique still has some way to go before clinical application is likely. Potentially of more interest is the application of fluid dynamics to contrast opacification of coronary arteries from which a virtual fractional flow reserve (an non-invasive functional test of perfusion) can be derived. Currently this can be done without stress and with little increase in radiation dose. However currently only one algorithm has been tested to any great extent, and while there is early promise, there are considerable technical and logistical problems with the technique. For example, the processing currently takes several hours, and the algorithm is owned by a commercial company. However with improvement in computing power likely to continue this may become a viable technique in the future and certainly would be one worthy of adoption should such promise be fulfilled.

### **Nuclear cardiology**

In terms of cardiac SPECT recent advances are now on the cusp of clinical use. Solid state detector cameras, which replace traditional Anger style gamma cameras with novel Cadmium-zinc-telluride detectors have distinct benefits. Such cameras are up to 10 times more sensitive, allowing reductions in imaging time and patient radiation dose of up to two thirds with maintained or improved image quality and much faster patient throughput. Such cameras have now become available commercially and should be strongly considered when current systems reach elective replacement. A small number have recently been installed in NHS facilities in London.

Cardiac PET use has been dramatically increasing in the United States over the last 10 years and many large centres have moved almost exclusively to this technology in place of SPECT. For functional perfusion imaging there are several advantages: shorter one visit studies, reduced patient dose, increased study accuracy, and absolute flow quantitation. The latter is the most attractive benefit allowing improved diagnostic capability in chest pain and IHD and reducing false negative studies. Unfortunately perfusion tracers such as ammonia and water require a cyclotron and radiochemistry expertise and may be impractical. Recently portable strontium

generators which elute 82-Rubidium have become available and have revolutionised perfusion PET; such technology can be cost effective for large throughput centres and is in use in a handful of UK centres (eg Manchester). FDG based perfusion tracers (e.g. flurpiridaz) have also completed phase 2 trials and would be a serious option. Should substantial increases in PET camera capacity become available then a transfer of perfusion imaging to this technology should be seriously considered.

PET imaging will likely also have a place to play in other cardiac diseases including cardiac sarcoidosis, prosthetic valve endocarditis, and pacemaker infections. Trials in many of these areas have reported and initial results are positive. As a result recently published guidelines support the use of FDG cardiac PET for these indications and so an expansion of cardiac PET should be planned over the next 5 years. Discussions around the development of a Regional service offering FDG PET imaging for cases of suspected device or prosthetic valve endocarditis should be planned in the near future.

### **Absolute flow quantitation**

The ability to measure coronary blood flow during stress and rest would improve diagnostic and prognostic capabilities significantly in IHD. Mention has been made of this in terms of PET. Attempts are ongoing to perfect this technology for CMR and possibly also for perfusion echo. New solid state detector gamma cameras should in theory also allow dynamic acquisitions in list mode similar to PET due to high detector sensitivity and so could also potentially provide this information. Flow quantitation is likely to be a major advance in the next 5-10 years in several imaging areas.

### **Multimodality and fusion imaging**

Due to the increasing complex needs of patients, information on flow, function and anatomy may all be required for patient management. The use of standalone or combined multimodality imaging is likely to be the solution to this problem. Already combined imaging systems exist such as CT-SPECT and CT-PET and other systems are becoming available (CMR-PET for example). An alternative to combined devices is software to combine images from different imaging systems and utilising off line-image fusion. Such software currently exists and is in use in selected

centres. It is likely that careful assessment of the indications for such advanced image analysis will be clarified in the next few years and the technology should then be introduced.

### **Moving from indications to pathways**

At present most imaging investigations are justified on the grounds of guidelines or appropriateness criteria. However recent and current clinical studies are now testing clinical management pathways with imaging embedded in various ways, rather than looking at imaging in isolation. For example the ISCHEMIA study is comparing final management strategies in patients with moderate severe ischaemia using imaging entry points and will report on the best pathway for patient management. Similarly the CE-MARC 2 study is comparing 3 pathways for patient management in IHD, each of which has specific imaging interventions embedded. Other similar studies are also recruiting patients at present. The reporting of these studies is likely to define clinical services in certain disease areas and will by default also define the imaging strategy; this will change the way in which commissioning happens. These new data will have to be balanced against imaging guidelines, including the upcoming review of NICE CG 95.



## Appendix 1: Strengths and weaknesses of imaging techniques

The decision as to which investigation to use will depend on many factors. The tables below compare imaging parameters for each cardiac imaging modality as published by the National Imaging Board (chest pain related tests highlighted blue).

	Echo	Nuclear	CMR	Inv Angio	CT Angio
Ventricular function	+++	++	+++	++	++
Valve function	+++	+	++	++	+
Valve morphology	+++	-	++	+	+
Coronary anatomy	-	-	-	+++	+++
Ischaemia	+++	+++	+++	+	-
Blood flow in the cardiac chambers	+++	+	++	++	-
Cost of basic test Cheapest = +	+	++	+++	+++	++
Time for basic test	+	+++	++	+++	+
Reporting time Shortest = +	+	+	++	+	++
Dedicated equipment	Y	N	N	Y	N
Ancillary equipment needed	N	N	Y	Y	Y

Key - = test not useful + to +++ = increasing level of diagnostic use Y =Yes N =No

## Selecting each imaging modality

The tables below detail suggested inclusion and exclusion criteria for the functional (Cardiac SPECT / Stress Echocardiography) or structural investigations (Cardiac CT).

