Clinical Research

Dual-phase contrast-enhancement multislice computed tomodraphy imaging for the assessment of elderly patients with acute myocardial infarction after primary percutaneous coronary intervention

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Background Evaluation of acute myocardial infarction after reperfusion by dual phase contrast-enhancement multislice computed tomography (MSCT) was implicated in porcine model. There have been few attempts to use this diagnostic modality for the early assessment of coronary reperfusion in patients with ST-elevation myocardial infarction (STEMI), especially after primary percutaneous coronary intervention (PCI). In elderly patients with STEMI, the safety issues remain unknown. Methods Dual phase contrast-enhancement MSCT examinations were performed in 11 elderly patients (≥60 years old) with STEMI within one week after primary PCI. The presence, location and enhancement pattern on MSCT were evaluated. MSCT findings were compared with the catheter angiographic results and area under the curve of creatine kinase (CK) release. Serum creatinine level was recorded before and after MSCT scan. Results MSCT scans were successfully performed in all the patients. Early myocardial perfusion defect (early defect, ED) was detected in all of the 11 patients (100%) in the early phase of the contrast bolus (subendocardial ED in 10 patients and transmural in 1 patient). Mean CT attenuation value of ED was significantly different from CT attenuation value of remote myocardium (46 ± 17 HU vs 104 ± 17 HU; P < 0.01). Location of ED area correlated well with infarction related artery territory on catheter angiography in all of the 11 patients (100%). On delayed phase of MSCT scan, different enhancement patterns were observed: isolated subendocardial late enhancement (LE) in 6 patients, subendocardial residual perfusion defect (RD) and subepicardial LE in 1 patient, subendocardial RD in 4 patients. Infarct volume assessed by MSCT correlated well with area under the curve CK release (R=0.72, P < 0.01). Serum creatinine level after MSCT scan showed no difference with that before MSCT scan. Conclusion Dual phase MSCT could be safely implicated in elderly patients with STEMI. Variable abnormal myocardial enhancement patterns were seen on dual phase MSCT in these patients with STEMI after primary PCI. Assessment of myocardial attenuation on MSCT gives additional information of the location and extent of infarction after reperfusion. (J Geriatr Cardiol 2009; 6:20-25)

Key words Computed tomography; myocardial infarction; percutaneous coronary intervention

Introduction

The multislice computed tomography (MSCT) has enabled more accurate evaluation of the coronary tree with its high temporal resolution and increased gantry rotation.¹ In recent years, there have been some attempts using MSCT to access myocardial perfusion in both animal models and human beings by dual phase scan.²-⁴ It is now known that infarcted myocardium showed a slight decrease in attenuation when compared with normal myocardium on early scan and hypoenhancement or paradoxical hyperenhancement on delayed scan 5 min or longer after the administration of contrast medium. An imaging tool that can provide detailed information on myocardial perfusion and coronaries at the same time will be helpful in the prognostic assessment of the patient with ST-elevation myocardial infarction (STEMI) especially in the elderly as numerous studies have reported higher mortality in elderly patients with STEMI.⁵,⁶ Until recently, only a few scientific reports have been published regarding to the myocardial enhancement of STEMI with dual-phase contrast-enhanced MSCT. Therefore, the aim of this study was to describe the myocardial enhancement patterns in elderly patients with STEMI especially after primary percutaneous coronary intervention (PCI) with dual-phase contrast-enhanced MSCT scan.

Materials and methods

Patient population and clinical assessment
From December 2007 to December 2008, 11 patients with the diagnosis of acute STEMI who underwent primary
PCI were assessed by dual phase MSCT scan. Patients with cardiogenic shock, atrial fibrillation or other arrhythmias, renal impairment (serum creatinine >1.5 mg/dl), known contraindications for the administration of iodine contrast agent, or clinical signs of severe heart failure (Killip class III or IV) were excluded. Our hospital’s Institutional Review board approved the research protocols, and all patients gave Informed written consent.

