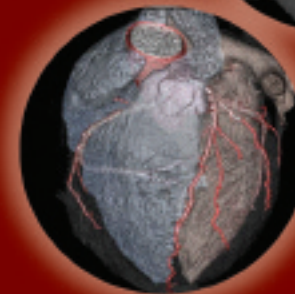
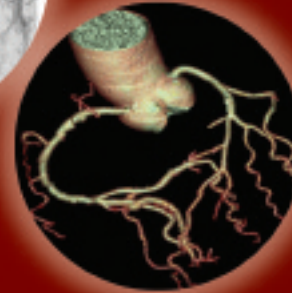


# Consensus Statement on the Utilisation of Cardiac CT



Printing supported by an unrestricted educational grant from

**SIEMENS**



Ministry of Health Malaysia



National Heart Association of Malaysia



## MESSAGE FROM THE FOUNDING PRESIDENT OF SOCIETY OF CARDIOVASCULAR COMPUTED TOMOGRAPHY

---

It is with great pleasure that I have received and read the “Consensus Statement on the Utilisation of Cardiac CT” which has been made possible through the effort, expertise and wisdom of a true group of experts under the leadership of Professor Dr. Sim Kui Hian and Associate Professor Dr. Yang Faridah Abdul Aziz. In the international community of clinicians and researchers that use cardiac computed tomography, Malaysia is recognised as a country with very advanced use and truly knowledgeable users of cardiac CT. This document once again provides evidence for the leadership role of physicians in Malaysia that set a truly remarkable example as far as providing guidance for the reasonable and beneficial use of cardiac computed tomography imaging.

This document is an excellent example of what guidelines should be: appropriate and inappropriate indications are clearly listed, reasonable and balanced, and recommendations also extend to data acquisition and reporting. The committee has accomplished a magnificent task of compiling a document that is profound, complete, and very well presented and I have no doubt that it will be truly useful to help identify patients that will benefit from a cardiac CT investigation.

I would especially like to commend Professor Dr. Sim Kui Hian and Associate Professor Dr. Yang Faridah Abdul Aziz on creating this document as a truly joint statement of the Malaysian cardiology and radiology community. Combining the knowledge and experience of both cardiology and radiology will ultimately provide maximum benefit for the patient. I am convinced that this “Consensus Statement on the Utilisation of Cardiac CT” will set an example for others to follow throughout the world.



**Dr Stephan Achenbach**

MD, FESC, FACC

Founding President

Society of Cardiovascular Computed Tomography

## MESSAGE FROM THE DIRECTOR GENERAL OF HEALTH, MALAYSIA

---

Computed tomography of the heart, also known as Cardiac CT, is rapidly becoming popular as a non-invasive imaging modality. Technological advances in this field have now allowed clinicians the ability to detect even subclinical coronary artery disease. Every passing year, advancements in both its hardware and software components have paved the way for more clinical applications to be introduced. It is not surprising; therefore, the Cardiac CT installations and examinations have seen a rapid rise, over the years, in Malaysia.

Every new technology in cardiovascular healthcare reaching our shores, both invasive and non-invasive modalities, must be subject to greater scrutiny. Only by the correct use of each new technology can the doctor use the information obtained to assist in making the best decisions in the clinical management of his or her patients. The published accuracy of Cardiac CT and its relative ease of use have allowed medical practitioners across the specialties to utilise it in their clinical practice. Hence, it is now time for : a Consensus Statement to guide local doctors on how to select appropriate patients, safely perform the Cardiac CT examination and interpret information from it, thereafter.

With cardiovascular disease remaining high on the list of causes of mortality in Malaysia, I am committed to sanction efforts to help prevent the acute manifestations of this condition and improve the management of this group of chronic diseases. Cardiac CT has a role in reducing the burden of cardiovascular Cardiac CT examination.

While I am proud to see Malaysia being the forefront of cardiovascular imaging, using latest equipments like the multislice Cardiac CT, I am equally pleased by the efforts of the National Heart Association of Malaysia and the College of Radiology in producing this timely Consensus Statement.

Congratulations!



**Tan Sri Datuk Dr Mohd. Ismail Merican**

MBBS (Malaya), FRCP (London) (Edinburgh) (Glasgow), FAMM (Malaysia), FACP (Hon), FRACP (Hon)

Director General of Health

Ministry of Health, Malaysia



## MESSAGE FROM THE PRESIDENT OF THE NATIONAL HEART ASSOCIATION OF MALAYSIA

---

First of all, I would like to congratulate Prof Sim Kui Hian (Vice-President of NHAM, Chairperson of Cardiac CT Consensus Statement Committee) and Associate Prof Yang Faridah Abdul Aziz (Co-Chairperson of Cardiac CT Consensus Statement Committee), and the committee for their very hard work in producing this excellent document that we have now. Indeed, this document is highly significant and important, in view of the very fast pace of advances in technology in the treatment and diagnosis of coronary artery disease; in particular the multislice computed tomography (MSCT).

In Malaysia alone, we now have well over 30 MSCT scanners. There is therefore a pressing need to produce a consensus statement to address this very important issue of the use and clinical application of this new technology. I believe this document will help guide doctors, clinicians and radiologists in Malaysia, in using this technology to its full potential and therefore benefiting the patients that they seek to treat. This is indeed important as many patients in Malaysia today are very up-to-date, and very well informed. This document will hopefully help doctors and clinicians involved in this technology to provide the very best, up-to-date and most appropriate care to such patients.

I would like to especially thank our colleagues from the College of Radiology, under the very able leadership of Dr Evelyn Ho, for their joint efforts and very hard work in helping to put together this comprehensive and impressive document. I believe that our cooperation will set an excellent example for other specialists in the country to do likewise – close cooperation and hard work for the ultimate benefit of our patients.

Congratulations!



