

The Clinical Benefits of 320-Row CT in the Emergency Department

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Introduction

Diagnosis and investigation of patients who present to the emergency department with chest pain continues to be a difficult problem despite technological advances and improved availability of new investigative techniques. This is unfortunate because clinical history and physical examination, although suggestive, are not definitive for myocardial ischemia in most patients. In the USA alone there are more than six million patients who present to the emergency services with chest pain related emergencies. The cost of chest pain triage and management has been estimated to be as high as \$8 billion annually, with most of those

patients ultimately not having acute coronary syndrome (ACS)¹.

In 2006, coronary heart disease (CHD) cost the healthcare system in the UK around £14.4 billion. There are 94,000 deaths from CHD in the UK each year². It is the most common cause of death in the UK. 20–40% of all medical admissions are for acute chest pain^{3,4}. In our hospital there are approx. 8,000 emergency department attendances with chest pain per year equating about 25 admissions per day with approx. 75% being admitted. 35% of these patients reattend with similar symptoms within a 12 months period.

In our current investigation pathway patients who present with chest pain are typically risk stratified with an appropriate history and physical, and ECG, chest X-ray and laboratory studies including cardiac biomarkers. However unfortunately these investigative tests have several limitations: ECG is diagnostic of acute myocardial infarction in only 40%–65% of patients⁵. Serum markers for myocardial necrosis detect only approx. 70% of patients with acute myocardial infarction on arrival⁶. Because of this diagnostic difficulty physicians have a low threshold for admitting patients with chest pain in whom the diagnosis is not immediately clear. Approximately 65% of these patients