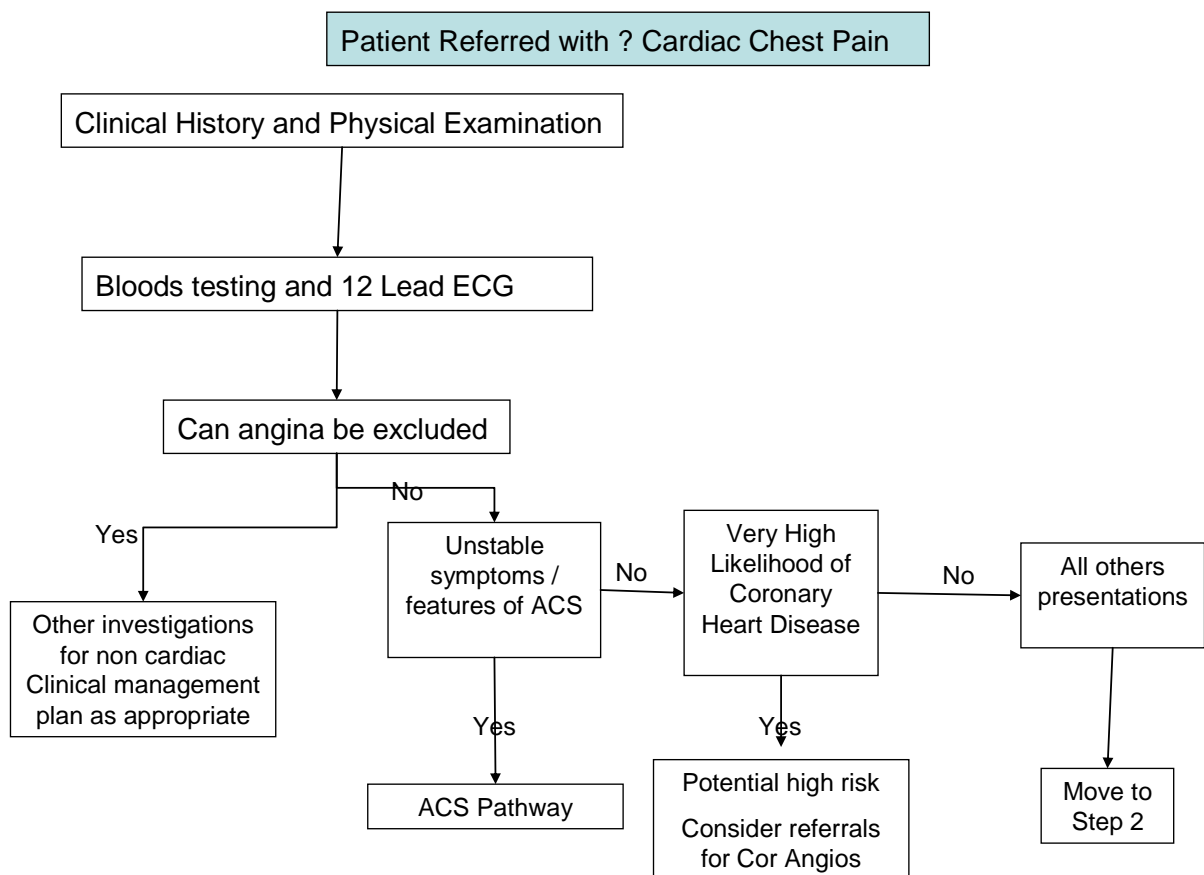
<b>Functional Stress Echo</b>	
<p>Stress echocardiography combines a painless ultrasound scan of the heart with a drip which makes the heart work harder than usual. This test allows the doctor to see how well the heart works when it is put under stress; a fall in heart function during the drip suggests that there may be underlying narrowing of the heart arteries which are unable to supply enough blood to the heart muscle during the stress.</p>	
Inclusion	<ul style="list-style-type: none"> <li>Suitable for many patients</li> <li>Valvular data important</li> <li>Young patient</li> <li>Sinus rhythm</li> <li>Low or intermediate risk</li> </ul>
Exclusion	<ul style="list-style-type: none"> <li>Poor echo window</li> <li>Morbid obesity</li> <li>Uncontrolled AF</li> <li>Ventricular arrhythmias</li> <li>Uncontrolled hypertension</li> <li>Recent ACS</li> <li>Other contraindications to dobutamine</li> </ul>
<b>Functional Cardiac SPECT</b>	
<p>This is a painless scan which measures the blood flow supplied to the heart by the heart arteries. Injection of a small amount of radioactive drug outlines the flow of blood to the heart and is detected by a camera. Blood flow is measured at rest and compared with results during heart stress, usually induced by a short drip which makes the heart work harder. A problem with blood flow during stress suggests narrowing of the underlying heart artery.</p>	
Inclusion	<ul style="list-style-type: none"> <li>Suitable for nearly all patient groups</li> <li>Low or intermediate risk</li> </ul>
Exclusion	<ul style="list-style-type: none"> <li>Young patient &lt; 40 (relative-risk/benefit considerations to be assessed individually on case by case basis)</li> <li>Breast feeding</li> <li>Multiple recent radiation exposures</li> <li>Unable to lie flat</li> <li>Contraindications to stress agents</li> <li>Morbid obesity (patients up to BMI 50 have been successfully scanned)</li> </ul>

<b>Structural</b>	
<u>Cardiac CT</u>	
Cardiac computed tomography (CT) scanning takes X ray pictures of the heart in a large circular scanner. It allows the heart arteries to be seen directly and so identifies any narrowing present. It may also allow the amount of the calcium in the arteries to be measured; this is associated with hardening of the arteries.	
Inclusion	Low or low/intermediate likelihood disease Inconclusive SPECT/DSE
Exclusion	Young patient < 40 (relative-risk/benefit considerations) Renal impairment (GFR<40mls/min) Previous contrast allergy Rhythm not sinus (AF, multiple ectopics) Inability to breath hold Previous coronary stenting / CABG / known severe CAD (see later) High risk patient Multiple recent radiation exposures Unable to lie flat
<b>Functional</b>	
<u>Stress Cardiac Magnetic Resonance imaging</u>	
Perfusion stress CMR will be discussed. This technique measures myocardial perfusion by observing the timing and extent of signal enhancement as a bolus of gadolinium contrast washes through the myocardium at rest and during vasodilator stress (similar to cardiac SPECT).	
Inclusion	Low/intermediate or intermediate likelihood disease Inconclusive CT angiogram
Exclusion	Renal impairment (GFR<30mls/min) Previous contrast allergy Rhythm not sinus (AF, multiple ectopics) Inability to breath hold Unable to lie flat Morbid obesity Claustrophobia Implanted ferromagnetic devices (e.g. pacemakers) Contraindications to stress agents