**Dr Hendrick Chia**

*MBBS (London), FRCP (Ireland), AM (Malaysia), FACC (USA), FNHAM (Malaysia), FASCC (Asean)  
President  
National Heart Association of Malaysia*

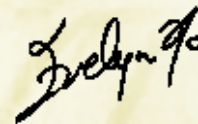
## MESSAGE FROM THE PRESIDENT OF THE COLLEGE OF RADIOLOGY

---

We are always excited with emerging technologies but these developments come with challenges. The need to understand and fully utilize these technologies, finding new applications for the technologies, ensuring its judicious use by properly trained personnel and the turf issues that can arise when technologies no longer respect the traditional boundaries of medical disciplines have to be addressed. So it is with the development of ultrafast computed tomography (CT) scanners. They come in the guise of multislice CT (MSCT), dual source CT and electron beam CT. As CT scanners use ionizing radiation to image the body, radiation safety issues also come into play.

The College of Radiology (CoR), Academy of Medicine of Malaysia is very happy to have collaborated with the National Heart Association of Malaysia to work on producing the Consensus Statement on the Utilisation of Cardiac CT. It is timely for such a Statement as it will offer practical guidance in the scenario of recent exponential growth of cardiac CT scans. The relatively non-invasive nature of cardiac CT offers an additional tool in the management of heart/coronary artery disease – a major public health issue in Malaysia. However to ensure the patient/public always benefits from this technology, one must understand its strengths and limitations. Training standards need to be set up to ensure there are adequately trained personnel to perform the cardiac CT scans and its interpretation.

The CoR hopes this Joint Statement will be received positively by all for the better management of the patient. This is a good starting point for more and future collaborations between the Cardiology and Radiology community. Together Everyone Achieves More!



**Dr Evelyn Ho**

*MBBS (Malaya), M Med Radiology (UKM) (Malaysia), AM (Malaysia), FAMS (Hon)  
President  
College of Radiology Academy of Medicine of Malaysia*

## WRITING COMMITTEE

### Chairperson:

Prof. Dr. Sim Kui Hian

*Consultant Cardiologist, Sarawak General Hospital, Sarawak*

### Co-Chairperson:

Associate Prof. Dr. Yang Faridah Abdul Aziz

*Consultant Radiologist, University of Malaya Medical Centre, Kuala Lumpur*

### Expert Panel Members (in alphabetical order)

Associate Prof. Dr. Chin Sze Piaw

*Consultant Cardiologist, International Medical University Clinical School, Seremban*

Dr. Chong Fook Looi

*Consultant Radiologist, Loh Guan Lye Specialist Centre, Penang*

Dr. Choo Gim Hooi

*Consultant Cardiologist, Selangor Medical Centre, Selangor*

Dato' Dr. David Chew

*Consultant Cardiologist, Institut Jantung Negara, Kuala Lumpur*

Dr. Evelyn Ho

*President, College of Radiology, Academy of Medicine of Malaysia*

Dr. Hendrick Chia

*President, National Heart Association of Malaysia*

Dr. Mohd Rahal Yusoff

*Clinical Specialist, Cardiology Department, Institut Jantung Negara, Kuala Lumpur*

Prof. Dr. Ng Kwan Hoong

*Consultant Medical Physicist, University of Malaya Medical Centre, Kuala Lumpur*

Dr. Hajjah Sharifah Mastura bt Syed Abu Bakar

*Consultant Radiologist, Hospital Kuala Lumpur, Kuala Lumpur*

Dr. Tan Kim Heung

*Consultant Cardiologist, Sunway Medical Centre, Selangor*

Dr. Zaharah Musa

*Consultant Radiologist, Selayang Hospital, Kuala Lumpur*

## TABLE OF CONTENTS

<b>INTRODUCTION</b> .....	7
<b>RATIONALE OF CARDIAC CT</b> .....	8-9
<b>REQUIREMENTS OF CARDIAC CT</b> .....	10-11
<b>INDICATIONS OF CCTA</b> .....	12-13
<b>APPROPRIATE INDICATIONS</b> .....	14
<b>INAPPROPRIATE INDICATIONS</b> .....	15
<b>REPORTING OF CARDIAC CT ANGIOGRAPHY</b> .....	16-17
<b>RADIATION PROTECTION IN CARDIAC CT</b> .....	18
<b>SAFETY ISSUES IN CARDIAC CT</b> .....	19
<b>TRAINING IN CARDIAC CT</b> .....	20-21
<b>TRAINING REQUIREMENTS FOR RADIOGRAPHERS</b> .....	22
<b>EXTRACARDIAC FINDINGS OF CORONARY CTA</b> .....	23
<b>REFERENCES</b> .....	24-26
<b>APPENDIX</b> <b>PRE-TEST PROBABILITY AND 10-YEAR ABSOLUTE RISK OF CORONARY</b> <b>ARTERY DISEASE (CAD)</b> .....	27
<b>NOTES TO CONSENSUS STATEMENT</b> .....	28
<b>ACKNOWLEDGEMENT</b> .....	29
<b>NOTES</b> .....	30-32



## INTRODUCTION

---

Cardiovascular disease is a conglomerate of diseases that affects the heart and the arterial system in the body. It remains the number one cause of death in developed countries. In Malaysia, between the years 2000-2004, 20-25% of death in Government hospitals is due to cardiovascular diseases [1].

Coronary artery disease (CAD) is characterised by the presence of atherosclerotic plaques in the coronary arteries. Coronary artery calcification is part of the development of these atherosclerotic plaques. These plaques progressively narrow the arterial lumen and hence impair blood flow. The reduction in coronary artery flow may be asymptomatic or symptomatic, may occur with or without exertion, and may culminate in a myocardial infarction, depending on obstruction severity and rapidity of development.

Various investigational modalities are available for the detection of CAD. These include electrocardiography, echocardiography and radionuclide imaging. Lately, there has been increasing awareness in newer imaging techniques such as Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) in diagnosing CAD.

CT as an imaging modality has been around for more than three decades. However only in the last few years, with the introduction of the multislice computed tomography (MSCT), has it allowed adequate imaging and interpretation of the status of the coronary arteries and its related structures. It is novel, in that it allows visualisation of the coronary artery lumen non-invasively. Although the gold standard for diagnosing obstructive coronary disease is still invasive coronary angiography, cardiac CT, in certain clinical situations may be an acceptable alternative [2 - 5]. Coronary calcium, a marker of plaque burden can also be quantified with this method, and to a certain extent, plaque composition can be characterised [6].

