Symposium: Clinical Research

Feasibility and accuracy of coronary imaging in elderly patients using the 64-row multi-detector computed tomography: a correlation study with conventional coronary angiography

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Background Elderly patients generally have higher occurrence of coronary calcification, increased heart rate and difficulty with prolonged breath-holding. The aim of our study was to investigate the feasibility and accuracy of using 64-row multi-detector computed tomography (MDCT) in the assessment of coronary artery stenoses in elderly patients. **Methods** One hundred and fifty two patients with suspected or known coronary artery disease were divided into 4 groups according to their age (Group A: 40-49 years, n=34; Group B: 50-59 years, n=57; Group C: 60-69 years, n=48; Group D: 70 years and above; n=13). Coronary CT angiography (CTA) using a 64-row MDCT was performed and the findings were compared with that of conventional coronary angiography (CCA). Using axial images, multi-planar reconstructions (MPR) and maximum intensity projections (MIP), coronary segments of lumen diameter = 1.5mm were analyzed for the presence of significant stenosis (= 50%). **Results** Percentages of poor image quality from coronary CTA preventing reliable correlations with CCA were 21%, 14%, 19% and 62% in Groups A to D respectively. Patients in Group D had significantly higher calcium scores compared with the other groups (P<0.001). In patients where CTA images were of acceptable quality, percentages of accurate correlations with CCA were 89.8%, 93.4%, 86.6% and 78.0% for Groups A to D respectively. There were no significant difference in serum creatinine, heart rate and contrast volume between the 4 groups. **Conclusions** The 64-row MDCT coronary angiography was less accurate and feasible for patients aged 70 years or above due to heavy coronary calcification and inability to perform a satisfactory breath-hold. However, a high diagnostic accuracy with the MDCT is possible in patients aged less than 70 years.(***J Geriatric Cardiol* 2006;3(1):9-14)**

Key Words computed tomography; angiography; coronary artery disease; elderly

Introduction

Conventional coronary angiography (CCA) is currently the gold standard for the detection of coronary stenosis. However, it is an invasive procedure associated with a risk of mortality (0.15%) and morbidity (1.5%).[1-3] Elderly patients, in particular, are at a higher risk of complications during CCA. However, they typically have more heavily calcified coronary arteries and higher heart rates which may impede the interpretation of coronary computed tomography angiography (CTA).[4-14] The latest technology using a spiral 64-row multi-detector CT (MDCT) offers improved spatial and temporal resolution, and preliminary reports have suggested that this most current modality may be superior to earlier MDCTs in detecting coronary artery disease.[15,16] Age had an impact on the image quality produced by 16-slice MDCT but did not impair the diagnostic accuracy.[17] Whether the latest 64-row MDCT technology can offer superior image quality suitable for the analysis of coronary arteries in elderly ($\geq$ 70 years old) patients has not yet been determined.

The purpose of our study was to investigate the feasibility of performing CTA using the 64-row MDCT in elderly patients and to determine the accuracy of CTA in detecting or excluding significant coronary disease in elderly patients aged

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70 years and above.

Methods

Study population

A total of 152 patients with new onset of angina pectoris, chronic stable angina pectoris or positive exercise tolerance test were recruited from the outpatient clinic and inpatient ward over a 4 months period. Based on their age at the time of CTA, patients were divided into 4 groups as shown in Table 1. Exclusion criteria included previous coronary artery bypass graft surgery, presence of tachyarrhythmia, atrial fibrillation and other irregular heart rhythms, known allergy to iodine contrast media, inability to hold breath for at least 15 seconds and documented renal insufficiency (serum creatinine>140 μmol/L). The study protocol was approved by the local institutional ethics committee, and all patients gave written informed consent to undergo both coronary CTA and CCA.

Coronary MDCT scan

All patients with a resting heart rate of > 60 bpm received 100 mg atenolol orally (AstraZeneca, UK) the night before the MDCT scan, and another 100 mg atenolol one hour before the scan. Patients who were intolerant of beta-blocker received 80 mg of verapamil (Pharmaniaga, Malaysia). If the prescan heart rate remained > 70 bpm, an additional 5 mg of metoprolol (AstraZeneca, UK) was intravenously administered before the scan to further reduce the heart rate. Patients with resting heart rates > 75 bpm were excluded. Patients were fasted for 4 hours prior to the scan and given instructions and exercises in breath-hold techniques. An 18G venous cannula was inserted into a large vein at the antecubital fossa. All patients received 2.5 mg of sublingual isosorbide dinitrate immediately before the scan.