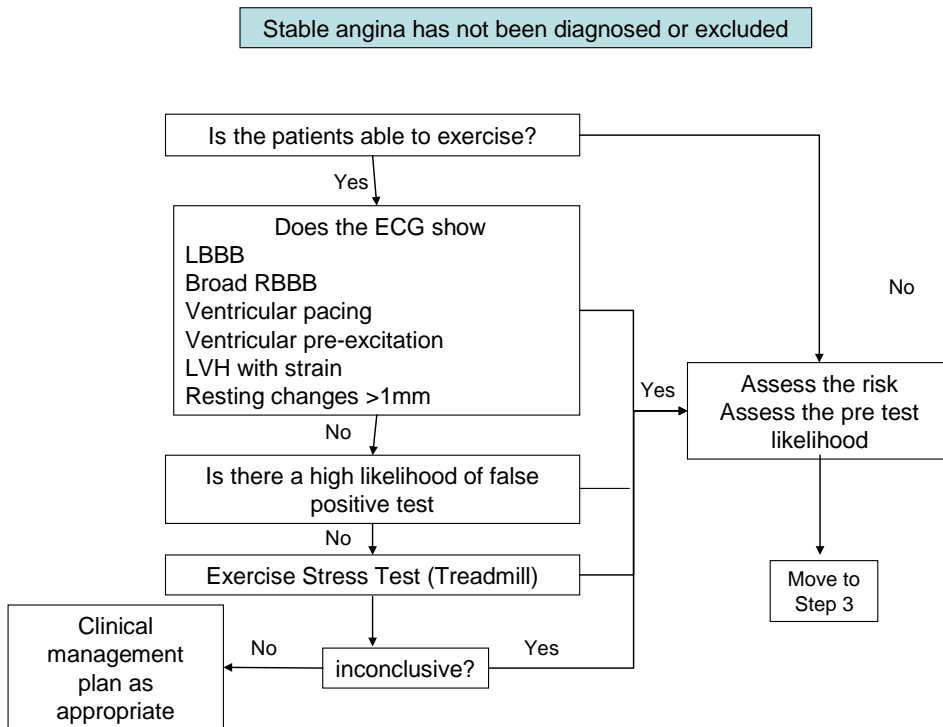
## Appendix 2: Hybrid pathway

This appendix details the hybrid imaging pathway developed by the Cardiac Network. It addresses the increase in imaging required by CG95 but does not go so far as to recommend it for everyone. The imaging is targeted at those felt likely to benefit the most. Subsequent research studies discussed already in this document shows that this is a reasonable strategy. The pathway has 3 steps shown below.

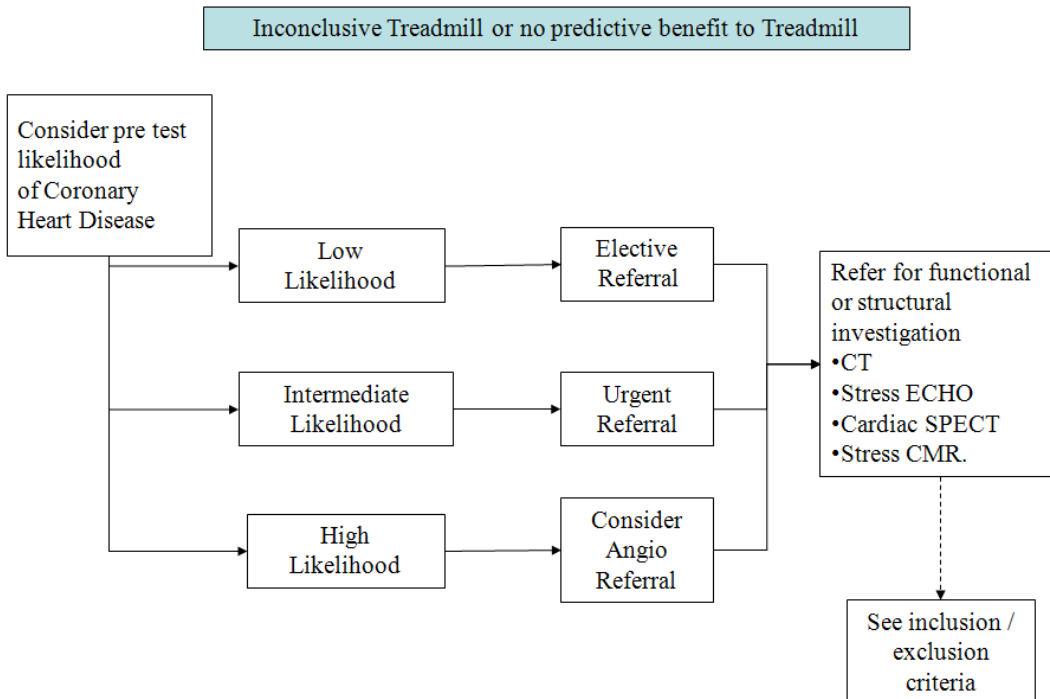
### Step 1



Step 2



Step 3



### **Appendix 3: Copy of 2007 report to network on cardiac CT.**

This is largely outdated but the assumptions on numbers are helpful and are partly used in the calculations in this document.

#### **Multidetector Computed Tomography (MDCT) coronary artery imaging - current role, future possibilities and estimate of service requirements.**

A report to the revascularization subgroup, Northern Ireland Cardiology Network.

February 2007

Draft 1

Dr. Mark Harbinson

## Contents

- MDCT-the technique and clinical results
- MDCT possible indications - (1) niche indications
- MDCT possible indications - (2) possible mainstream indications
- Estimation of possible need
- Current service provision and future service and training requirements
- Fusion imaging
- Work in progress
- Summary
- Appendix – tables and figures
- References

### **1. Multidetector Computed Tomography cardiac imaging – technique and clinical results**

#### *Introduction*

Recent years have seen marked advances in imaging technology, particularly in the application of cross sectional imaging using computed tomography (CT) and magnetic resonance imaging (MRI) to cardiology. In particular, non-invasive coronary artery imaging with multidetector CT (MDCT) has attracted great interest and holds the prospect of producing images almost equivalent to traditional invasive angiography without some of the associated risk. This report was motivated by these recent changes in imaging technique, and by the expected large increase in angiography requirements projected for Northern Ireland. In particular the report seeks to address the impact that MDCT coronary angiography may have on invasive angiography numbers.

#### *Technique and results*

MDCT or 'multislice CT' is performed on a standard multidetector computed tomography machine equipped with cardiac gating and appropriate processing software. The method therefore requires the use of ionizing radiation and contrast media to enhance the signal from the coronary arteries. The best images are obtained when the heart rate is relatively slow, and beta blockade may be needed particularly for older scanners with fewer detectors.