The growth and availability of MSCT services in Malaysia has been immense. Therefore, it is important for the local medical profession to understand the requirements to obtain a minimum dataset for adequate interpretation of the cardiac study, and most importantly patient selection, preparation and safety. In order to make full use of this powerful imaging tool in daily clinical practice to increase the diagnostic yield, its potential and limitations have to be understood. This document aims to outline the requirements for cardiac CT, current indications, safety, reporting and training issues in Malaysia. The committee understands that CT technology and applications are evolving rapidly, and it is only pertinent that this document will be constantly revised to parallel the developments.

## RATIONALE OF CARDIAC CT

---

Comprehensive cardiac assessment requires information on coronary vascular anatomy, cardiac morphology, function, perfusion, metabolism and tissue characterisation. At the moment, no single imaging modality is able to successfully achieve accurate global assessment of the heart, which is a difficult organ to image because of its rapid, complex, cyclical, variable rate-dependent motion and its small vessels.

Cross sectional CT imaging of the coronary arteries was first performed with the electron beam CT in 1984. However, low spatial resolution and high image noise limited the image quality. Since 1998, with the introduction of the 4-slice mechanical CT scanners and subsequently 16 and 64-slice CT scanners with higher spatial and temporal resolutions, accurate visualisation of the coronary arteries, cardiac anatomy as well as functional imaging is possible. At the time of writing, the evolving CT technology has presented us with various new developments, including dual source CT scanners as well as 320-slice CT scanners (which boast of greater anatomical coverage and shorter scan time).

Invasive imaging techniques, especially selective conventional coronary angiography, will remain vital to planning and guiding catheter-based and surgical treatment of significantly stenotic coronary lesions. However, because coronary angiography is associated with a small but not negligible risk of complications (inherent in invasive procedures), inconvenience to patients, and significant costs, coronary CT angiography (CTA) is an attractive alternative to invasive selective coronary angiography, with the potential to reduce the number of purely diagnostic angiograms. In particular, patients with intermediate likelihood of CAD may benefit from coronary CTA [7].

Cardiac CT is usually performed as a two-part examination – first, the coronary artery calcium score, and secondly, the coronary artery CT angiogram.

The calcium score measures the amount of calcified plaques in the coronary arteries as a surrogate marker for atherosclerotic disease. The majority of published studies have reported that the total amount of coronary calcium (usually expressed as the Agatston score) predicts coronary disease events beyond standard risk factors. Calcium score is useful given a negative CT test as atherosclerotic disease is less likely (negative predictive value 96-100%). In addition intermediate risk patients (10-20% 10 year Framingham Risk Score) may benefit from a calcium score by refining clinical risk prediction and selecting patients for more aggressive risk factor modification and pharmacological intervention [8, 9].

*continue to next page...*

Coronary CTA has been shown to be accurate in the detection and quantification of haemodynamically significant stenosis. Several studies have shown that the overall sensitivity is between 95%-99% and specificity 93-96% for detection of coronary artery stenosis [10 - 12]. Sensitivity, specificity, and the negative predictive value (NPV) of 64-slice MSCT per patient are approximately 97%, 79%, and 96%, respectively [13]. In addition, coronary CTA is able to display non-calcified plaque and vascular remodelling with good correlation with intravascular ultrasound [7].

The dataset obtained during the contrast enhanced coronary scans can also be processed to obtain functional information of the heart.

This document represents a joint effort between the National Heart Association of Malaysia and the College of Radiology (Malaysia) to:

1. Present a summary of existing medical literature and data on cardiac CT. As this is an emerging technology, there are still areas of uncertain significance which are being explored in current studies. The appropriate and optimal application of this technology must be individually tailored to each patient taking into account risks, benefits, cost effectiveness and availability of alternative technology.
2. Make suggestions regarding the training of physicians wishing to participate in this field. The current criteria are formulated based on prevailing practices and conditions in Malaysia with reference to accepted standard clinical practices worldwide.

## REQUIREMENTS OF CARDIAC CT

Imaging of the heart using CT demands exact performance requirements from the scanner. These requirements include:

### **(a) Minimisation of cardiac motion artifacts**

This is the most critical aspect of cardiac imaging. The coronary arteries go through a series of complex movements during the cardiac cycle. Therefore, in order to image the coronary artery successfully, a scanner with a high temporal resolution is needed. One method of achieving this is by reducing the gantry rotation time [14]. The 4-slice CT scanners have rotation times of 0.5 sec. Newer scanners have gantry rotation times of 0.42 sec or less. Currently a 64-slice CT scanner has a temporal resolution of 165 msec.

Furthermore, the artifacts from cardiac motion can be further suppressed by imaging during the quiescent phase of the cardiac cycle [14]. This can be achieved by synchronising the image acquisition and image reconstruction with the ECG signal of the patient. This is done by using cardiac gating mechanism during scanning. Two ECG gating techniques are employed, namely, prospective ECG triggering and retrospective ECG triggering.

Another method that can be employed to improve the temporal resolution is to combine projection data from consecutive cardiac cycles [14]. This is called multi-segment reconstruction and provides a significant improvement in the temporal resolution by combining data from as many as four cardiac cycles. However, this technique relies heavily on the regularity of the heart rate for its success [15].

### **(b) Minimisation of respiratory artifacts**

Cardiac CT scans are performed during a single breath-hold to minimize motion from respiration. In order to achieve this, the acquisition time for the total coverage of the heart has to be short. The acquisition time for cardiac scans using the 4-slice CT scanners ranged between 33 and 40 sec. With the introduction of 16-slice CT scanners, the acquisition time was reduced to less than 20 sec. Further reduction in acquisition time (of less than 10 sec) was achieved with the 64-slice CT scanners, further reducing the occurrence of involuntary motion artifacts from respiration and movements of the patients.

### **(c) High spatial resolution**

The epicardial coronary arteries are small with diameters ranging from 5 mm proximally to less than 1 mm distally. Imaging of these small structures requires high spatial resolution. With the introduction of the 16-slice CT scanners, the presence of submillimetre detector widths has provided significant improvement in the in-plane (x-y) resolution. The current 64-slice CT scanners have detector widths ranging between 0.5 and 0.625 mm [14].