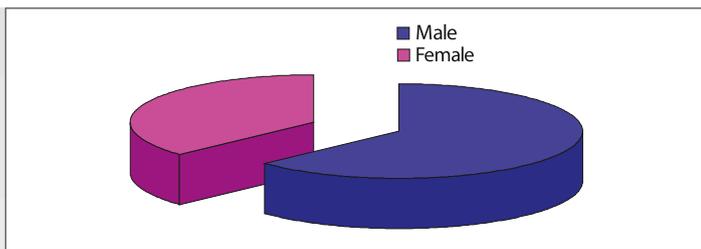


Fig. 1

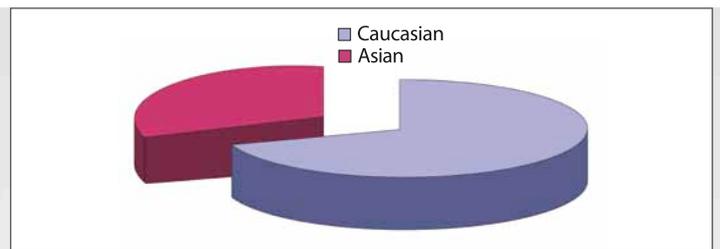


Fig. 2

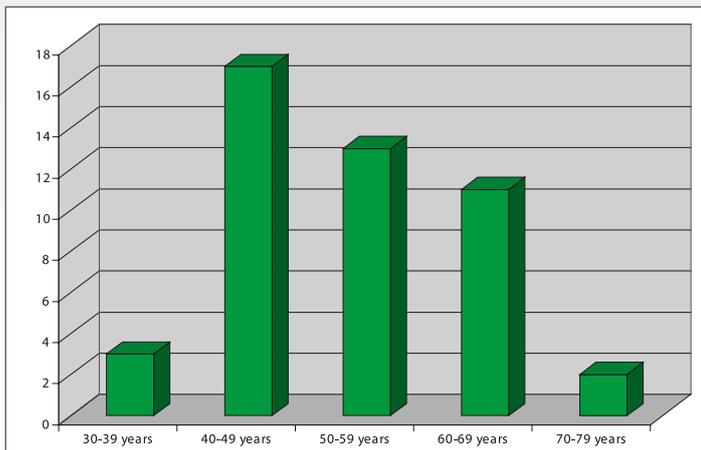


Fig. 3

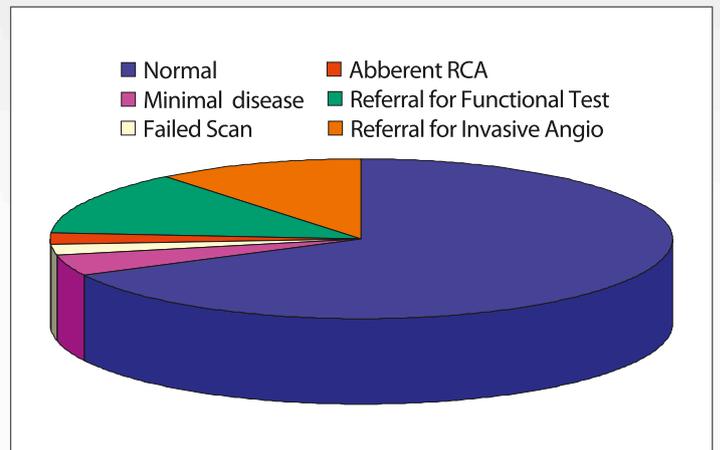


Fig. 4

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however have an eventual diagnosis of non-cardiac chest pain.

One risk stratification tool that is widely used in emergency departments is the Thrombosis in Myocardial Infarction (TIMI) risk score that predicts the triple endpoint of death, new or recurrent myocardial infarction (MI), or need for urgent target vessel revascularization within two weeks of presentation. The TIMI risk score includes:

- Age > 65 years
- History of known coronary artery disease (documented prior coronary artery stenosis > 50 %)
- >3 conventional cardiac risk factors (age, male, sex, family history, hyperlipidemia, diabetes mellitus, smoking, obesity)
- Use of aspirin in the past 7 days
- ST-segment deviation (persistent depression or transient elevation)
- Increased cardiac biomarkers (troponins)
- >2 anginal events in the preceding 24 h

One point is recorded for each of the above characteristics. The score is the total number of points.

The low-risk group is defined by a score of 0 or 1 and a <5 % likelihood of requiring intervention. The high-risk group is defined by a score of 6 or 7

and a 40 % likelihood of = requiring intervention. This approach has been validated in a number of additional trials.

Currently in our hospital patients in the low to intermediate risk group undergo serial ECGs; cardiac enzymes and troponins and then have a further investigation: exercise tolerance test (ETT), myocardial perfusion scintigraphy, stress MRI or invasive angiography. The decision as to which of these investigations is performed next will depend upon the clinical risk profile and the degree of suspicion that the underlying chest pain will be cardiac in nature. All patients will however have some form of further investigation with an OP ETT being the most common further investigation undertaken if the patient is well and other basic tests are negative.

Change in practice

Developments in cardiac CT have offered the opportunity to change practice and to increase the diagnostic accuracy with which coronary artery disease is diagnosed at the point of first contact. There is now a significant amount of evidence to show that cardiac CT is a better test than other available tests:

1) The NICE Assessment Report reviewed 21 studies with 100 or more patients that evaluated the sensitivity and specificity of both SPECT

and stress ECG (ETT) in the diagnosis of coronary artery disease compared with invasive coronary angiography.

Median sensitivity values for SPECT were higher than those for ETT in all studies (SPECT: 81 % for the largest subcategory of studies, with a range of 63–93 %; ETT: 65 % for the largest subcategory of studies, with a range of 42–92 %). Median specificity values were similar for SPECT (65 %, range 10–90 %) and ETT (67 %, range 41–88 %).

American College of Cardiologists / American Heart Association Task Force guideline, with average sensitivity and specificity reported as 89–90 % and 70–76 %, respectively for SPECT. This demonstrates that both nuclear medicine SPECT imaging and stress exercise tolerance test imaging are suboptimal in the diagnosis of coronary artery disease.