Two types of scan are usually helpful when assessing patients for coronary artery disease. The 'calcium score' is a quick and accurate method of detecting the presence of coronary calcification, which is ubiquitous in patients with coronary artery disease. The extent of calcification has prognostic implications and has been widely used as a screening test in patients with risk factors. The use of MDCT for 'screening' is not discussed further here due to controversies over its effectiveness. The calcium score however is helpful as it identifies patients with large amounts of calcium in whom CT coronary angiographic images are likely to be poor.

The second and most important application of MDCT is the ability to perform non-invasive coronary arteriography. This technique forms the basis of this discussion paper. Technology in this area is changing very rapidly. Initial papers from 4 and then 16 slice MDCT scanners reported sensitivities and specificities in the mid 80% for detection of coronary disease, but excluded patients with difficult

images; the actual success rate was therefore somewhat lower (table 1). Currently 64 detector CT is routinely available and even further refinements such as dual-source CT and flat panel detectors are being assessed. Many investigators suggest that a calcium score is performed first-if the score is high the patient has significant atheroma, and a CT angiogram will be hard to interpret; a different test should be performed to inform management. If there is little calcium then the angiogram images are generally good and CT angiography should be performed. Using this protocol and with the most up to date scanners sensitivities and specificities in the mid 90% are being reported (table 1). Although data are scarce as this is a rapidly progressing area, a recent review identified 4 studies using 64 detector CT and demonstrated that good results could be reproduced consistently between studies (Schussler 2007).

## **2. Possible indications for MDCT coronary angiography– (1) Niche indications**

The ability to perform non-invasive angiography has led to great interest and widespread endorsement of the technique. Suggestions that its use will reduce the number of invasive angiograms performed have however still to be proven. The current indications may be divided into 2 categories: niche and mainstream. Niche areas are those where MDCT angiography is particularly helpful and may have clear advantages over other techniques. However, many of these areas are relatively small and may not have a major impact on waiting times for other tests. Furthermore as many of these will be new tests rather than replacements for traditional angiography, it is therefore likely that they may be cost generating rather than cost saving. Nonetheless they represent an improvement in current diagnostic performance. More mainstream indications are those where MDCT angiography may be used as an alternative to current techniques. These indications are those where MDCT may have the biggest impact in terms of waiting times for other procedures. Some potential niche indications are reviewed below.

A list of possible 'niche' indications is given in table 2. Some of the proposed niche indications for MDCT represent a real improvement in current diagnostic capabilities; identification of anomalous coronary arteries and mapping their proximal course is an obvious example. MDCT angiography is clearly indicated for some patients in whom invasive angiography is very difficult or impossible. This may be the case in patients with vascular access problems or morbid obesity for example. Furthermore clinicians may wish to avoid invasive studies in certain high risk situations unless they are confident that percutaneous revascularization will follow, as this makes the risk acceptable. These patients can be scanned with MDCT at less risk and then invasive studies selectively performed in those suitable for PCI. As discussed, many of such studies will be 'extra' and will not replace invasive angiography. Certain of these MDCT studies however may replace traditional invasive angiography in a proportion of cases. Two particular examples are patients with previous bypass surgery where a graft study can be performed, and patients requiring coronary study prior to valve surgery. Modelling of possible numbers is presented later in this paper. US guidelines, and recently appropriateness criteria, have been published, and embrace some of these potential indications. There is evidence in the literature for some of the others. One or two listed indications are clinically intuitive but as yet not supported by published evidence. The ACC appropriateness criteria for MDCT coronary arteriography are appended to this report, and some supportive references given.

## **3. Possible indications for MDCT coronary angiography– (2) Mainstream indications**

If MDCT angiography is to have a large impact on the number of patients awaiting diagnostic invasive coronary arteriography, then mainstream indications embracing large patient groups are required. The aim will be to reduce the number of normal invasive angiograms by investigating patients with a low to intermediate pre-test likelihood of coronary disease using MDCT. Patients at high risk or with a high pre-test likelihood should probably be investigated by invasive study as revascularisation is likely to follow. The indications for MDCT arteriography in this group given below (table 3), especially the first 3, are therefore potentially attractive as they will screen out a large number of patients with normal arteriograms who will not need to have invasive studies. Such patients have traditionally been investigated via 2 main routes-straight to invasive angiography, or a functional test such as stress echo or perfusion study. For those who would have had arteriography, there will be a clear advantage to a MDCT strategy with a reduction in the number of normal diagnostic invasive arteriograms. There



is of course debate about the best strategy in such patients with an intermediate likelihood of disease who are unsuitable for standard treadmill testing; many guidelines would advocate a functional test, and which ever test is selected there will be a small number who will need both a functional and an anatomical test. Other of the potential indications are slightly controversial or as yet with supporting evidence, such as using MDCT heart failure to assess aetiology. Current scanning technology may be inadequate to assess coronary stent patency in a significant number of cases.

For the second group of indications below (general anatomy), MDCT is attractive for pericardial disease as it detects pericardial calcification accurately, and probably for disease of the great vessels. A niche has been found in imaging the pulmonary and cardiac veins to aid planning of interventional procedures. For the vast majority of functional imaging studies however, CMR imaging may be preferable, particularly if follow up studies are to be required.

#### **4. Estimate of need for MDCT coronary angiography**

Accurate estimation of the required provision in this area is currently not possible. There are no national or local statistics reflecting MDCT use, and no national targets or guidance have been issued (personal communication from British Society for Cardiac Radiology). An estimation of need has been made using the following methods:

For some of the potentially larger indications outlined, an estimate of numbers has been made using the modeling performed recently for the network (Dr Green paper)

When this has not been possible, extrapolation from alternative techniques applied to the same clinical indication has been undertaken

Assumptions from other modelling papers in this area have been applied when necessary

Modelling for 3 indications is given below: the niche indications of assessment after previous bypass grafting (CABG) and angiography prior to valve surgery, and the mainstream indication of diagnostic coronary arteriography in IHD.