**(d) Adequate and uniform contrast enhancement**

Poor vessel opacification is one of the factors that affects the image quality of the CT examination and renders distal vessels to be non-evaluable. Therefore, contrast injection protocol must be tailored to optimise contrast-to-noise ratio and to obtain uniform contrast enhancement. This is achieved by using contrast delivery techniques such as the automatic bolus tracking or the test bolus technique. Contrast needs to be administered via a powered contrast medium injector.

**(e) Employment of radiation dose-reduction techniques**

Managing radiation dose to the patient during a cardiac CT scan is a primary concern. Various methods for dose-reduction are available. During the scan, the tube current (mA) can be modulated to be optimum at the time of the targeted phase acquisition (usually diastolic). At other times, the tube current is kept at a nominal level. Using this technique, a dose saving of about 45% can be achieved, depending on the heart rate during the acquisition [14].

**(f) Management of large volume of image data**

Cardiac CT using submillimetre detector thickness results in a large amount of image data to be reconstructed and interpreted. This provides a challenge to the clinician in management of these data. CT scanners currently need to be equipped with software, which enable these data to be visualised in the native axial images, multiplanar reconstruction (MPR), maximum intensity projection (MIP) as well as 3D volume rendering images. In order to do this, powerful workstations are needed for image reconstruction and evaluation. Software for measurement including quantitative manual and semiautomatic tools is useful for further analysis of coronary artery stenosis [14].

In view of the above requirements, it is the recommendation of the committee that the acceptable imaging systems that can be utilised for cardiac imaging includes a minimum of a 16-slice MSCT, electron-beam CT or the dual-source CT scanner. A minimum of a 4-slice CT scanner is required for calcium scoring.

## INDICATIONS OF CCTA

As coronary computed tomographic angiography (CCTA) is a relatively new imaging modality, there is limited clinical evidence available for many indications and case scenarios for which CCTA may be useful. The committee has proposed an 'Appropriateness Criteria' championed by the American College of Cardiology Foundation [16] which blends scientific evidence and practical experience by engaging a diverse technical panel to rate each indication as appropriate or inappropriate application of CCTA. In formulating a consensus, these authors are greatly aided by the report of the American College of Cardiology Foundation Quality Strategic Directions Committee Appropriateness Criteria Working Group that included the 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 [17].

- (a) An appropriate imaging study is one in which the expected incremental information, combined with clinical judgment, exceed the expected negative consequences by a sufficiently wide margin for a specific indication that the procedure is generally considered acceptable care and a reasonable approach for that indication (negative consequences include the risks of radiation or contrast exposure and test inaccuracies).
- (b) An inappropriate test for that indication means that CCTA is not generally acceptable and is not a reasonable approach for that indication.
- (c) In many instances, CCTA may be regarded as generally acceptable or a reasonable approach for that indication but would require more research and/or patient information to classify that indication definitively. Examples of such indications are detection of CAD in patients with acute chest pain but without typical ECG or cardiac enzyme changes; patients with typical chest pain and previous bypass graft or coronary stenting procedure; and screening for CAD in the asymptomatic high-risk population; and evaluation of left ventricular function in clinical heart failure patients with technically limited images from echo.

In deliberating the appropriateness of CCTA, the committee evaluated only clinical evidence from CCTA imaging using slice collimations of less than 1.0 mm for the detection of haemodynamically significant coronary artery stenosis – usually accepted as 50% luminal stenosis or greater [8]. Any local data that is more relevant to the Malaysian population were also included [18, 19]. The

indications are for coronary imaging and calcium scoring unless otherwise specified. Provided that image quality is adequate, evaluation is performed by CCTA level 2 or 3 trained doctors (see under Section: Training), and the patients are properly chosen and prepared for the study. CCTA has been investigated and reported for the following indications:

- Detection of haemodynamically significant coronary artery disease in a heterogeneous group of patients
- Coronary stent and bypass graft patency

## APPROPRIATE INDICATIONS

---

### **Detection of CAD in patients with:**

- Chest pain and intermediate pre-test probability of CAD [20] and
  - o not suitable for exercise treadmill test (ETT)
  - o uninterpretable or equivocal functional tests (ETT, perfusion or stress echo)
  - o no ischaemic ECG changes and negative serial enzymes
- Asymptomatic and low-to-moderate cardiovascular risk [21] but positive stress ECG
- Cardiomyopathy to exclude coronary disease

### **Structure and Function Evaluation**

- Suspected coronary anomalies
- Assessment of complex congenital heart disease
- Evaluation of intra-cardiac masses and pericardial diseases in patients with technically limited images on echocardiogram, magnetic resonance imaging (MRI) or transesophageal echocardiogram (TEE)
- Evaluation of pulmonary vein anatomy prior to radiofrequency ablation for atrial fibrillation
- Coronary vein mapping prior to placement of biventricular pacemaker



## INAPPROPRIATE INDICATIONS

---

### Detection of CAD in patients with:

- Typical cardiac chest pain and high pre-test probability
- Acute chest pain, high pre-test probability demonstrating ischaemic ECG changes and/or positive cardiac enzymes
- Evidence of moderate-to-severe ischaemia on functional tests (ETT, perfusion, stress echo)

### Asymptomatic patients/population with:

- Low-to-moderate cardiovascular (CV) risk score for screening
- High CV risk but CCTA or conventional angiography was normal up to 2 years previously

### Asymptomatic patients/population without inducible ischaemia on functional tests for

- Evaluation of bypass grafts
- Evaluation of coronary stents

### CALCIUM SCORE ONLY

Recent publications suggest calcium scoring provides additional prognostic information to traditional risk scoring methods. Calcium scoring is appropriate for patients deemed at medium risk for cardiovascular events based on risk factor models. The presence of calcium and the incremental levels of coronary artery calcium score denotes higher levels of risk and hence, guides the aggressiveness of preventive therapies and target goals. This is because there is no well-defined boundaries of risk levels but instead a risk continuum relationship similar to hypertension. Calcium scoring has been shown to be independently predictive of cardiovascular risk and adds incremental prognostic information to the conventional risk factor scoring methods [22 - 24].