Coronary CTA was performed using a 64-row MDCT (Siemens Somatom Sensation 64 Cardiac, Germany). A volume data set was acquired covering the region from the pulmonary hilum to the diaphragmatic surface of the heart. CT Gantry rotation time was 330 ms. Tube voltage and effective tube current-time product were 120 kV and 500-900 mAseff.

ECG-controlled tube current modulation (ECG Pulsing) was used to reduce radiation dose if the patient had a steady heart rate of 60 bpm. Furthermore, an implemented fully automated real-time anatomy based dose regulation (CAREDose 4D) was utilized for all patients. An average of 84 ml of contrast (Ultravist 370, Schering, Germany) was continuously injected followed by 50 ml of saline injected at a flow rate of 5 ml/s. As soon as the signal density in the ascending aorta reached a predefined threshold of 100 Hounsfield units (HU), the patient was instructed to maintain an end-inspiratory breath hold during which the CTA volume data set and ECG trace were acquired. All coronary CTA scans were completed within 12 s (mean 9.1±1.1s).

An effective slice thickness of 0.75 mm and a reconstruction increment of 0.5 mm were applied for axial image reconstruction using an ECG-gated half-scan reconstruction algorithm. Initial data set reconstruction was performed at 65% of the cardiac cycle. If motion artifacts were present, further reconstructions were performed at different positions within the cardiac cycle. All data sets were reconstructed with a 512×512 reconstruction matrix and B25f convolution kernel, resulting in a spatial resolution of equal or better than 0.4×0.4×0.4 mm^3 as shown by Flohr et al.[17] If the vessel segment was heavily calcified, additional reconstructions were performed using a slice thickness of 0.6 mm with a reconstruction increment of 0.4 mm and B46f++ kernel for better plaque delineation and precise evaluation.

Image quality was graded by degree of motion artifacts and noise-to-contrast ratio based upon previous published reports.[18, 19] Images were considered of good quality if there were only minor or no motion artifacts and unrestricted evaluation was possible. Moderate quality images were defined as those with some motion artifacts that still permitted analysis of most segments, while a poor image quality was defined as reconstructions with severe artifacts that impaired adequate interpretation.

The coronary CTA images were analyzed by two cardiologists who had formal training in coronary CTA and were blinded to the CCA findings. A combination of axial images, multi-planar reconstructions (MPR), and thin-slab 3.0- to 9.0-mm maximum intensity projections (MIP) was used in every case. The inter-observer variability was <5%. Sixteen segments were identified based on the modified American Heart Association (AHA) criteria that comprised the right coronary artery and distal branches (5 segments), left main stem (1 segment), left anterior descending artery and branches (5 segments), and circumflex artery and branches (5 segments). Each segment was determined to be diseased or normal. Diseased segments were graded as 1 (none or mild stenosis), or 2 (moderate to severe stenosis with= 50% of luminal narrowing). Grading was determined by visual estimation with the aid of simple computer tools or measurements. Segments that were absent or too small (<1.5 mm diameter), stented, or of poor image quality were excluded from analysis in this study.

Conventional coronary angiography

Conventional coronary angiography (CCA) was performed with a bi-plane digital fluoroscopy (Infinix, Toshiba Corp., Japan) via radial approach under local anaesthesia with a Terumo radial 5F catheter and Omnipaque 350 contrast agent. A minimum of 6 orthogonal views were obtained. All patients underwent CCA and CTA within a 6-month interval (mean 21 days). The CCA was interpreted by a cardiologist blinded to the CTA findings. Assessment of diameter stenoses was by visual estimation. The same segments and grading were used as for CTA.