##### *4.1 Estimation of possible MDCT use in patients with previous CABG*

According to the RVH database, around 252 invasive angiograms were performed in 2006 in patients with previous CABG. To account for studies performed in BCH, Altnagelvin and Craigavon among others, the number was doubled to around 504 cases per year. This number was then expressed as a percentage of the total number of invasive angiograms to estimate the proportion of all angiography which was performed in patients with previous CABG. This was then projected onto the estimated numbers of studies in the previous model presented to the network by Dr Green (figure 1). Finally it was assumed that about 50% of these cases would be elective and therefore suitable for MDCT; it is assumed that acutely presenting patients will go on to invasive study. This proportion has been accepted in other parts of the Green model. It is of interest that fewer than 50% of the cases performed at RVH actually went on to intervention as presumably the anatomy was unsuitable; using MDCT as a screening test therefore appears to have some merit. The calculation steps are therefore:

- 189 cath in CABG patients over 9 months of 2006 at RVH
- Extrapolates to 252 cath annually
- 99 diagnostic only, 90 intervention
- Extrapolates to 132 diagnostic, 120 interventional annually
- To account for BCH and others, double numbers
- Final numbers 504 / yr

- Just over 50% diagnostic only – potentially avoidable
- In 2006 3045 caths / million population i.e. 5176 assuming 1.7 million population
- Cath in CABG patients accounted for 504 of these i.e. 504/5176
- Therefore 9.7% caths in patient with CABG
- Assume that 50% suitable for MDCT (mainly elective)
- Project this onto angiography predictions for 2008, 2010, 2015

<b>Year</b>	<b>Total angios</b>	<b>CABG angios (9.7% of total)</b>	<b>MDCT angios (50% of CABG)</b>
2008	7965	773	386
2010	8431	818	409
2015	9673	938	469

#### *4.2 Estimation of possible MDCT use in patients awaiting valve surgery*

The number of patients awaiting valve surgery was taken from the estimates in the Green projections. A conservative estimate was made that about one third of patients would be suitable for MDCT coronary angiography. This takes into account the patients with known IHD or who are very elderly, both of whom may have a lot of coronary calcification. In addition young patients may not need angiography. Conversely, some patients may require cardiac catheterisation for diagnostic purposes (e.g. pulmonary hypertension associated with the valve disease).

<b>Year</b>	<b>Projected number of valve operations</b>	<b>Possible MDCT angiograms (1/3 of total)</b>
2008	225	75
2010	248	83
2015	316	105

#### *4.3 Estimation of possible MDCT use in patients with possible IHD*

Use of MDCT in patients at risk of IHD represents the largest group where it may be indicated. The number of possible MDCT angiograms was estimated by starting with the projected number of angiograms as reported in the Green projections (see figure 1). The middle value of the 3 possible rates was selected. Estimating the number of these studies which represent intermediate or low / intermediate risk patients is problematic. One approach is that which the British Cardiovascular Society has taken in its upcoming report on imaging requirements; this is to estimate the number of normal or almost normal angiograms currently performed in invasive centers from published data and available local databases. The estimate is that around 15% of such studies are normal and a further 10% are low risk requiring medical therapy and no intervention; clearly these are the patients we

would wish to have MDCT and avoid invasive study. This assumption was applied to the locally projected angiography numbers to identify the possible number of MDCT angiograms.

<b>Year</b>	<b>Total no. of angios</b>	<b>Normal angio (15%)</b>	<b>Low risk angio (10%)</b>	<b>Total angios avoidable</b>
2008	7965	1195	796	1991
2010	8431	1265	843	2108
2015	9673	1451	967	2418

#### 4.4 Summary of potential total numbers of MDCT coronary angiograms

The total number of possible MDCT angiograms is estimated below, expressed as number of sessions (half days). This has been calculated using the following assumptions:

The estimates from the 3 largest groups of suitable patients as outlined above have been summed

The other niche indications have not been included, as though important, the numbers are likely to be small

The use of MDCT for general cardiac CT (excluding coronary angiography) has not been included-potentially this will lead to some degree of underestimation of need

The final numbers have been slightly adjusted down as there may be a small degree of overlap in the groups assessed due to differences in the source of the data used for the calculations

An estimate of the number of sessions per week has been made assuming that 7 studies are performed per session. This is ambitious at the start but readily achievable in large volume centers with experience.

The model assumes a service can be provided for 46 weeks per year, to allow breaks for annual holidays and equipment servicing etc. The actual number of scans can therefore be calculated by multiplying the number of sessions by 46.

<b>Year</b>	<b>Sessions IHD</b>	<b>Sessions Valve</b>	<b>Sessions CABG</b>	<b>Total sessions</b>	<b>Sessions per week (corrected)</b>
2008	284	75	55	414	9.0 [8.0]
2010	301	83	58	442	9.6 [9.0]
2015	345	105	67	517	11.2 [10.0]

It can be appreciated therefore that to embrace as candidates for MDCT patients with intermediate likelihood of IHD who cannot perform a standard stress test, and to also include some of the niche indications, a minimum of a whole time scanner scanning up to 14 patients per day will be needed to meet these projections.

#### 4.5 Estimating impact on number of invasive angiograms

The above calculations have tried to estimate the number of patients in whom MDCT may be performed. Even with careful selection however, some will turn out to have significant disease and hence will need an invasive angiogram. Also as discussed above some niche indications are new and may not replace an invasive study. The number of estimated MDCT angiograms does not therefore equal the potential number of saved invasive studies, which will clearly be less. Estimating the number of saved invasive angiograms using this model is problematic. Experience elsewhere, including data from the USA, shows that a large increase in the number of non-invasive tests is required to reduce the number of low risk angiograms, but that if this is implemented, the reduction should definitely follow. Making the following assumptions using the data above:

For CABG patients having MDCT fewer than 50% will be suitable for intervention and will therefore need an invasive study [this was extrapolated from RVH cath lab data for 2006]. The numbers given above will therefore be reduced by 50% to account for invasive studies required as part of the intervention.

For valve disease patients there may be a small number in whom MDCT angiography is of poor quality and an invasive study is required. As part of the original assumptions however only one third of possible candidates were included as MDCT patients, so no further adjustment will be made.

For patients with low or low/intermediate risk of IHD a certain proportion will turn out to have IHD requiring intervention, and thus a small number of invasive studies will be generated. The way in which the data for numbers in this group was calculated is not directly related to pre-test risk and so any adjustment is difficult. Assuming the patients in the low/intermediate category are those sent for MDCT, the incidence of significant IHD in this group should be less than 10%, depending on the exact risk definitions chosen. For the purpose of the calculation therefore, the number of invasive studies saved will be adjusted downwards by 10%.

