Full Length Research Paper

Diagnostic accuracy of dual-source computed tomography in the detection of coronary chronic total occlusion: Comparison with invasive angiography

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The present study is designed to evaluate the diagnostic accuracy of dual-source computed tomography (CT) in the detection of coronary chronic total occlusion (CTO). Dual-source CT diagnosed 149 patients with 258 significant coronary artery lesions including CTOs. The diagnosis was redecided by subsequent invasive coronary angiography (ICA). Eighty seven CTOs were finally identified by ICA. Dual-source CT correctly detected 84 of these 87 occlusions, but falsely diagnosed 9 severe stenosis lesions as CTOs. Calcification had an influence on the accuracy of CTO detection. Our findings indicated that dual-source CT had a good ability to detect CTOs, in spite of a slight bias towards overestimating the stenosis degree, especially when there was severe calcification.

Key words: Dual-source computed tomography, invasive coronary angiography, coronary chronic total occlusion.

INTRODUCTION

Multi-slice spiral computed tomography (CT) has developed into a non-invasive tool to rule out coronary stenosis in patients with an intermediate pretest likelihood for coronary artery disease. Numerous studies have shown that the sensitivity of CT for the detection of coronary artery stenosis is very high (Mollet et al., 2005). However, the exact grading of stenosis severity remains difficult (Johnson et al., 2006), and it is even harder to differentiate coronary chronic total occlusion (CTO) from high-grade stenosis by CT (von Erffa et al., 2008). They may both appear as a complete interruption of the contrast-enhanced lumen. Prior to this study, to our knowledge, there are no published studies that focus on

the accuracy of dual-source CT to identify CTO lesions. Currently, the standard modality to identify CTO remains invasive coronary angiography (ICA). This study was done to bring novel data to support the use of noninvasive CT to achieve the same goal of CTO identification.

MATERIALS AND METHODS

Patients

This study was performed at a major University Hospital from March to December in 2009. By using dual-source CT, we screened patients with significant lesion (high-grade stenosis ≥75% in diameter or total occlusion) of coronary artery with a reference vessel diameter ≥2.5 mm. Then, we referred these patients to the Department of Cardiology to undergo ICA. 149 patients with 258 coronary lesions were identified with CT enrolled ultimately. Patients with a history of acute myocardial infarction within 90 days were excluded. The study protocol was approved by the hospital ethics committee.

Dual-source CT scan protocol

CT examinations were performed on a dual-source CT scanner (Somatom Definition, Siemens Medical Solutions, Forchheim, Germany). All patients whose heart rates were less than 100

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Abbreviations: CT, Computed tomography; **CTO,** chronic total occlusion; **ICA,** invasive coronary angiography; **ROI,** region of interest; **RCA,** right coronary artery; **LM,** left main; **LAD,** left anterior descending; **LCX,** left circumflex; **ECG,** electrocardiogram; **PCI,** percutaneous coronary intervention; **PPV,** positive predictive value; **NPV,** negative predictive value.

beats/min received 1.0-mg glycerol trinitrate sublingually directly before the scan. Nonenhanced dual-source CT for calcium scoring was performed from 1 cm below the level of the tracheal bifurcation to the diaphragm in a cranio-caudal direction. The coronary angiography scan was started by continuously injecting a bolus of 65 to 85 ml of iopamidol (Iopamiro, Bracco S.p.A.; Milano, Italy) (370 mg/ml) followed by 50 ml saline solution into an antecubital vein via an 18-gauge catheter (injection rate 5 to 5.5 ml/s). Contrast agent application was controlled by bolus tracking. A region of interest (ROI; mean diameter 10.1 ± 3.4 mm, range 7.5 to 15.0 mm) was placed into the aortic root, and image acquisition started 5 s after the signal attenuation reached the predefined threshold of 100 Hounsfield units (HU). The CT parameters were as follows: detector collimation, 2 × 64 × 0.6 mm; pitch, adapted to heart rate (range, 0.2 to 0.46); 330-millisecond rotation time; tube current 400 mA-s per rotation, and tube voltage, 120 kV. Tube current modulation was used to reduce the patient dose. Full current was applied from 35 to 70% of the R-R interval.