## REPORTING OF CARDIAC CT ANGIOGRAPHY

---

### Format

The documentation of a CTA report should include the following headings:

1. Patient demography
2. Reporting physician(s)
3. Type of examination
4. Indication for CT angiography
5. CT Hardware and acquisition protocols (scanning and contrast)
6. Need for beta-blocker or any adjunctive medications and dosage used
7. Adequacy of image quality
8. Contrast used and amount
9. Findings
10. Complication(s) if any
11. Conclusion(s)
12. Recommendations

### Reporting

The CTA volume dataset must be examined in multiple reconstruction protocols including axial, multiplanar, maximum intensity projection (MIP) [25]. Axial images are the most valuable in evaluation of the coronary arteries [7, 26]. Advanced post-processing tools e.g. 3D-Volume-rendered techniques, MIP are most accurate when viewed together with the axial data. Proper window width and level or appropriate kernel should be used to visualise structure of interest or excessive calcification, if present.

Every segment of the coronary tree needs to be examined and documented using established nomenclature. This paper proposes one model of the coronary tree segmentation (Figure 1). This would allow cross-referencing with findings during catheter angiography. It also provides standardisation in the reporting which is crucial for clinical trials and communication. Presence of non-assessable segments should be noted.

In reporting the coronary arteries, dominance, presence of variants and anomalies should be noted. Description of plaques should include segmental location, extent of disease, attenuation characteristics and degree of stenosis and presence of vessel remodelling.

Stenosis quantification is based on referencing to adjacent segment's luminal calibre rather than vessel luminal wall to outer wall diameter. Vessel cross-sectional and longitudinal views should be used for estimation [25]. Stenosis quantification can be performed by visual estimate and/or electronic callipers. Lesion severity are usually categorised as mild, moderate, severe or occluded which corresponds to stenotic severities of <50%, 50-70%, >70% and 100% narrowing. Plaque attenuation

*continue to next page...*

characteristics may be described e.g. calcified, non-calcified or mixed. Special features e.g. plaque ulceration, vessel dissection, and thrombus may sometimes be seen.

Additional information may be reported by experts if optimal images are available e.g. cardiac chambers (size, morphology), myocardium (thinning, contour change or attenuation difference), pericardium (masses, thickness, calcification, effusion) and extra-cardiac structures. Information on cardiac function and valve structures, and function may be obtained with other post-processing methods if needed.

### Bypass graft assessment

Volume-rendering technique (VRT) displays good 3D-orientation of the grafts and the target anastomotic sites [2, 27]. Venous grafts are well visualised by CTA owing to its larger size and lack of mobility. Graft disease and stenosis are reported in a manner similar to native coronary arteries. Presence of surgical clips and often dense calcification in native vessels of post-CABG patients may give rise to artifacts that make assessment rather challenging.

### Stent assessment

Limited reports are currently available on stent evaluation with MSCT [27]. The accuracy of assessment is influenced by the type and size of stents. Owing to the high attenuation from stent material, appropriate window width and level or kernels should be chosen. Intrastent filling defects owing to in-stent restenosis (ISR) / occlusion should be noted. Adequacy of stent expansion may explain the reason for restenosis.

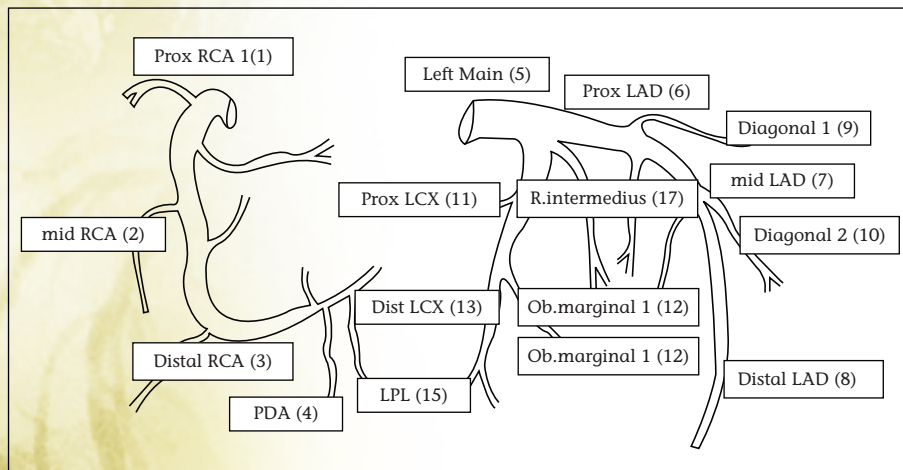


Figure 1. Modified 17-segment of the AHA reporting system [28].

## RADIATION PROTECTION IN CARDIAC CT

The major drawback of imaging of the heart using MSCT is the high radiation dose. The effective dose at coronary angiography using EBCT ranges from 1.5 to 2.0 mSv while a similar examination using 4-slice MSCT ranges from 6 to 13 mSv [29]. Recent MSCT multicentre studies have documented higher radiation doses of up to 30 mSv in day to day practice. However with dose reduction techniques such as ECG-dependent dose modulation as mentioned before, dose saving of about 45% can be achieved. In a study by Hausleiter et al, the use of ECG-dependent dose modulator resulted in a significant reduction in the effective dose estimate from  $10.6 \pm 1.2$  to  $6.4 \pm 0.9$  mSv (using 16-slice MSCT scanner) and  $14.8 \pm 1.8$  to  $9.4 \pm 1.0$  mSv (using 64-slice MSCT scanner) [30]. The new 'step and shoot' technique available in some systems today allows a 50-80% dose reduction [31].

It is imperative then that the principles of radiation exposure namely justification, limitation and ALARA (as low as reasonably achievable) should be upheld at all times. Therefore, in view of the considerable radiation doses, it is the recommendation of the committee that:

- The decision to expose a patient to cardiac CT has to be made by physicians aware of the radiation risks that will be incurred by the patient. At the time of writing, CT coronary artery angiography is not considered as a screening procedure and each patient should have justifiable indications to undergo the procedure. The use of MSCT for calcium scoring for risk stratification purposes are acceptable in clinical practice.
- The use of dose-reduction techniques should be employed whenever possible. Effective dose during cardiac CT should ideally not exceed 13 mSv [29]. Special care should be taken when imaging children and young females (as the breast would be included in the scanning field).