The following numbers of potentially avoided invasive angiograms therefore results:

<b>Year</b>	<b>No. angios for IHD</b>	<b>No. angios for Valve</b>	<b>No angios for CABG</b>	<b>Total angios</b>
2008	1792	525	189	2506
2010	1890	581	203	2674
2015	2170	735	231	3136

## **5. Current service provision and future service and training requirements**

### *Current provision*

There is no regional service for MDCT coronary arteriography in NI. The Ulster Hospital has developed expertise in this technique but has no funding to provide a province wide service. Occasional cases from elsewhere can be arranged if discussed specifically with the team there. The service is provided by a consultant cardiologist and radiologist working together. There are also some patients being studied in the Tyrone County/South Tyrone area on a 16 slice scanner again with a service led by radiology and medicine jointly. Again this unit is not funded to provide a regional service.

### *Future provision*

The data presented in the report are preliminary and more complete data on service provision are currently being sought. Most modern general MDCT machines have the ability to perform coronary arteriography if the appropriate software and analysis packages are purchased. As CT scanners come for replacement in radiology departments across NI, it is inevitable that they will be replaced with MDCT technology, the majority of which should be suitable for coronary imaging. Unlike CMR, the extra expense in terms of upgrades may be less. If MDCT does become an accepted test for low/intermediate risk patients to rule out coronary disease, then a reasonably large number of studies may be needed. One possible model would be to have centre capable of providing a MDCT coronary artery imaging service in each of the new board areas. The projected numbers are such that this could realistically run for 1 or 2 sessions per week with the scanner being used for general radiology the remainder of the time. A service for more difficult cases including anomalous coronary arteries and specialist conditions such as angiography in patients being considered for surgery for endocarditis or aortic dissection could be provided at a single site, where more sessions would be required. An alternative, particularly when numbers might be small initially, would be to provide all the service on a single scanner and allow patients, and those with expertise, to travel to this centre from their own board areas.

### *Staff training*

As outlined above there is currently very limited expertise in this technique in Northern Ireland. Indeed UK wide there are very few centres experienced in the method and training remains a problem (personal communication, British Society of Cardiac Radiology). UK training guidelines are currently under review but as yet remain unpublished. Some American guidelines are available, and training courses are widely available via The American Society for Nuclear Cardiology among others. The latter has the advantage that it runs hands-on course, theory courses and web based learning courses which allow a large number of studies to be reviewed over the internet. The staffing will need to take into account radiologist, cardiologists, appropriate trainees (SpR/STs), radiographers and possibly also physicists. The exact number and balance of staff will depend on the model chosen.

A more detailed survey of possible sites for service provision, physician expertise, and perceived local imaging requirements will be undertaken to better inform this document and make more concrete suggestions about ways of meeting the suggested target number of studies.

## **6. Fusion imaging**

Currently there is a move to multi-modality imaging, particularly in patients with coronary artery disease. This incorporates functional (e.g. myocardial perfusion) with anatomical (e.g. coronary arteriography) data for the same patient. Indeed this has been relatively common practice in patient management, at least for a subset of individuals for some time. Now however the studies are being combined rather than being performed in isolation. The 2 most developed are SPECT-CT and PET-CT. This comprises nuclear perfusion data (SPECT or PET) and MDCT coronary arteriography. There are in fact 2 methods of performing such studies. The 2 scans can be performed sequentially on the one scanner which is good for throughput, efficiency and patient convenience. Such combined systems are very new, expensive and such a service is currently not available in NI. The other option

is to scan patients on separate equipment as at present, and when required to view fused images generated by a software system. This may potentially be considerably cheaper, though issues of image and manufacturer compatibility, and image registration are problematic. The advantages of this method of investigation are still under assessment. While no definite information in terms of cost effectiveness or clinical utility is available, the techniques are being adopted in many top cardiac centres. As such we should be aware of this in NI so that we are not disadvantaged if important data on clinical utility becomes available.

## **7. Next steps**

A detailed survey of cardiac and radiology centres in NI will be undertaken to ascertain the current level of MDCT coronary arteriography being performed, the type of equipment being used, and the staff involved. In addition the number of potential sites with multidetector CT systems will be ascertained. Staff with expertise in, or an interest in performing, MDCT coronary angiography will be identified. It is hoped that these data will inform the later stages of this document, and will be presented with conclusions in the final report.