Statistical analysis

All data were stored on Microsoft Access and transferred to SPSS 11.5. Significant lesions were first identified on CCA. A second cardiologist identified any significant lesion on CCA and analyzed this against the corresponding segment on CTA to confirm if there was a correlation. A correlation meant the score assigned to the segment on CTA matched CCA findings. Over-estimation was defined as CTA score higher than CCA score for each particular segment. Under-estimation was defined as CTA score being lower than CCA score for each particular segment. Should CTA images conclude a segment to be not evaluable due to high calcification or other factors but otherwise is clearly able to be evaluated by CCA, that segment is also considered an under-estimation by CTA. The mean heart rate and age between patient groups with satisfactory and poor image quality were compared using unpaired *t* tests and ANOVA and expressed as mean ±standard deviation. Calcium scoring was determined by 1-sample Kolmogorov test to be non-parametric and therefore analyzed by Mann-Whitney and Kruskal-Wallis tests, and expressed as median (interquartile range).

Results

Safety and feasibility

Of the 152 patients, 120 patients produced adequate image quality for analysis. The 32 patients with poor image quality comprised 7 patients (20.6%) from Group A, 8 patients (14%) from Group B, 9 patients (18.8%) from Group C and 8 patients (61.5%) from Group D. These patients were excluded from further correlation analysis. Group D patients had significantly higher calcium scores (Agatston method) compared with other groups ($P<0.001$). There was no significant difference between groups in serum creatinine concentration, heart rate and contrast volume used (Table 1).

One patient (age 75 years) developed renal impairment after CTA. He was a smoker, had hypertension, no diabetes mellitus but was suspected to have coronary artery disease. CCA with 46 ml contrast had been performed four weeks prior to the CTA. His baseline serum creatinine a week before the CTA was 92 μmol/L. During the CTA he received 88 ml of contrast as per protocol. His serum creatinine rose to 270μmol/L 24 hours after the CTA.

Diagnostic accuracy of coronary stenosis by CTA compared to CCA

Significantly stenosed coronary segments expressed as a proportion of total coronary segments were more prevalent in Group D than in the other groups (Table 2). Group D also had a poorer correlation between CTA and CCA (Groups A to D: 89.8%, 93.4%, 86.6% and 78.0% respectively) as well as a higher rate of underestimation of lesion severity by CTA (5.9%, 3.9%, 7.5% and 10.0% respectively).

Discussion

Even though CCA is performed frequently, it is not without risk. Its complication rate varies according to the experience of the operator and age of the patient.[2,3] Elderly patients generally have more tortuous coronary and peripheral arteries which increase the rate of complications and failure of access. Hence, it would be reasonable for this group of patients to undergo a less-invasive procedure while achieving the same coronary imaging results.

For the general patient population, preliminary data showed non-invasive CTA by MDCT offered adequate accuracy at a reduced risk.[12-17] The latest generation 64-row MDCT allowed us to acquire images at even thinner slices and faster speed, resulting in improved spatial and temporal resolution. With the 64-row MDCT, all vessel segments > 1.5 mm diam-

Table 1. Proportion of image quality for 152 patients by 64-row MDCT angiography

	Age group			
	40-49 (Group A)	**50-59 (Group B)**	**60-69 (Group C)**	**70 and above (Group D)**
Total number	34	57	48	13
Mean age (yr)	46±3	55±3	63±3	74±3
Creatinine (μmol/L)	96±16	96±18	97±15	100±19
Heart rate (bpm)	63±10	61±8	63±9	59±8
Contrast volume (ml)	87±12	90±17	89±16	92±23
CTA image quality				
Good	21 (61.8%)	42 (73.7%)	28 (58.3%)	3 (23.1%)
Moderate	6 (17.6%)	7 (12.3%)	11 (22.9%)	2 (12.4%)
Poor	7 (20.6%)	8 (14.0%)	9 (18.8%)	8 (61.5%)

Table 2. Percentage of diseased segments on CCA, true correlations between CCA and CTA, and under-estimations by CTA compared to CCA in 152 patients