## SAFETY ISSUES IN CARDIAC CT

---

Safety issues in cardiac CT involve issues regarding radiation, intravenous contrast administration and administration of  $\beta$ -blockers and nitrates.

Issues regarding radiation have been mentioned before. It is important that all personnel involved in cardiac CT are aware of radiation risks and undergo basic training in radiation effects and radiation protection.

Risks with contrast media administration include adverse reactions to the contrast, its nephrotoxic properties and risk of extravasation. The supervising physician should be able to identify patients with increased risk of developing adverse reactions or in which contrast media is contraindicated. Patients with renal failure should also be identified. The physician should be well versed in treating and managing contrast media reactions.

$\beta$ -blockers are currently the preferred method to reduce heart rate. Supervising physicians should be aware of the dosage, action and the contraindications of  $\beta$ -blockers.

## TRAINING IN CARDIAC CT

---

CT is an important imaging modality for the detection and characterisation of cardiac disease; therefore it is crucial that physicians who supervise and interpret cardiac CT should have appropriate competency, experience and expertise [32].

Competencies are divided into:

1. Criteria for performing calcium scoring exclusively
2. Criteria for interpreting cardiac CT
  - (a) Level 1 competency
  - (b) Level 2 competency
  - (c) Level 3 competency

### **1. Criteria for performing calcium scoring exclusively**

Any physician such as cardiologists and radiologists who are certified from the acceptable body/board and have undergone training which includes cardiac anatomy and experience with training in interpretation of cross sectional imaging are qualified to interpret coronary artery calcium scoring [32].

### **2. Criteria for interpreting cardiac CT**

Physicians should have adequate knowledge and understanding of the anatomy, physiology and pathophysiology of the cardiac systems for cardiac CT interpretation.

#### **(a) Level 1 competency**

This is defined as the minimal introductory training for familiarity with CCTA but is not sufficient for independent interpretation of the CCTA studies [33, 34]. The trainee should have been actively involved in CCTA interpretation under the direction and supervision of a qualified level 2 or 3 mentor.

The trainee should undergo mentored interpretation of at least 25 cases of CTA with contrast (of which a minimum of 10 cases should be in correlation with conventional coronary angiography). Studies may be taken from an established teaching file or previous CCT cases. Trainees are required to provide proof of training (e.g. verified log book, letter of certification by a qualified level 2 or 3 mentor).

#### **(b) Level 2 competency**

This is defined as the minimum level of training for a doctor to independently perform and interpret CCTA [33, 34]. This is intended for individuals who wish to

*continue to next page...*

practise or be actively involved with CCTA. The doctors at this level should have sufficient training to interpret the CT examination accurately and independently.

The trainee should undergo mentored interpretation of at least 75 cases of CCTA, of which the trainee must perform at least 15 cases under supervision of a qualified level 2 or 3 mentor. A minimum of 25 should be correlated with coronary angiography. Studies may be taken from an established teaching file or previous CCTA cases.

The trainee should also undergo training in advanced anatomy, contrast administration, principles of 3 dimensional imaging/post processing, principles of radiation protection and its hazard to patients and personnel and appropriate post procedural patient monitoring.

Trainees are required to provide proof of training (e.g. verified log book, certificate of attendance, letter of certification by a qualified level 2 or 3 mentor)

### **(c) Level 3 competency**

This represents the highest level of expertise that would enable an individual to serve as a director of a cardiac CT centre [33, 34]. This person would also be directly responsible for quality control and training of radiographers.

This requires a further minimum cumulative training period of 6 months after completion of level 2 training. Trainee should interpret at least 150 cases of CCTA. The cases reflect the broad range of pathology expected in cardiac imaging. The trainee must be involved in performing at least 75 cases and ongoing participation in quality assurance and safety programmes as well as be involved in research activities. Studies may be taken from an established teaching file or previous CCTA cases.

Trainees are required to provide proof of training (e.g. verified log book, certificate of attendance, and letter of certification by a qualified level 3 mentor)

## **TRAINING REQUIREMENTS FOR RADIOGRAPHERS**

CT radiographers should possess a diploma in radiography, or any equivalent radiography qualifications recognised by the Ministry of Health Malaysia or Society of Radiographers Malaysia.

It is encouraged that the radiographers performing the cardiac CT have advanced certification in at least post basic CT. The radiographers must also be able to prepare, position, ensure patient safety, monitor the patient, apply the contrast injection and scanning protocol as prescribed by supervising doctors. They should also perform regular quality control testing [32].

If the radiographer does not have an advance certification in CT, a minimum of 3 months full time CT training is required under the supervision of a suitably trained CT radiographer and radiologist before being allowed to operate a CT scanner independently. Radiographers are encouraged to keep a log book of the number of CT cases performed.

The radiographer should also have adequate Continuous Professional Development (CPD) on CCTA related topics (at least attend one conference/workshop/course every 2 years).

CT scanners should not be operated by any person without the above stated qualifications e.g. medical physicists, technicians, research staff, post doctorate fellows, nurses and any other non-radiological qualified staff.

Intravenous contrast materials can be administered by radiographers and nurses under the direction of supervising doctors, if the practice is in compliance with institutional regulations.



## EXTRACARDIAC FINDINGS OF CORONARY CTA

---

CT scans performed for cardiac evaluation includes visualisation of extracardiac structures within its scan range. The importance of this is two-fold. Firstly, some of the risk factors for CAD such as smoking, male sex, and age overlap with the risk factors for other chest diseases such as bronchial carcinoma [35].

Secondly, chest pain is not unique to cardiac disease, and may be a result of other chest pathology [36, 37].

With the same raw data, at no additional radiation exposure to the patient, reconstructions of the images into a larger field of view allow visualisation of the lung and chest wall at the level of the scan. Dedicated coronary artery CT focused on the heart displays 35.5% of total chest volume, while images reconstructed at maximal field of view visualises 70.3% [35].

