Non-invasive imaging of the coronary arteries by CT for excluding significant coronary stenoses in patients requiring aortic valve replacemennt

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Abstract

It is routine practice to evaluate the coronary arteries in patients with aortic valve disease in whom valve replacement is being planned. This is presently done invasively by x-ray coronary angiography (ICA). CT coronary angiography (CTA) provides good visualisation of the proximal/mid courses of the epicardial vessels with fewer complications and lower cost.

Thirty one patients with aortic valve disease were studied by both ICA and CTA as a prelude to aortic valve replacement. Results were analysed for six pre-specified proximal/mid course segments (AHA classification) and grouped into individual coronary arteries. The sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) for detection of a stenosis of 70% that required a bypass graft at the time of surgery were 82%, 81%, 30% and 98% respectively. After grouping vessel segments into individual coronary arteries the following indicators were obtained: sensitivity: 100%; specificity: 80%; PPV: 37%; NPV: 100%. PPV increased further (69%) for detection of any graftable disease.

Conclusion: CTA is sufficiently sensitive to exclude a stenosis of 70% in the proximal/mid course of the 3 epicardial coronary arteries in patients with aortic valve disease and would therefore be an effective screening tool in this group of patients.

Introduction

It is standard practice to assess the coronary arteries in patients with aortic valve disease (AVD) in whom surgery is planned. The current method for doing this is with an invasive coronary angiogram (ICA). Whether combined aortic valve replacement and coronary artery bypass grafting is essential in all patients is a subject of debate but it is generally agreed that patients with aortic valve disease who have a stenosis of >70% in the proximal or mid-course of one of the epicardial coronary arteries should have a bypass graft to that territory at the time of aortic valve replacement (AVR)[1]. This is particularly important if the stenosis is in the left main or left anterior descending artery. ICA is associated with higher procedural complications in patients with AVD[2] and in some patients images are suboptimal. The prevalence of coronary disease in patients undergoing AVR is generally considered to increase with age being estimated at >50% in patients over 70 years of age and >65% in subjects over 80. However there remains across all age groups a significant number of patients who are free of obstructive coronary disease.

Multislice computed tomography (MSCT) is an emerging non-invasive tool for the visualisation of the coronary arteries. Despite advances in scanner design it is still hampered by an inability to image the distal coronary artery segments. Therefore it has not yet become an accepted alternate clinical modality for routine imaging of the coronary arteries in patients with angina and chest pain. However the proximal and mid courses of the epicardial coronary arteries are seen well in most patients and it is significant stenoses in these segments of the coronary arteries that are of clinical relevance in patients requiring AVR.

The purpose of the study was to evaluate the ability of MSCT to visualise adequately the proximal and mid courses of the epicardial coronary arteries in patients with aortic valve disease in order to detect a stenosis of >70% in these locations or to indicate appropriately when either excess calcium or motion artefact potentially obscured a significant coronary stenosis. The intention was to assess CT coronary angiography (CTA) using currently available equipment as a potential clinical tool that would remove the need for patients in whom CTA was normal from undergoing ICA and therefore reserve ICA for patients in whom the CTA was either abnormal or uninformative.

Methods

Patients who had undergone ICA as a prelude to referral for AVR were invited to undergo a CTA whilst waiting for their operation. Thirty-one patients agreed to take part. Patients were excluded if under 30 years of age; serum creatinine >150 mmol/l; had critical AVD requiring urgent surgery or a history of significant allergy. All patients gave written informed consent, the study complied with the declaration of Helsinki and the design was approved by the Newcastle Hospitals Research Ethics Committee.