## **Summary**

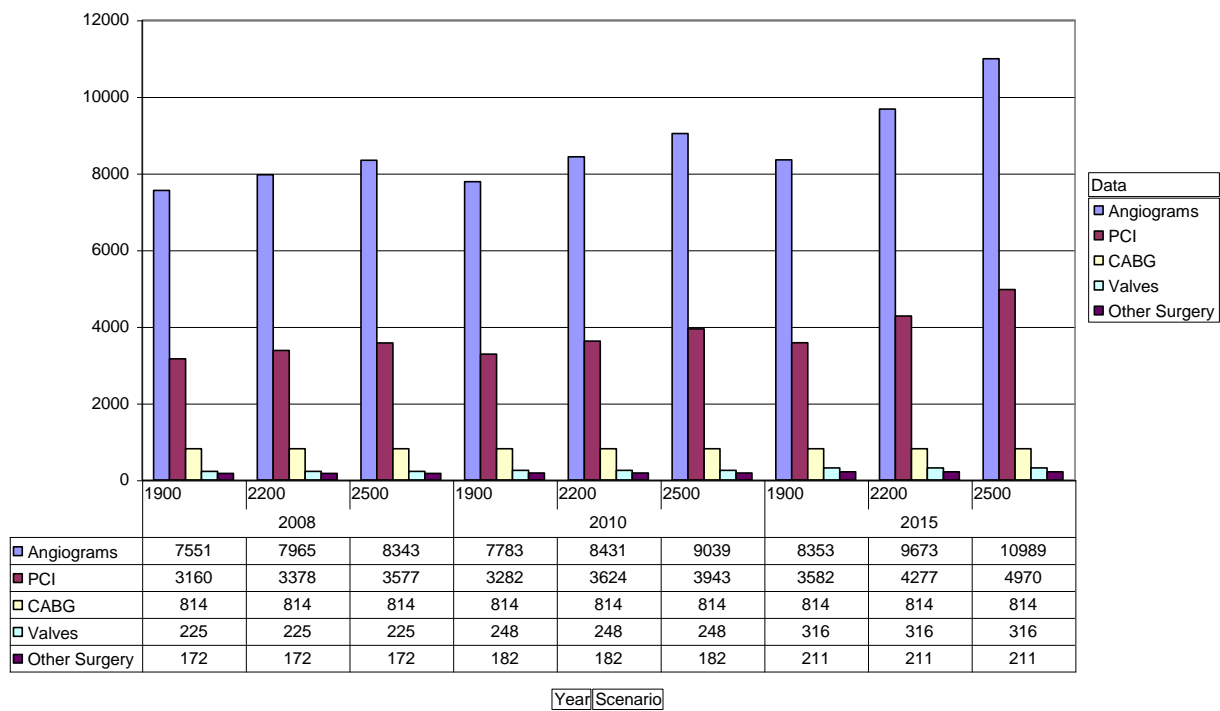
1. MDCT coronary angiography is a new rapidly developing technology which holds the promise of providing good quality clinically useful coronary angiograms without an invasive procedure.
2. This is one of the fastest growing areas in cardiology and new applications for the technique are appearing almost on a weekly basis. The assumptions of future indications, and of need in NI, are made on the best available evidence, but are inevitably slightly speculative and risk being out-of-date. Despite this, research evidence for this modality is appearing at a rapid rate, and already US bodies have produced guidelines and appropriateness criteria for use.
3. This document proposes 2 groups of indications for MDCT angiography. Niche indications are those where MDCT may be particularly helpful and possibly more appropriate, at least initially, than traditional invasive arteriography. Two of these are study of patients with previous CABG (where the majority of invasive angiograms do not lead to intervention), and coronary imaging in patients scheduled for valve surgery. None of the niche indications comprise large numbers of patients, and overall use of MDCT in such individuals is unlikely to avoid many invasive angiograms, though of course will represent an improvement in diagnostic utility.
4. Application of MDCT angiography to larger populations with suspected coronary disease could significantly reduce the number of diagnostic invasive angiograms, if a relatively low risk group, with a low likelihood of needing coronary intervention, is targeted.
5. Using a variety of assumptions outlined in this document, a large number of invasive angiograms could potentially be replaced by MDCT angiography. The calculations suggest that as many as 2500 invasive studies could be avoided in 2008 with widespread application of the technique. Given the timescale this is unlikely, but similar reductions in the projected number of invasive studies for the period up to 2015 may be more realistic.
6. The current level of cardiac imaging provision and availability in NI is already well behind even current guidelines. Given that an expansion in proven indications and clinical use is inevitable, clearly there will be major challenges in delivering an appropriate service for NI.
7. The other major challenge is training and expertise. As this is a relatively new technique, the clinical base available to provide such investigations is very limited. A significant investment in training and staff will be required. As CT scanners across the province are replaced by multislice machines, the number of sites with suitable hardware to perform the investigation will increase. Dedicated software and gating packages will however be needed.

8. As the techniques under discussion are new, audit and research should be built into their implementation.

9. While this report concentrates on new MDCT technologies, such techniques should not be viewed in isolation but in comparison with the tests in routine clinical practice at present, and with the overall investigative protocols for patients presenting with possible cardiac disease. Consideration of alternative and complementary imaging techniques such as stress echocardiography and myocardial perfusion scintigraphy should logically be performed along side the current evaluation of CT (and MRI).

**Figure 1**

Projected numbers of invasive angiograms and valve replacement operations for NI for 2008, 2010 and 2015. [Based on Dr Stephen Green model presented to the Cardiac network previously].



**Figure 2**

Appropriate indications for MDCT cardiac imaging

[taken from ACCF/ACR/SCCT/SCMR/ASNC/NASCI/SCAI/SIR Appropriateness

Criteria for Cardiac Computed Tomography and Cardiac Magnetic Resonance Imaging , J Am Coll Cardiol 2006.]

**Table 10.** Appropriate Indications (Median Score 7–9)

Indication		Appropriateness Criteria (Median Score)
<b>Detection of CAD: Symptomatic—Evaluation of Chest Pain Syndrome (Use of CT Angiogram)</b>		
2.	<ul style="list-style-type: none"> <li>• Intermediate pre-test probability of CAD</li> <li>• ECG uninterpretable OR unable to exercise</li> </ul>	A (7)
<b>Detection of CAD: Symptomatic—Evaluation of Intra-Cardiac Structures (Use of CT Angiogram)</b>		
4.	<ul style="list-style-type: none"> <li>• Evaluation of suspected coronary anomalies</li> </ul>	A (9)
<b>Detection of CAD: Symptomatic—Acute Chest Pain (Use of CT Angiogram)</b>		
6.	<ul style="list-style-type: none"> <li>• Intermediate pre-test probability of CAD</li> <li>• No ECG changes and serial enzymes negative</li> </ul>	A (7)
<b>Detection of CAD With Prior Test Results—Evaluation of Chest Pain Syndrome (Use of CT Angiogram)</b>		
16.	<ul style="list-style-type: none"> <li>• Uninterpretable or equivocal stress test (exercise, perfusion, or stress echo)</li> </ul>	A (8)
<b>Structure and Function—Morphology (Use of CT Angiogram)</b>		
28.	<ul style="list-style-type: none"> <li>• Assessment of complex congenital heart disease including anomalies of coronary circulation, great vessels, and cardiac chambers and valves</li> </ul>	A (7)
29.	<ul style="list-style-type: none"> <li>• Evaluation of coronary arteries in patients with new onset heart failure to assess etiology</li> </ul>	A (7)
<b>Structure and Function—Evaluation of Intra- and Extra-Cardiac Structures (Use of Cardiac CT)</b>		
33.	<ul style="list-style-type: none"> <li>• Evaluation of cardiac mass (suspected tumor or thrombus)</li> <li>• Patients with technically limited images from echocardiogram, MRI, or TEE</li> </ul>	A (8)
34.	<ul style="list-style-type: none"> <li>• Evaluation of pericardial conditions (pericardial mass, constrictive pericarditis, or complications of cardiac surgery)</li> <li>• Patients with technically limited images from echocardiogram, MRI, or TEE</li> </ul>	A (8)
35.	<ul style="list-style-type: none"> <li>• Evaluation of pulmonary vein anatomy prior to invasive radiofrequency ablation for atrial fibrillation</li> </ul>	A (8)
36.	<ul style="list-style-type: none"> <li>• Noninvasive coronary vein mapping prior to placement of biventricular pacemaker</li> </ul>	A (8)
37.	<ul style="list-style-type: none"> <li>• Noninvasive coronary arterial mapping, including internal mammary artery prior to repeat cardiac surgical revascularization</li> </ul>	A (8)
<b>Structure and Function—Evaluation of Aortic and Pulmonary Disease (Use of CT Angiogram*)</b>		
38.	<ul style="list-style-type: none"> <li>• Evaluation of suspected aortic dissection or thoracic aortic aneurysm</li> </ul>	A (9)
39.	<ul style="list-style-type: none"> <li>• Evaluation of suspected pulmonary embolism</li> </ul>	A (9)

\*Non-gated, CT angiogram which has a sufficiently large field of view for these specific indications.