Studies have shown that cardiac CT demonstrated significant number of previously unknown extracardiac findings, some of which had an immediate impact on workup, follow up or both. The incidence of extracardiac findings ranged from 7.8 to 58.1% [37, 38]. The extracardiac findings that required some form of therapy was 3 to 5% [35, 37]. These included pulmonary embolism, bronchogenic carcinoma, liver tumours and congenital anomalies. Evaluation of extracardiac structures should be performed by a radiologist.

However, cardiac scans have a small field of view restricted to the heart which precludes a complete evaluation of the thorax. Therefore both patients and referring physicians have to understand that the focus of the cardiac CT is for the detection of cardiac diseases.

## REFERENCES

---

1. Number of discharges and deaths due to circulatory system by age and sex. Information and Documentation System Unit. Annual Report, Ministry of Health Malaysia. 2004
2. Achenbach S. Computed Tomography coronary angiography. *J Am. Coll Cardiol* 2006;48:1919-1928
3. Nieman K, Cademartiri F, Lemos PA, et al. Reliable non-invasive coronary angiography with fast submillimeter multislice spiral Computed Tomography. *Circulation* 2002;106:2051-4
4. Raff GL, Gallagher MJ, Oneill WW, et al. Diagnostic accuracy of non-invasive angiography using 64-slice spiral computed tomography. *J Am Coll Cardiol* 2005;46:552-7
5. Achenbach S, Ropers D, Kuettner A, et al. Contrast enhanced coronary artery visualization by dual source computed tomography. *Eur J Radiol* 2006;57:331-5
6. Leber AW, Becker A, Knez A, et al. Accuracy of 64-slice computed tomography to classify and quantify plaque volumes in the proximal coronary system: a comparative study using intravascular ultrasound. *J Am Coll Cardiol* 2006;47:672-7
7. Hoffmann U, Ferencik M, Cury RC, et al. Coronary CT Angiography. *J Nucl Med* 2006; 47:797-806
8. Budoff MJ, Achenbach S, Blumenthal RS, et al. Assessment of coronary artery disease by cardiac computed tomography: a scientific statement from the American Heart Association Committee on Cardiovascular Imaging and Intervention, Council on Cardiovascular Radiology and Intervention, and Committee on Cardiac Imaging, Council on Clinical Cardiology. *Circulation* 2006; 114: 1761-91
9. Greenland P, Bonow RO, Brundage BH, et al. American College of Cardiology Foundation/ American Heart Association 2007 clinical expert consensus document on coronary artery calcium scoring by computed tomography in global cardiovascular risk assessment and in evaluation of patients with chest pain. *J Am Coll Cardiol* 2007; 49:378-402
10. Mollet NR, Cademartiri F, van Mieghem CA et al. High-resolution spiral computed tomography coronary angiography in patients referred for diagnostic conventional coronary angiography. *Circulation* 2005; 112: 2318-2323
11. Ropers D, Rixe J, Anders K et al. Usefulness of multi-detector row computed tomography with 64 x 0.6mm collimation and 330 ms rotation for the non invasive detection of significant coronary artery stenoses. *Am J Cardiol* 2006; 97: 343348
12. Fine JJ, Hopkins CB, Ruff N, et al. Comparison of accuracy of 64-slice cardiovascular computed tomography with coronary angiography in patients with suspected coronary artery disease. *Am J Cardiol* 2006; 97:173-174

## REFERENCES

13. Nikolaou K, Knez A, Rist C, et al. Accuracy of 64MDCT in the diagnosis of ischaemic heart disease. *AJR* 2006; 187:111-117
14. Vembar M, Walker M, Johnson P. Cardiac Imaging using Multislice Computed Tomography Scanners: Technical Considerations. *Coronary Artery Disease* 2006; 17:115-123
15. Flohr T, Schaller S, Stierstorfer K, et al. Multi-detector Row CT Systems and Image-Reconstruction Techniques. *Radiology* 2005; 235:756-773
16. Patel MR, Spertus JA, Brindis RG, et al. ACCF proposed method for evaluating the appropriateness of cardiovascular imaging. *J Am Coll Cardiol* 2005;46:1606-13
17. Hendel RC, Patel RM, Kramer CM, et al. ACCF/ACR/SCCT/SCMR/ASNC/NASCI/SCAI/SIR 2006 Appropriateness Criteria for Cardiac Computed Tomography and Cardiac Magnetic Resonance Imaging. *J Am Coll Cardiol* 2006;48:1475-97
18. Ong TK, Chin SP, Sim KH, et al. Accuracy of 64-row Multi-detector computed tomography in detecting coronary artery disease in 134 symptomatic patients: influence of calcification. *Am Heart J*. 2006;151(6):1323e1-1323e6
19. Sim KH, Ong TK, Chin SP, et al. Computed Tomography Scan for Cardiac Intervention. *Indian Heart J*. 2007;59:B25-32
20. Gibbons RJ, Balady GJ, Bricker JT, et al. ACC/AHA 2002 guideline update for exercise testing: summary article. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Update the 1997 Exercise Testing Guidelines). *J Am Coll Cardiol* 2002; 40:1531-40
21. Grundy SM, Pasternak R, Greenland P, et al. ACC/AHA scientific statement: assessment of cardiovascular risk by use of multiple-risk-factor assessment equations: a statement for healthcare professionals from the American Heart Association and the American College of Cardiology. *J Am Coll Cardiol* 1999; 34:1348-59
22. Agatston AS, Janowitz WR, Hildner FJ, et al. Quantification of coronary artery calcium using ultrafast computed tomography. *J Am Coll Cardiol* 1990;15:827-32
23. Detrano R, Guerci A, Carr J, et al. Coronary Calcium as a Predictor of Coronary Events in Four Racial or Ethnic Groups. *N Engl J Med* 2008; 358(13):1336-1345
24. Budoff M, Shaw L, Liu S, et al. Long-Term Prognosis Associated with Coronary Calcification. Observations from a Registry of 25,253 Patients. *J Am Coll Cardiol* 2007; 49:1860-1870
25. Cury RC, Ferencik M, Achenbach S, et al. Accuracy of 16-slice multi-detector CT to quantify the degree of coronary artery stenosis: Assessment of cross-sectional and longitudinal vessel reconstructions. *Eur J Radiology* 2006; 57(3): 345-350