STEMI was diagnosed if the patient had: 1) chest pain >30 min in duration with presentation within 12 h after the onset of symptoms; 2) ST-segment elevation 0.1 mV within two continuous electrocardiograph leads, and 3) characteristic elevation of the serum enzyme levels. All patients were also given oral 300 mg aspirin and 75 mg clopidogrel daily after an initial loading dosage of 600 mg clopidogrel. Other medications such as β-blockers, angiotensin-converting enzyme inhibitors, and nitrates were also used as clinically indicated. Infarction related artery (IRA) was defined as the first angiogram showed acutely total occluded coronary artery. Stent was implanted in IRA as indicated. TIMI (Thrombolysis In Myocardial Infarction study) flow was graded on the angiograms performed immediately after primary PCI by 2 experienced investigators who were blind to all data apart from the coronary angiograms and was assessed as previously described: grade 0=no perfusion, grade 1=penetration without perfusion, grade 2=partial perfusion, and grade 3=complete perfusion. Serum creatinine kinase (CK) blood samples were taken at admission, every 4 hours after opening the coronary artery during first day, and every 6 hours on the second and the third day. Area under the curve (AUC; arbitrary units) of serum CK release (expressed in IU/L) was measured in each patient by computerized planimetry (Image J 1.29x) and was used as a surrogate marker of infarct size.

Serum creatinine blood samples were taken at admission, before MSCT scan and the day after MSCT scan.

MSCT scanning and image analysis protocol

In order to obtain motion-free coronary imaging, the heart rate of each patient was decreased to less than 70 beats/min by oral β-blocker (25mg or 50 mg metoprolol).

MSCT was performed in supine position with a 64-slice MSCT scanner (Brilliance 64, Philips Medical Systems) using ECG-gated acquisition during end-inspiratory breath-hold. Standardized examination protocols were used with effective slice thickness of 0.8mm and an increment of 1.0 mm and a tube voltage of 80kV with 800 effective mAsE. Bolus of 80 ml iopromide (Ultravist 370) was injected at the speed of 4ml/s and followed by 0.1ml/s intravenous infusion. MSCT scan was performed at 45 second after contrast injection for both early myocardial perfusion phase and coronary imaging, and 5 minutes after contrast injection for delayed perfusion.

Early and late phase MSCT images were transferred to a computer workstation (Mxview, Philips Medical Systems) and were analyzed anonymously in duplicate by 2 experienced radiologists who were blind to all data sets. The images used for interpretation and for quantitative analysis were reconstructed at a slice thickness of 0.8 mm and an increment of 1.0 mm at 60% of the RR interval.

The location and extent of the early hypoenhanced and late hyperenhanced regions was analyzed both qualitatively and quantitatively. For all the perfusion defects and delayed enhancement detected on the two-phase images, the location of each detected MI within the left ventricular myocardium was defined with using a 17-segment model in the cardiac short axis, as recently suggested by the American Heart Association (AHA). The depth of myocardial involvement was classified into three regions: 1) subendocardial: involvement of less than 1/2 of the left inner ventricle wall thickness; 2) subepicardial: involvement of less than 1/2 of the outer wall thickness; and 3) transmural: involvement of more than 50% of the wall thickness. The typical window width and level settings ranged between 100 400 and 50 200 HU, respectively.

Infarct area was defined as the sum of the hyperenhanced area and surrounding hypoenhanced area in all slices on delay enhanced phase.

Infarct volume (%)=LV mass (g)/Infarction volume (g) = (the sum of LV epicardial area-the sum of LV endocardial area) ×slice thickness×1.06/ (the sum of infarct area× slice thickness×1.06) ×100%.

Statistical analysis

Values are given as mean±SD. Comparison of the CT attenuation value of the normal and abnormally enhanced myocardial segments on the dual-phase MSCT images and serum creatinine level before and after MSCT scan were done with paired Student’s t-tests. Pearson’s correlation is used to find a correlation between the infarct volume assessed by MSCT and area under the curve CK release. A value of P<0.05 was considered statistically significant. Statistical analysis was performed with SPSS version 11.5 software.

Results

Baseline characteristics of the study population

The baseline patient characteristics are shown in Table 1. Primary PCI was successfully performed in all of 11 patients and final angiogram showed IRA of all patients were in TIMI 3 flow. The mean interval time from primary PCI to MSCT scanning was 6.2±1.0 days. Nine patients (82%) received oral β-blocker prior to MSCT scan. The mean HR at the time of MSCT scan was 69.7 ± 5.2 bpm, ranged from 52 bpm to 82 bpm.