Age-group	40-49 yr	50-59 yr	60-69 yr	70 + yr
LMS				
Diseased segment	0	0	2.7	33.3
Correlation	96.3	100	100	100
Underestimation by CTA	*0*	*0*	*0*	*0*
pLAD				
Diseased segment	11.5	33.3	21.6	33.3
Correlation	87.5	97.9	81.1	80.0
Underestimation by CTA	*8.3*	*2.1*	*8.1*	*0*
mLAD				
Diseased segment	23.1	23.4	28.9	16.7
Correlation	88.5	93.6	81.6	40.0
Underestimation by CTA	*3.8*	*4.3*	*5.3*	*0*
dLAD				
Diseased segment	4.2	4.3	2.6	0
Correlation	87.5	93.6	86.8	60.0
Underestimation by CTA	*4.2*	*4.3*	*5.3*	*20.0*
pLCx				
Diseased segment	3.7	10.2	18.4	50.0
Correlation	100	95.9	78.4	100
Underestimation by CTA	*0*	*2.0*	*10.8*	*0*
mLCx				
Diseased segment	15.4	4.1	10.5	33.3
Correlation	88.0	91.8	88.9	100
Underestimation by CTA	*12.0*	*2.0*	*5.6*	*0*
dLCx				
Diseased segment	11.1	2.0	5.3	0
Correlation	85.2	91.8	86.5	100
Underestimation by CTA	*11.1*	*6.1*	*13.5*	*0*
pRCA				
Diseased segment	19.2	18.4	21.6	16.7
Correlation	92.3	89.8	97.3	60.0
Underestimation by CTA	*7.7*	*6.1*	*2.7*	*20.0*
mRCA				
Diseased segment	15.4	6.1	18.9	16.7
Correlation	80.0	87.5	81.1	60.0
Underestimation by CTA	*12.0*	*8.1*	*16.2*	*40.0*
dRCA				
Diseased segment	3.8	14.3	2.9	0
Correlation	92.3	91.8	84.2	80.0
Underestimation by CTA	*0*	*4.1*	*7.9*	*20.0*
Total				
Diseased segment	10.74	11.61	13.34	20.0
Correlation	89.8	93.4	86.6	78.0
Underestimation by CTA	*5.9*	*3.9*	*7.5*	*10.0*

LMS, left main stem; LAD, left anterior descending artery; LCx, left circumflex artery; RCA, right coronary artery. Prefixes p,m,d refer to proximal, mid and distal segments respectively.

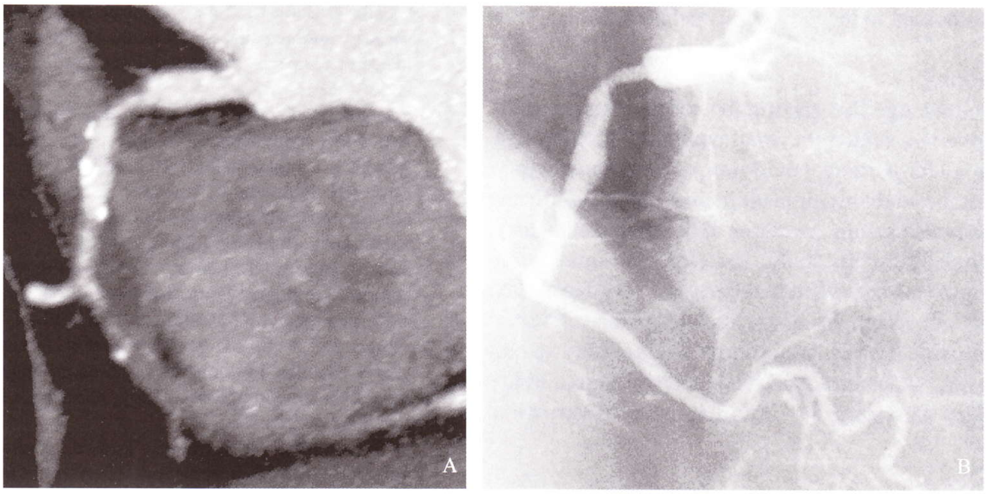

Fig.1. CTA of right coronary artery (A) with poor image quality and corresponding CCA of right coronary artery (B).