## REFERENCES

26. Achenbach S. Coronary CT angiography: A cardiologist's perspective. *Suppl to Applied Radiology* 2005; 22-32
27. Soon KH, Kelly AM, Cox N et al. Non-invasive multislice computed tomography coronary angiography for imaging coronary arteries, stents and bypass grafts. *Intern Med J* 2006; 36:43-50
28. Austen WG, Edwards JE, Frye RL, et al. A reporting system on patients evaluated for coronary artery disease. Report of the Ad Hoc Committee for Grading of Coronary Artery Disease, Council on Cardiovascular Surgery, American Heart Association. *Circulation* 1975; 51:5-40
29. Hunold P, Vogt FM, Schmermund A, et al. Radiation Exposure during Cardiac CT: Effective doses at Multi-detector Row CT and Electron-Beam CT. *Radiology* 2003; 226:145-52
30. Hausleiter J, Meyer T, Hadamitzky M, et al. Radiation Dose Estimates From Cardiac Multislice Computed Tomography in Daily Practice. *Circulation* 2006; 113:1305-1310
31. Hsieh J, Londt J, Vass M, et al. Step-and-shoot data acquisition and reconstruction for cardiac x-ray computed tomography. *Med Phys* 2006; 33(11): 4236-48
32. Weinreb JC, Larson PA, Woodard PK, et al. American College of Radiology Clinical Statement on noninvasive cardiac imaging. *Radiology* 2005; 235 (3): 723-7
33. College of Physicians and College of Radiologists Joint Writing Committee, Thye HK, Han KB, Chen K et al. Guidelines on Cardiac CT in Singapore (2006). *Ann Acad Med Singapore* 2006; 35(4): 287-96
34. Budoff MJ, Achenbach S, Fayad Z, et al. Task Force 12: Training in advanced cardiovascular imaging (computed tomography). *J Am Coll Cardiol* 2006; 47:915-20
35. Haller S, Kaiser C, Buser P, et al. Coronary artery imaging with contrast-enhanced MDCT: Extracardiac findings. *AJR* 2006; 187:105-110
36. Romey A, Ross MA, Gallagher M, et al. Non-cardiac findings by multislice computed tomographic angiography aid patient diagnosis. *Acad Emerg Med* 2006;13 (Supplement 1): S189-S190
37. Onuma Y, Tanabe K, Nakazawa G, et al. Non-cardiac findings in cardiac imaging with multi-detector computed tomography. *J Am Coll Cardiol* 2006;48:402-406
38. Horton KM, Post WS, Blumenthal RS, et al. Prevalence of significant noncardiac findings on electron-beam computed tomography coronary artery calcium screening examinations. *Circulation* 2002; 106: 532-534



## APPENDIX

### PRE-TEST PROBABILITY AND 10-YEAR ABSOLUTE RISK OF CORONARY ARTERY DISEASE (CAD)

#### Pre-Test Probability

The Pre-test Probability estimates the likelihood of coronary artery disease (defined as presence of angina pectoris, recognised and unrecognised myocardial infarction, unstable angina, and CHD deaths) for any given patient based upon the type of presenting symptoms, age and gender. The risk generally increases with age.

**Table: Pre-test Probability of Coronary Artery Disease by Age, Gender and Symptoms (Reproduced from ACC/AHA 2002 Guideline Update for Exercise Testing) [20].**

Age(yrs)	Typical/Definite Gender	Atypical/Probable Angina Pectoris	Nonanginal Angina Pectoris	Chest Pain	Asymptomatic
30-39	Men Women	Intermediate Intermediate	Intermediate Very Low	Low Very Low	Very Low Very Low
40-49	Men Women	High Intermediate	Intermediate Low	Intermediate Very Low	Low Very Low
50-59	Men Women	High Intermediate	Intermediate Intermediate	Intermediate Low	Low Very Low
60-69	Men Women	High High	Intermediate Intermediate	Intermediate Intermediate	Low Low

**High:** Greater than 90% pre-test probability;

**Intermediate:** Between 10% and 90% pre-test probability;

**Low:** Between 5% and 10% pre-test probability;

**Very Low:** Less than 5% pre-test probability.

#### Coronary Artery Disease (CAD) Risk

The risk of developing coronary artery disease during a 10-year period may be calculated from a multifactorial equation recommended by, and summarised in the AHA/ACCF Joint report, ACC/AHA Scientific Statement: Assessment of Cardiovascular Risk by Use of Multiple-Risk-Factor Assessment Equations [21]. The equation takes into account gender, age, total cholesterol, HDL Cholesterol, smoking history, presence of left ventricular hypertrophy and diabetes. For example, Low-risk level is defined in the Framingham Report as the risk of coronary heart disease (CHD) at any age for a non-smoker, non-diabetic, with blood pressure less than 120/80 mmHg, total cholesterol of 4.0-5.0 mmol/L, LDL-C 2.5-3.2 mmol/L, and HDL-C greater than or equal to 1.13 mmol/L in men and greater than or equal to 1.39 mmol/L in women.

**Low Risk:** 10-year absolute risk of less than 10%; generally risk is below age-specific risk level.

**Medium risk:** 10-year absolute risk 10 to 20%; risk is average or above average of age specific risk level.

**High Risk:** Presence of Diabetes Mellitus or 10-year absolute risk greater than 20%.

## NOTES TO CONSENSUS STATEMENT

#### Use of words physician, doctor, radiologist and cardiologist in this document:

Physician refers to any medically trained doctor from recognised institutions and registered with the Malaysian Medical Council. A doctor is synonymous with a physician in this document. A radiologist or cardiologist, if specified would refer to a medical doctor/physician who has received the recognised training in the specialty of radiology and cardiology respectively.

## ACKNOWLEDGEMENT

1. Ministry of Health Malaysia
2. National Heart Association of Malaysia
3. College of Radiology, Academy of Medicine of Malaysia

## NOTES

[illegible]



[illegible][illegible]