Cardiac catheterisation and coronary angiography were carried out according to standard Judkin techniques. The coronary arteries were divided into segments according to the American Heart Association classification[3] and comprised the left main stem (LMS), proximal and mid left anterior descending artery (LAD), the proximal circumflex artery and the proximal and mid right coronary artery (RCA). Although the distal segments were also evaluated they were not included in the final analysis since disease in these locations would not receive a bypass graft. Stenoses in the six pre-specified locations were graded between 0 and 3 (0: no visible stenosis; 1: stenosis of <70%; 2: stenosis 70% or excess calcification potentially obscuring significant stenosis; 3: vessel segment not interpretable) and the same classification system was used for the CTAs. The grades were transcribed from the reporting cardiologist's original interpretation by a study investigator who was blind to the data from the CTA.

CTA was performed using a Siemens Somatom Volume Zoom multidector (4 row) CT scanner using a single breath hold at full inspiration. Patients whose resting heart rate was >60 beats/min were given metoprolol up to a maximum dose of 200mg (orally) and 4 mg (intravenously). If their heart rate was maintained above 60 the scan was not undertaken. Patients with a history of asthma did not receive metoprolol. A non-contrast coronal scout view was performed for positioning of the image volume, which extended from below the carina to the apex of the heart. A low dose calcium-scoring scan was then performed. If, in the opinion of the radiologist there was severe dense calcification present, then CTA was not performed. Contrast enhancement was achieved by injecting 130 ml contrast agent (Omnipaque 300) via a 20-gauge cannula in an ante-cubital vein at 3 ml/s. Optimal aortic contrast opacification was ensured by using a test bolus of 20 ml of contrast. Using this technique the mean scan delay was 22-24 seconds. Images were acquired in spiral mode with a 4 x 1 collimation (1.25 mm effective slice thickness), 1.5 mm table feed per rotation and 500 ms gantry rotation. The field of view was adapted to the required volume range and the mean breath-hold time was 22-35 seconds. The images were transferred to a workstation for post-processing. The CTA data were analysed by a single radiologist blind to the knowledge of the ICA data.

Statistical analysis

Sensitivity, specificity, PPV, NPV and accuracy of CTA to exclude a coronary stenosis of >70% in the pre-specified vessel locations were determined. Data were analysed for significance using 2-sample chi-square and Fisher's exact tests (SPSS v 11). Statistical significance was taken as $p<0.05$.

Results

Demographic data are given in table 1.

Table 1: Clinical characteristics of subjects

	n
Number of subjects	31
Age (years)	62 ±12.8
Males	24
Peak aortic gradient (mmHg)	89±22.5
Aortic valve area (cm2)	0.71±0.2
Severe aortic regurgitation	4
AVR and CABG	13
Hypertension	10
Diabetes	4
Smokers	7
Breathlessness	19
Angina	16
Syncope/presyncope	5

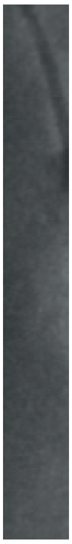
Both elderly and young patients were included. The mean time interval between ICA and CTA was 4 months. The indication for ICA in the young patients was multiple risk factors for coronary disease. MSCT was well tolerated in all patients. One additional further patient could not be studied because of a persistent heart rate >60 beats/min despite metoprolol.

The distal segments of the LAD, RCA and circumflex artery could not be visualised in 10% of segments. Data analysis was confined to the six pre-specified vessel segments. All these segments could be adequately visualised on CTA giving a total of 186 segments for analysis.

Illustrative examples of representative ICA and corresponding CTA are shown in Figures 1 A, B, C and D, 2 A and B and 3 A and B.

Figure 1

A



C

Figure 1: MPR image with volume rendering of the LAD system with corresponding ICA image (A and B – LAO cranial projection and C and D – left lateral projection). No stenoses evident.

Figure 2

A

Figure 2: MPR image with volume rendering of the RCA system with corresponding ICA image (A and B – LAO cranial projection). A moderate stenosis of 50-70% severity is seen in the RCA just beyond a small RV branch in both the CTA and ICA images (black arrow). The RCA was not grafted at the time of aortic valve replacement.