2) Cardiac CT angiography is now sufficiently robust to be used routinely for a number of clinical applications. More than 16 published studies have compared 64-slice MDCT with coronary angiography for the detection of coronary artery stenoses. These papers, which together draw on data from 1400 patients, conclude that on average 95 % of all coronary segments are fully accessible and can be com-

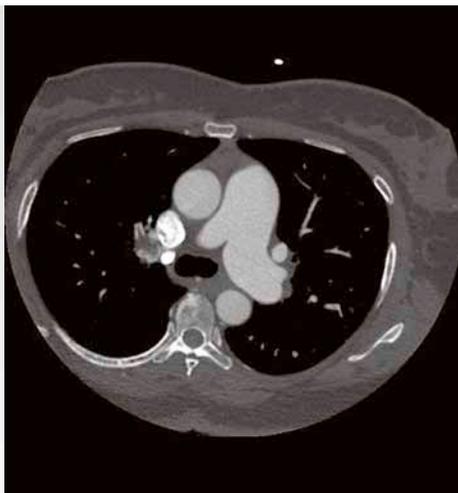


Fig. 5: Right main pulmonary artery embolus



Fig. 6: Left lung – segmental artery embolus



Fig. 7: Acute bronchiolitis – apical segment left lower lobe changes

pared to cardiac catheter findings. Sensitivity, specificity, and positive and negative predictive values have been reported as 85%, 96%, 85%, and 96%, respectively^{7,8,9,10}.

3) A head-to-head comparison between stress ECG and cardiac CT showed CT to have a significantly higher sensitivity (91% versus 73%) and specificity (83% versus 31%). CT was unable to assess 8% of patients, while stress ECG failed to evaluate 19% of study subjects¹¹.

4) More recently, Goldstein et al performed a randomized trial in 197 patients with acute chest pain at low risk for ACS presenting to the ED and compared the safety, diagnostic efficiency, and cost of 64-MDCT with the standard of care diagnostic evaluation.

Physicians using multidetector CT were able to immediately exclude or identify coronary disease as the source of chest pain in 75% of patients. The remaining 25% of patients required stress testing because of intermediate severity lesions or nondiagnostic scans.

The patients who underwent multidetector CT had a safety profile (no adverse coronary events for 6 months) equal to that of patients treated with the standard of care approach.

Initial evaluation with multidetector CT reduced

diagnostic time to an average of 3.4 hours compared with an average of 15 hours with a standard of care evaluation.

Average cost per patient was lowered from \$1872 to \$1586 when the multidetector CT algorithm was used.

Patients in the multidetector CT arm of the study also required fewer subsequent evaluations for recurrent chest pain.

5) In March 2010 new guidelines by the National Institute for Health and Clinical Excellence (NICE) were published, Chest pain of recent onset: Assessment and diagnosis of recent onset chest pain or discomfort of suspected cardiac origin. According to these guidelines in patients with suspected angina where there is an estimated likelihood of coronary artery disease of 10–29% calcium scoring / cardiac CT are the “first-line diagnostic investigations”.

6) There is also evidence that a “better” CT scanner means better images. A study presented at RSNA in 2008 analyzing the diagnostic performance of scanners with different numbers of rows of detectors showed a significant improvement in accuracy¹².

Image quality was rated poor for the following percentages of coronary artery segments:

33.1% at four-slice CT, 14.4% at first-generation 16-slice CT, 6.3% at second-generation 16-slice CT, and 2.6% at 64-slice CT.

Sensitivity, specificity, PPV and NPV, respectively, were as follows: 57%, 91%, 60%, and 90% at four-slice CT; 90%, 93%, 65%, and 99% at first-generation 16-slice CT; 97%, 98%, 87%, and 100% at second-generation 16-slice CT; and 99%, 96%, 80%, and 100% at 64-slice CT.

So there is good evidence now that ETT has poor sensitivity in the detection of coronary artery disease and that cardiac CT is more sensitive than ETT; more sensitive and specific than SPECT with a considerably lower dose profile and cost; has the potential for cost and time savings – and ought to be the new first-line investigation in the low /intermediate risk group.

In addition better scanners appear to be of greater diagnostic performance.

The purpose of our study was therefore to determine how to integrate this new technology into our chest pain pathway. Heart of England NHS Foundation Trust is the first UK institution to offer volume cardiac CT (VCCT) scanning of chest pain admissions via the accident and emergency department. We present data from the first 3 months of this trial novel chest pain management pathway.