**Table 1**

Clinical results for the detection of coronary artery disease by MDCT imaging; per patient based detection of significant stenosis.

[Adapted from Stein et al. Am J Med 2006;119:203-16.]

No. detectors	4	16	64
Sensitivity	95%	95%	100%
Specificity	84%	84%	100%
No. Segments	78%	91%	100%

**Table 2**

Possible niche indications for MDCT coronary angiography [For evidence see appended appropriateness criteria and references]

- Coronary bypass graft assessment (i.e. previous CABG)
- Anomalous coronary arteries
- Difficult arterial access & morbid obesity
- Pre valve replacement work up
- Pre non-cardiac surgery workup
- In acute aortic dissection
- In bacterial endocarditis
- Before PCI for CTO (to delineate route to distal vessel)
- Ostial coronary disease

**Table 3**

Proposed 'mainstream' indications for MDCT coronary angiography and general use of cardiac CT. [For evidence see appended appropriateness criteria and references]

*Coronary arteriography:*

- Intermediate likelihood of IHD, unable to exercise
- Intermediate likelihood of IHD, ECG unsuitable for EST / uninterpretable
- Intermediate likelihood of IHD, inconclusive EST
- Intermediate likelihood of IHD, inconclusive stress echo or myocardial perfusion study
- Intermediate cardiac risk, preoperative risk stratification for non-cardiac surgery
- Assess for IHD in heart failure
- Assess coronary stent patency

*General anatomy:*

Structural cardiac disease including ACHD

Pericardial calcification / constriction

Structural cardiac disease with CMR contraindication

Suspected acute aortic dissection (including coronary arteriography)

Suspected acute PE

Pulmonary vein anatomy prior to AF ablation

Coronary vein anatomy prior to CRT therapy

**References**

ACCF/ACR/SCCT/SCMR/ASNC/NASCI/SCAI/SIR Appropriateness

Criteria for Cardiac Computed Tomography and Cardiac Magnetic Resonance Imaging , J Am Coll Cardiol 2006.

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## **Appendix 4: Membership of the group**

The Cardiology non-invasive imaging and diagnostics clinical advisory group of the Cardiology Network has led the work in this report, with the able assistance of several colleagues listed below. I acknowledge all the following contributors to the report.

**Chair:** Dr Mark Harbinson

**Administrators:** Ms Lynne Charlton  
Ms Gillian Wells

### **Membership and review group**

Dr Nicola Johnston	Ms Virginia Anderson
Dr Lana Dixon	Ms Aran Hale
Dr Paul Horan	Mr Adam Workman
Dr Kris Lyons	Ms Nicky Harvey
Dr Sinead Hughes	Ms Maria Wright
Dr John Purvis	
Dr Daniel Flannery	From the radiology network:
Dr Paddy Donnelly	Dr Peter Ball
Dr Andrew Hamilton	Dr Barry James
Dr Brian Grant	Dr Jonathon Malloy
Dr C Russell	

## Appendix 5: Abbreviations

ACHD	Adult Congenital Heart Disease
ASSE	Accredited Specialist Scientific Expertise
BCH	Belfast City Hospital
BCIS	British Cardiac Intervention Society
BCS	British Cardiovascular Society
BHSCT	Belfast Health and Social Care Trust
BNCS	British Nuclear Cardiology Society
BSCI	British Society of Cardiovascular Imaging (now includes British Society for Cardiac CT)
BSE	British Society of Echocardiography
BSCMR	British Society of Cardiovascular Magnetic Resonance
CABG	Coronary Artery Bypass Grafting
CAD	Coronary Artery Disease
CMR	Cardiovascular Magnetic Resonance
CP	Cardiac Physiologist
CT	Computed Tomography (Tomographic)
CVIS	Cardiovascular Information System
DHSSPS	Department of Health, Social Services and Public Safety
DSE	Dobutamine Stress Echo
ECG	Electrocardiograph
ECR	Electronic Care Record
ESC	European Society of Cardiology
EST	Exercise Stress Testing
FDG	Fluorodeoxyglucose
FTE	Full Time Equivalent
GORD	Gastro-oesophageal Reflux Disease
HEE	Health Education England
HSST	Higher Specialist Scientific Training
IHD	Ischaemic Heart Disease
IPT	Investment Protocol Template
LCG	Local Commissioning Group
LETB	Local Education Training Board
MPI	Myocardial Perfusion Imaging
MSC	Modernising Scientific Careers
NHSCT	Northern Health and Social Care Trust
NICE	National Institute for Health and Care Excellence
NIECR	Northern Ireland Electronic Care Record
NIPACS	Northern Ireland Picture Archiving and Communication System
PA	Programmed Activity
PACS	Picture Archiving and Communication System
PCI	Percutaneous Coronary Intervention

PET	Positron Emission Tomography
PTP	Practitioner Training Programme
RACPC	Rapid Access Chest Pain Clinic
RBHSC	Royal Belfast Hospital for Sick Children
RVH	Royal Victoria Hospital
SBA	Service and Budget Agreement
SCMR	Society for Cardiovascular Magnetic Resonance
SCST	Society for Cardiological Science and Technology
SEHSCT	South Eastern Health and Social Care Trust
SPECT	Single-photon emission computed tomography
SSFP	Steady State Free Precession MRI Sequence
STP	Scientist Training Programme
SWAH	South Western Acute Hospital
TAVI	Trans Arterial Valve Implantation
WHSC	Western Health and Social Care Trust
WLI	Waiting List Initiative
WTE	Whole Time Equivalent