Different enhancement patterns on dual phase MSCT scan

Early myocardial perfusion defect(early defect, ED)
Table 1  Baseline characteristics of the patients (n=11)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
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<tbody>
<tr>
<td>Mean age (years; mean ±SD)</td>
<td>66±5 (from 60 to 79)</td>
</tr>
<tr>
<td>Risk factors, n (%)</td>
<td>7 (63.6%)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>10 (90.9%)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>4 (36.4%)</td>
</tr>
<tr>
<td>Current smoking</td>
<td>5 (45.5%)</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>7 (54.5%)</td>
</tr>
<tr>
<td>Time from symptom onset of primary PCI (hours; mean ±SD)</td>
<td>8.7±1.5</td>
</tr>
<tr>
<td>TIMI flow grade 3 after primary PCI, n (%)</td>
<td>11 (100%)</td>
</tr>
<tr>
<td>Ejection fraction (%) after primary PCI, n (%)</td>
<td>53.1±2.9</td>
</tr>
<tr>
<td>Blood pressure (mmHg; mean ±SD)</td>
<td>142±18/86±22</td>
</tr>
<tr>
<td>Time between primary PCI and MSCT scan (days; mean ±SD)</td>
<td>6.2±1.0</td>
</tr>
<tr>
<td>Heart rate (beats/min; mean ±SD)</td>
<td>75.9±8.6</td>
</tr>
<tr>
<td>Before MSCT scan</td>
<td>69.7±5.2</td>
</tr>
<tr>
<td>At the time of MSCT scan</td>
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</tbody>
</table>

MSCT=multislice computed tomography; TIMI= Thrombolysis In Myocardial Infarction study; PCI=percutaneous coronary intervention

was observed in 11 patients (100%). Mean CT attenuation value of ED was significantly different from CT attenuation value of remote myocardium (46 ± 17 HU vs 104 ± 17 HU; P < 0.01) (Fig 1A). Among the ED territories in 11 patients, 10 were located in subendocardium (Figs 1A, 3A) and 1 was transmural (Fig 2A). All of the 11 patients (100%) with ED were in consistency with IRA of coronary angiography.

On delayed phase of MSCT scan, different enhancement patterns were observed: isolated subendocardial late enhancement (LE) in 6 patients (55%) (Fig 1B), subendocardial residual perfusion defect (RD) and subepicardial LE in 1 patient (9%) (Fig 2B), subendocardial RD in the remaining 4 patients (36%) (Fig 3B). Mean CT attenuation value of LE was significantly higher than CT attenuation value of remote myocardium (112±23 HU vs 73±19 HU; P < 0.01) (Fig 1B) and RD was significantly lower than that of remote normal myocardium (40±13 HU vs 73±19 HU; P < 0.01).

CT attenuation value of infarct and normal myocardium was listed in Table 2.

Distribution territories of myocardial infarctions and specific enhancement patterns were listed in Table 3. RD

Table 2  CT attenuation value of infarction and normal myocardium

<table>
<thead>
<tr>
<th></th>
<th>Early phase</th>
<th>Delayed phase</th>
</tr>
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<tbody>
<tr>
<td>ED</td>
<td>44±16 HU*</td>
<td></td>
</tr>
<tr>
<td>LE</td>
<td></td>
<td>112±23 HU*</td>
</tr>
<tr>
<td>RD</td>
<td>-</td>
<td>40±13 HU*</td>
</tr>
<tr>
<td>Remote normal myocardium</td>
<td>107±16 HU</td>
<td>73±19 HU</td>
</tr>
<tr>
<td>LV cavity</td>
<td>448±41 HU</td>
<td>146±32 HU</td>
</tr>
</tbody>
</table>

ED= early defect; *P<0.01, CT attenuation value of ED, LE, RD compared with remote normal myocardium

Table 3  Distribution territories of myocardial infarctions and specific enhancement patterns

<table>
<thead>
<tr>
<th>Coronary artery</th>
<th>MI(n=11)</th>
<th>ED(n=11)</th>
<th>LE(n=7)</th>
<th>RD(n=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td>6</td>
<td>6</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>LCX</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>RCA</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

Note: MI = myocardial infarction; ED= early perfusion; LE=late enhancement; RD=residual perfusion defect; LAD = left anterior descending coronary artery (AHA segments 1, 2, 7, 8, 13, 14, 17); LCX = left circumflex coronary artery (AHA segments 5, 6, 11, 12, 16); RCA = right coronary artery (AHA segments 3, 4, 9, 10, 15); AHA = American Heart Association

Fig 1  Images obtained in a 69-year-old man with reperfused acute myocardial infarction. 2 stents were implanted in middle LAD
A. The short-axis early-phase MSCT scan image showed an early perfusion defect involving subendocardial mid-anterior myocardium (arrow), which corresponded to total occlusion of middle LAD; B. the short-axis delayed-phase MSCT scan image showed subendocardial late enhancement in the same area (arrow)
Fig 2 Images obtained in a 75-year-old man with reperfused acute myocardial infarction. 3 stents were implanted in proximal LAD
A. The short-axis early-phase MSCT scan image showed an early perfusion in the whole thickness of the mid-anterior myocardium (arrow), which corresponded to total occlusion of proximal LAD; B. the short-axis delayed-phase MSCT scan image showed subendocardial residual perfusion defect (black arrow) and subepicardial late enhancement (white arrow) in the same area