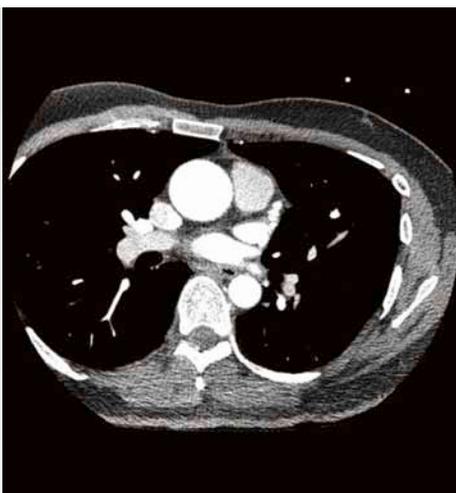


Fig. 8: Dilated ascending aorta measuring 4.2 cm in diameter

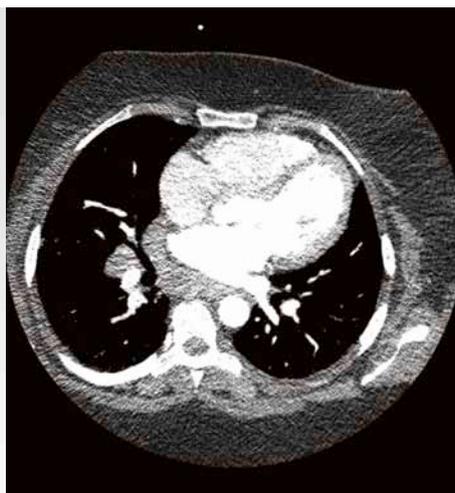


Fig. 9: Active sarcoid – subcarinal and right hilar lymphadenopathy is demonstrated



Fig. 10: Active sarcoid – peripheral nodules (arrow)

Methods and materials

All patients presenting via the accident and emergency department in whom there was a strong clinical suspicion of coronary artery disease and who met strict inclusion and exclusion criteria were potentially eligible to have a VCCT.

Inclusion criteria

- Strong clinical suspicion of angina
- No acute ECG changes
- Negative troponin (initial)
- No known history of coronary artery disease
- Age < 70 years and > 35 years (male), > 40 years (female)
- BMI < 38
- TIMI Score of low or intermediate - < or = 4

Exclusion criteria

- Positive troponin
- ECG changes
- Creatinine eGFR < 40
- Known coronary artery disease
- Severe asthma/aortic stenosis/LVF

All patients initially underwent standard investigations for chest pain: history; examination; bloods including cardiac enzymes and troponin T; and an ECG. If all these investigations were negative but there was still a suspicion that the pain was cardiac

in origin the patient was eligible for a VCCT.

Patients were given an OP appointment to return for a VCCT rather than the existing protocol of having an OP ETT.

All cardiac CTs were carried out with a Toshiba Aquilion ONE CT scanner. A volume cardiac CT was performed on this 320-row CT system which allows up to 16 cm of z-coverage which means that the whole heart can be imaged in a single, non-helical rotation (0.35 s). Patients were positioned on the couch supine, with head first and were asked to hold their breath for approximately 3–4 s for the duration of the scan. The scan was optimized by attempting to reduce the patient's heart rate using the IV β -blocker metoprolol. It was titrated up in 10 ml aliquots as required in order to reduce the heart rate to below 65 beats per minute (bpm). β -blockers however were avoided in patients with one or more of the following contraindications:

- Asthma
- Sinus bradycardia
- Hypotension: BP < 90 systolic
- Overt heart failure
- Cardiogenic shock
- 2nd or 3rd degree block
- Right ventricular failure secondary to pulmonary hypertension

Further image optimization was performed by using 500 micrograms of sublingual GTN.

70 mls of Optiray 350 strength contrast was used. A variable sliding scale of kV and mA is used depending on the patient's BMI. The purpose of using a sliding scale is to obtain the best quality images while giving the patient the lowest dose. For patients with a BMI < 28, a 100 kV technique is used while patients with BMI of 28–35 use a 120 kV technique and patients with BMI > 35 use a 135 kV technique.

The scan is triggered by bolus tracking of contrast in the ascending aorta. A dual injector is used with an initial 100 mls of 350 mg/ml iodine concentration contrast at a rate of 5 ml/s followed by a 15 ml saline chaser at the same rate. This is injected via a 21G cannula sited in the right antecubital fossa. When attenuation within the ascending aorta is at the level of 180 HU the VCCT is initiated after a breath-hold command.