Figure 3

A

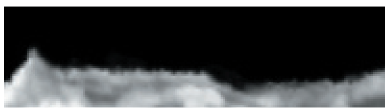


Figure 3: MPR image with volume rendering of LAD system with corresponding ICA image (A and B – LAO cranial projection). A significant stenoses of >70% severity is seen proximal to a small diagonal branch followed by an abrupt reduction in vessel diameter in the mid vessel corresponding to a virtual occlusion of the LAD on the ICA image (black and white arrows).

Seventy-four percent of patients had no visible stenosis by either CTA or ICA. CTA found that 24% of vessel segments contained a stenosis or potential stenosis of >70%. CTA correctly identified the presence a stenosis of >70% in 82% of vessel segments in whom ICA had identified a significant stenosis. In 18% of patients the precise location of the stenosis along the vessel tree was incorrect by CTA but the presence of a stenosis somewhere in the vessel was correctly identified. In one patient a stenosis of 70% was seen in a small obtuse marginal branch of the circumflex artery by ICA which was not seen by CTA. However this vessel was not grafted at the time of AVR. In one patient a stenosis localised to one vessel segment by CTA covered two segments by ICA. In 14 patients CTA would have recommended ICA to clarify the severity of coronary disease. Five of these patients had densely calcified coronary arteries and did not have CTA performed. Nine of these patients (including 3 of the patients with dense calcification) had bypass grafts performed at the time of aortic valve replacement. The sensitivities, specificities, PPVs and NPVs of CTA for the identification of a stenosis or potential stenosis of >70% are summarised in table 2.

Table 2: Sensitivities, specificities, PPV and NPV for datasets

	Six vessel segments (%)	Individual coronary arteries (%)	Any graftable disease (%)
Sensitivity	82	100	100
Specificity	81	80	82
NPV	98	100	100
PPV	30	37	69
p	<0.001	<0.001	<0.001

NPV=negative predictive value; PPV=positive predictive value

No patient with a coronary stenosis of >70% that subsequently received a bypass graft was missed by CTA. The accuracy of CTA for detecting a significant coronary stenosis was 81% when using the six pre-specified vessel segments, 82% when grouped according to each coronary artery and 87% for the presence of any graftable disease ($p<0.001$ for all 3 methods of data analysis).

Conclusions

CTA is an emergent technique for the evaluation of coronary artery disease. Current technical limitations mean that its overall accuracy for evaluating patients with ischaemic chest pain has not yet reached a level where it would replace ICA for the routine investigation of such patients. However visualisation of the proximal coronary arteries has been found to be excellent as confirmed in this and other studies[456].

Patients with aortic valve disease require visualisation of the coronary artery tree prior to aortic valve replacement. This has traditionally been done by ICA but image quality is often suboptimal due to awkward or aberrant "take-off" of the coronary ostia making catheter engagement difficult and catheters being too small in patients with a dilated aortic root. Procedural complication rates are increased above the already documented risks of ICA[2]. An alternative to ICA would be preferable in many patients. Since only stenoses of >70% in the proximal and mid course of a coronary artery would receive a bypass graft, it is adequate visualisation of these segments that is required. This study shows that 4 slice spiral CT equipment is indeed adequate to visualise these proximal and mid-course segments and should be the first-line investigation for the routine assessment of coronary artery anatomy in such patients.

Similar results have now been published by Gilard et al using 16-slice CTA in a slightly larger group of patients with aortic stenosis[7]. Although we did not formally calculate the Agatston calcium score it was also our experience that patients who had extensive calcification were likely to be more difficult to evaluate by CTA. We also found that the prevalence of coronary disease was rather lower at 24% than has been previously reported[8] but our patient cohort is representative of patients referred for aortic valve replacement in this part of the UK.

Summary

CTA provides good visualisation of the proximal and mid-course segments of the coronary arteries with an excellent NPV and therefore should become the routine method for visualisation of coronary anatomy in patients with aortic valve disease requiring aortic valve replacement.

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