CT data postprocessing and analysis

All data were transferred to an offline workstation (Leonardo, Siemens). For data analysis, coronary arteries were classified into 15 segments according to the basis of the model suggested by the American Heart Association (Austen et al., 1975). The right coronary artery (RCA) included segments 1 to 4, the left main (LM) is segment 5, the left anterior descending (LAD) included segments 6 to 10, and the left circumflex (LCX) included segments 11 to 15. All segments with a diameter of at least 2.5 mm at their origin were included. All reconstructed images were analyzed and graded by two independent readers. For each coronary segment, both readers inspected all optimal reconstruction windows. For any disagreement in data analysis, consensus agreement was used.

Invasive coronary angiography

ICA was performed utilizing standard techniques. The results were evaluated by an experienced cardiologist blinded to the CT results. A total occlusion was defined as 100% luminal diameter stenosis without a discernable lumen or an anterograde flow. The diameter stenosis, as a percentage of the reference diameter, was determined in 2 orthogonal directions and the average between these 2 values determined the stenosis severity.

Statistical analysis

Sensitivity, specificity, positive and negative predictive values, for the detection of CTO using dual-source CT in comparison with ICA, were calculated. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) software (version 12.0, SPSS Inc., Chicago, Illinois). A value of $p < 0.05$ was considered statistically significant.

RESULTS

Patient characteristics and scan condition

Of the 149 patients, 115 were male and 34 were female. The mean age was 63.5 ± 9.6 years of age (range 37 to 83). 21 patients had a history of old myocardial infarction. 25 patients had abnormal Q waves in >2 leads of electrocardiogram (ECG). Six patients had undergone

coronary artery stent implantation, but no significant lesion was found within stented segments. 33 patients were on a beta-blocker daily but no patients were required to receive it before the CT procedure. Dual-source CT was successfully performed in all the patients without complications. The mean heart rate recorded during scanning was 71.3 ± 10.1 beats/min (range 48 to 105 beats/min). Patient characteristics and scan condition are shown in Table 1.

CTO diagnosis: Comparison with ICA

In total, 258 segments with significant lesions were obtained. 87 lesions were located in RCA, 17 were in LM, 92 were in LAD and 62 were in LCX. ICA was performed in all patients 1 to 14 days after the dual-source CT scanning. The results are shown in Table 2.

Via ICA, CTO was determined in 87 segments of 59 patients. Of these 87 ICA-diagnosed CTOs, CT correctly detected 84 (56 patients). Similarly, ICA assessed 171 lesions that were not CTO, and CT correctly ruled out the presence of CTO in 162 lesions (85 patients). The sensitivity was 97% (84 of 87), specificity was 95% (162 of 171), Positive predictive value (PPV) was 90% (84 of 93) and negative predictive value (NPV) was 98% (162 of 165). The predictive accuracy was 95%. The kappa-values of interobserver for the CT evaluation of CTO were 0.984.

Regarding patient-based analysis, the sensitivity and specificity of CT to detect CTO were 95 (56 of 59) and 94% (85 of 90). PPV and NPV were 92 (56 of 61) and 97% (85 of 88). The predictive accuracy was 95%.

Failure to detect CTO (false negative) occurred in 3 lesions with calcification. One of them is shown in Figure 1. The 9 falsely detected CTOs (false positive) were moderately or severely calcified as well. Calcification was a factor exerting a significant influence on the accuracy of CTO detection ($P < 0.001$).