Reconstructions were performed at 75% of the R-R interval and then 3% above and below this level allowing for analysis of 3 sets of data. Data was reconstructed at a slice thickness of 0.5 mm. Reconstruction of the width of the chest covered using a lung kernel was also performed. Data was

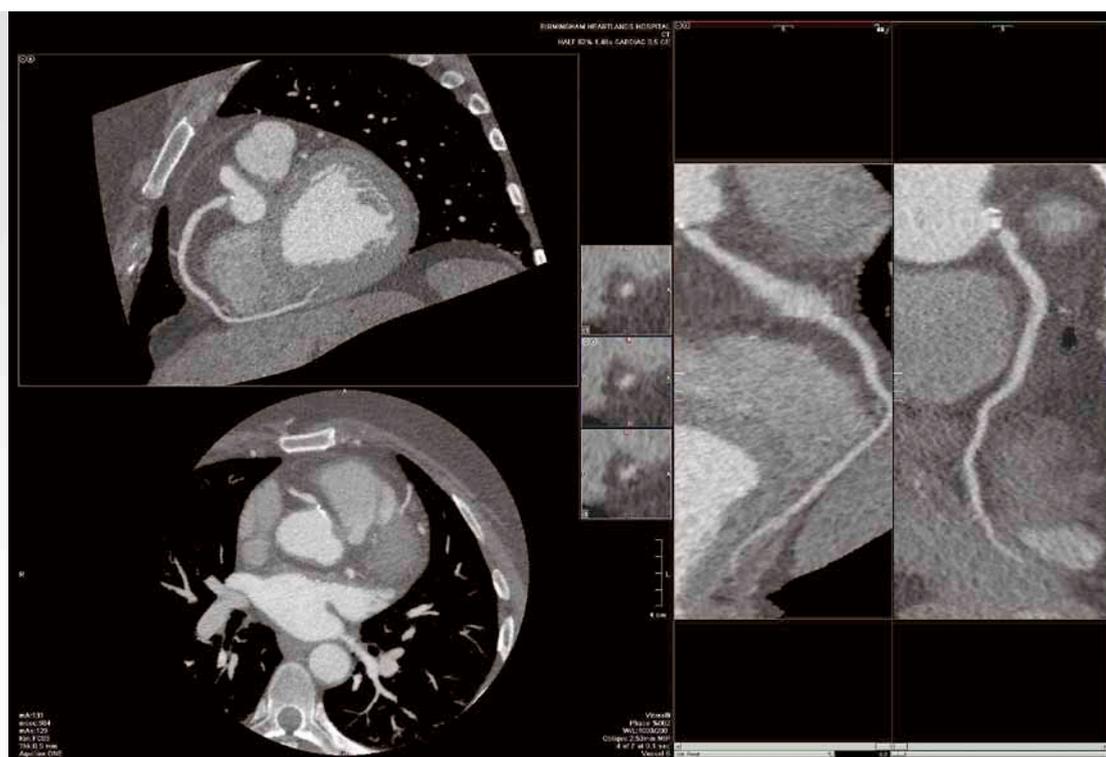


Fig. 11: Cardiac CT image demonstrating an ostial RCA stenosis

transferred to a Vitrea workstation and was analyzed by a consultant cardiothoracic radiologist.

Results

46 patients in total were referred from the accident and emergency department and underwent a VCCT. Of these 63% were male and 37% were female (Fig. 1). 70% were Caucasian and 30% were of south Asian origin (Fig. 2). Average age was 61 years. Age distribution is shown in Figure 3. The results of the VCCTs are shown in the following table:

Normal	31
Minimal disease	2
Failed scan	1
Aberrent RCA	1
Referral for functional test	6
Referral for invasive angio	5

Significant coronary artery disease (normal/minimal disease) was excluded in 72% (Figure 4). However an alternative pathology was identified in 7 of the patients in this group. These included:

- Pulmonary emboli (Figures 5, 6)
- Acute bronchiolitis (Figure 7)
- Dilated cardiomyopathy
- Dilated ascending aorta approx. 4.2 cm (Figure 8)
- Active sarcoidosis (Figure 9, 10)