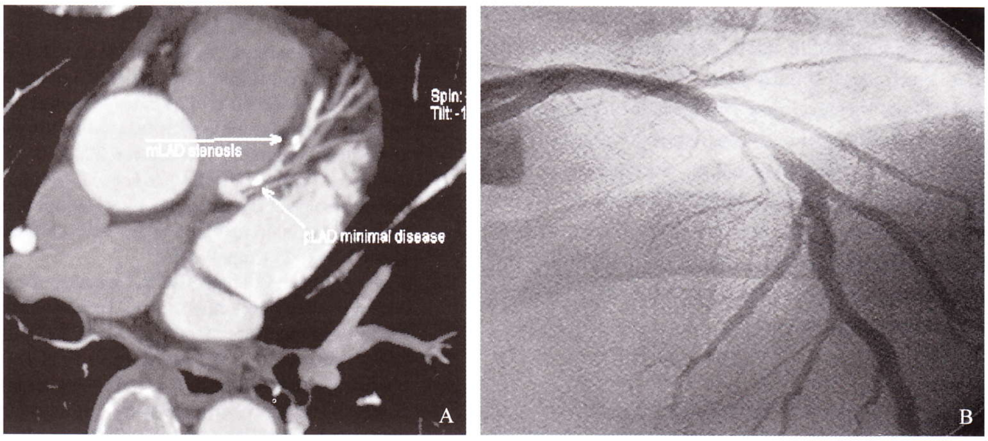

Fig.2. CTA of LAD (A) with significant stenoses in the mid-LAD. This was confirmed by CCA (B).

eter could be evaluated. Our data suggested that it was able to accurately detect clinically significant coronary stenoses (= 50% diameter reduction) in all vessel segments regardless of luminal diameter, tortuosity or calcium scoring with a sensitivity and specificity of 96% and 87% respectively.[16] This raises the potential of CTA as a coronary imaging tool of choice for elderly patients. However, as far as we are aware, the feasibility and accuracy of CTA across different age groups have currently not been compared with the latest 64-row MDCT. Recently, a paper has used 16-row MDCT to detect coronary artery disease in the elderly. The paper concluded that age has an impact on the image quality but did not affect diagnostic accuracy.[17]

As presented in the result section of this study, 64-row MDCT technology is still not able to provide adequate accuracy compared to CCA for the evaluation of significant coronary stenoses in elderly patients particularly for those aged 70 years and above. Not only was the overall correlation with CCA less than 80%, CTA also under-estimated the severity of coronary lesions in 10% of segments. Furthermore, one-fifth of the total evaluated segments in this group of patients were significantly diseased – predominantly in the proximal segments–indicating the possible need for invasive revascularization. The majority of elderly patients also produced poor quality images that prevented conclusive interpretation. The main contributing factors of poor image acquisition were higher coronary calcification and inability to perform at least 10 second breath-hold. In fact, there was a trend towards reduced feasibility, reduced correlation, increased under-estimation of lesion severity and increased prevalence of diseased segments with every decade of increment between the ages of 40 to 80 years. CTA did not under-estimate lesions in the left main stem, proximal and mid left anterior descending artery segments.

Finally, although it was not our primary objective to determine the safety of CTA, the single event of contrast-induced nephropathy (CIN) in a 75-year old male is also worth noting. In our department the amount of contrast used during CCA without intervention is about 50 ml. For CTA, the average amount used was 84 ml per procedure. Patients therefore received at least 15% more contrast volume during CTA than CCA. The overall rate of CIN in our study (1 out of 152) was small when compared to recently published data.[20]

Study limitations

We acknowledge that the number of patients aged 70 years and above was relatively small compared to other age groups. Many older patients could not perform satisfactory breath-holds at the study recruitment period, and a significant number had elevated serum creatinine at baseline, hence they had to be excluded from the study. Therefore, the small number of elderly patients in this study reflects the poor feasibility of CTA for this sub-group. We also acknowledge the very early experience of using MDCT in coronary angiography in our centre. However, two cardiologists had received formal training and attended workshops in CTA imaging, reconstruction and analysis.

Conclusion

Our study has shown that 64-row MDCT coronary angiography was less accurate and feasible for patients aged 70 years or above due to heavy coronary calcification and inability to perform a satisfactory breath-hold. We therefore do not recommend MDCT as the modality of choice for the assessment of the coronary vessels in patients above 70 years of age. Bearing in mind the projected increase in prevalence of elderly population and the increase in MDCT technology of the recent years, we believe that CTA technology will continue to improve to counter the limitations described, especially the breath hold time. Certainly, more studies into this area by other institutions would be welcomed.

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