DISCUSSION

Prior to this study, to our knowledge, there are no published studies researching the accuracy of CT to identify CTO, which are problematic to treat, even by the most skilled cardiology interventionalists. The results of this study demonstrate the utility of dual-source CT as a suitable modality to identify CTO lesions, with sensitivity and specificity similar to that of ICA, without the financial burden and patient risk, and recovery time inherent with invasive techniques.

We excluded patients with a history of acute myocardial infarction within 90 days. Acute total occlusions differ from CTOs by length of time the occlusion has existed in the coronary vasculature. The former can be easily diagnosed by medical history and ECG changing. CTOs are by definition greater than 90 days old, and may be the

Table 1. Patient characteristics and scan condition.

Parameter	Value
Patients (no)	149
Age (years)	63.5±9.6
Body weight (kg)	58.2±8.7
Male (no)	115 (77%)
Diabetes (no)	57 (38%)
Hypertension (no)	82 (55%)
Hyperlipidemia (no)	36 (24%)
OMI (no)	21 (14%)
Abnormal Q waves (no)	25 (17%)
Post stent implantation (no)	6 (4%)
Diseased vessels (no)	
1 vessel	34 (23%)
2 vessels	51(34%)
3 vessels	64(43%)
Patient with CTO on ICA (no)	59 (40%)
Patient with one CTO (no)	31
Patient with two CTO (no)	28
Incidental rhythm irregularity during scan (no)	5 (3%)
Use of beta-blocker (baseline) (no)	33 (22%)
Use of nitroglycerin	115 (77%)
Mean heart rate during scan (beats/min)	71.3±10.1
Scan time (s)	13.2±1.5
Total amount of contrast material (ml)	73.5±10.6

Table 2. Validation of CTA in comparison with ICA for CTO.

Parameter	TP	TN	FP	FN	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Lesion-based (258)	84	162	9	3	97	95	90	98	95
Vessel									
RCA (87)	36	46	3	2	95	94	92	96	94
LM (17)	0	17	0	0		100		100	100
LAD (92)	27	60	4	1	96	94	87	98	95
LCX (62)	21	39	2	0	100	95	91	100	97
Calcification									
Absence to mild (136)	44	92	0	0	100	100	100	100	100
Moderate to severe (122)	40	70	9	3	93	89	82	96	90
Patient-based (149)	56	85	5	3	95	94	92	97	95

etiology for present collateral bypass circulation, a phenomenon, not a feature of the acutely occluded vasculature. This study assessed the use of dual-source CT for assessment of CTO only, not acute coronary occlusions.

Currently, the standard of care modality to identify CTO remains the invasive techniques such as ICA. This research study brings novel data to support the use of noninvasive CT to achieve the same goal of CTO identi-fication. A noninvasive detection of occlusion and an exact differentiation between CTOs and high-grade stenosis would be of great clinical importance in both treatment and prognosis, especially for percutaneous coronary intervention (PCI) outcome prediction. While the success rate of PCI for CTO is relatively low, patients with severe stenosis may confidently benefit from PCI.

Figure 1. Effects of calcification on lumen evaluation.

Our study demonstrates that CT is reliable for describing the coronary vasculature in comparison with ICA, but the largest confounding variable in the interpretation of CT is the presence of severe calcification (Zhang et al., 2008). As CT evaluation is often challenging in the presence of severely calcified vessels, patients with extensive calcium load may require ICA for accurate identification of stenotic lesions. Although ICA can easily detect lumen narrowing or occlusion, it is insensitive to detection of wall calcification. CT not only asses luminal stenosis, it also demonstrates plaque morphology. Calcification is more readily identified, localized and graded with CT than conventional ICA. Heavy calcification of CTO has been reported to be an independent predictor of failed PCI (Mollet et al., 2005). Therefore, calcification assessment with CT may become a useful clinical tool in the selection of appropriate PCI patient candidates.

Our findings indicated that dual-source CT had a good ability to detect CTOs in spite of a slight bias towards overestimating the stenosis degree, especially when there was severe calcification.

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