- Bronchiectasis
- AVMs

Six patients with mild or mild-moderate disease, the functional significance of which was uncertain, were referred for functional testing. In this group:

- 1 patient had a normal exercise tolerance test, i.e. non-functional stenosis, and was managed medically
- 1 patient had a normal stress MRI, i.e. non-functional stenosis, and was managed medically
- 2 patients were reviewed in clinic and it was decided to try medical management
- 2 patients did not attend for follow up

Five patients with severe/moderate to severe disease or with heavy calcified atherosclerotic plaque that made interpretation of the cardiac CT difficult were referred for invasive angiography. In this group:

- 2 patients had disease confirmed and underwent angioplasty (Figures 11–15)
- 1 patient had disease confirmed and was listed for a coronary artery bypass graft (CABG)
- 2 patients had disease overestimated by cardiac CT and it was decided to initially try medical management

Conclusion

72% had no coronary artery disease and were

therefore given a definitive diagnosis of no CAD. There were no readmissions at the 6 months follow-up which shows:

- cardiac CT is a robust accurate test with a high negative predictive value
- by giving a definitive diagnosis it reduces unnecessary representation to A&E

Of these, however, 21% had some other, frequently significant pathology to explain their presenting symptoms, including pulmonary embolus, aortic dissection, acute bronchiolitis, active sarcoid. These life threatening pathologies would not be identified on other “cardiac” tests. Thus VCCT allows for identification of alternative pathologies to explain the patients symptoms which other tests such as ETT, MIBI, stress MRI and invasive angiography would miss.

13% had mild or moderate disease and were referred for functional testing, that is ETT. Of these no patients progressed to angiography, i.e. the test was considered “normal”. Previously these patients would have been discharged with a diagnosis of non-anginal pain, i.e. no CAD. However cardiac CT has shown that they all have CAD which although not functionally significant requires lifestyle modification and secondary prevention. This certainly will have a public health benefit.

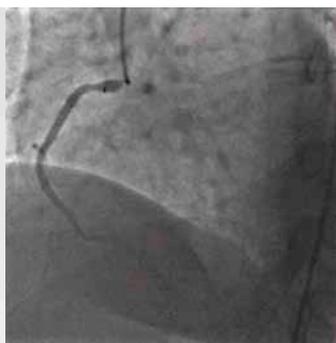


Fig. 12: Invasive angiogram image confirming RCA ostial stenosis

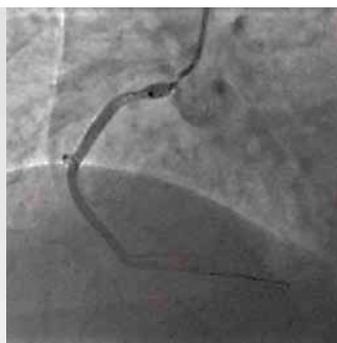


Fig. 13: Invasive angiogram image confirming RCA ostial stenosis



Fig. 14: Invasive angiogram image showing angioplasty and stent insertion

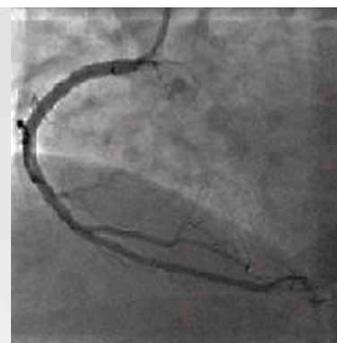


Fig. 15: Invasive angiogram post procedural image shows a good result

11 % had severe disease and went onto invasive angiography of which 7 % underwent revascularisation (2 angioplasty and stent and 1 CABG). Again the other 4 % need lifestyle modification and secondary prevention and again this will have a public health benefit.

VCCT, therefore, has been shown to be a low dose test which, when available in the emergency department, can give a definitive diagnosis of coronary artery disease. The test has a negative predictive value of close to 100 %. Since it identifies non-functionally significant coronary artery disease there are likely to be benefits to the health economy in general through preventative measures. The other potential benefit of VCCT offered as a first-line investigation is the fact that it obviates the need for an overnight bed stay or for a serial cardiac enzymes/troponin. This would significantly reduce cost and patient inconvenience.

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