Fig 3 Images obtained in a 75-year-old woman with reperfused acute myocardial infarction. One stent was implanted in middle LAD
A. The short-axis early-phase MSCT scan image showed an early perfusion defect involving subendocardial of the mid-anterior myocardium (arrow), which corresponded to total occlusion of middle LAD; B. the short-axis delayed-phase MSCT scan image shows subendocardial late enhancement in the same area (arrow)

territories were mainly in left anterior descending coronary (LAD) supplying myocardium (4 of 5, 80%).

Comparison of MSCT infarct volume with AUC of CK curve
The average infarct volume assessed by MSCT was 8.7±4.7% (ranged from 2.9% to 15.4%). The average AUC of serum CK release was 82.35±39.905 (ranged from 49.186 to 182.302). There was a significant linear association between the infarct volume assessed by MSCT and AUC of serum CK release(R=0.72, P<0.01).

Serum creatinine level before and after MSCT scan
Mean amount of contrast media used in coronary intervention was 156±42 mL.
Mean serum creatinine level, before and after MSCT scan were 82.2±17.2 µmol/L and 87.7±17.5µmol/L, which showed no difference (P=0.25). Serum creatinine level increased from 96.2 µmol/L to 129.1µmol/L in one patient after MSCT scan an decreased to normal value after a week.

Discussion
Single-slice nonspiral CT has been attempted to be used for evaluating MI in both animal models and human being in 1980s, because of the low temporal and spatial resolution this modality was unable to get satisfactory results1. In recent years, a few studies confirmed the value of modern MSCT as a non-invasive imaging method for evaluating acute MI after thrombolysis or unreperfused MI2-8,10 In contrast to those studies, we enrolled patients who received primary PCI therapy for coronary reperfusion, so our results were focused on assessing the coronary reperfusion
status of the IRA using dual phase MSCT scan after reperfusion. In our study, all of the enrolled elderly patients showed typical enhancement patterns on dual phase MSCT scan despite of small infarct volume, as patients in our study received early revascularization. MSCT scan was more sensitive than magnetic resonance imaging (MRI) and single photon emission computed tomography (SPECT) due to its high resolution at the slice thickness less than 1 mm.

The mechanism of myocardial hyperenhancement and hypoenhancement in acute myocardial infarction after contrast injection is similar to that proposed for delayed gadolinium-enhanced MRI. Myocardial enhancement patterns on MSCT scan reflect the distribution of contrast. On early phase, the contrast medium reached myocardium from its supplying microvascular bed. In case of acute myocardial infarction, myocardium is underperfused because of obstructed infarct-related epicardial artery, microvascular obstruction, or extensive capillary disorder, the infarct-related myocardial territories show ED. On delayed phase 5 min later, most of contrast medium flowed into the interstitium and myocardium was then washed out slowly, so the CT attenuation value in normal myocardium area decreased gradually. While in infarct-related area, iodine molecules are able to be washed out owing to myocyte membrane dysfunction and fail to exclude iodine from the intracellular space, which result in marked hyperenhancement relative to the normal myocytes and LE is detected on the second scan. In the area of myocardial necrosis with extensive capillary damage exists, contrast fails to get into both interstitium and myocardium even after 5 min, this was always at the core of the infarction region and RD is detected.

The second scan provides additional information for myocardial perfusion than a single scan. In the era of reperfusion therapy, the addition of hypoenhanced and hyperenhanced myocardial regions best reflects the extent of myocardial infarction. In our study, despite epicardial arteries of all patients were patent, RD was still found in 6 patients with TIMI 3 flow. This showed related myocardium was underperfused as the circulation disorder at the microcirculation level such as microvascular no-reflow. Since MSCT can also define the depth and extent of ED, RD, and LE, these parameters can be fully used to investigate reperfused myocardial infarction.

In our study, infarct volume assessed by MSCT correlated well with area under the curve CK release, which indicates that MSCT can evaluate infarct volume accurately. These results are consistent with animal studies of dual phase MSCT scan. Acute myocardial infarction late hyperenhancement on MSCT is well correlated to histomorphometric infarct size staining and accurately predicts its transmural extent in Lardo et al’s study. MSCT hyperenhancement infarct imaging was an excellent tool for full characterization of infarct morphology in occlusion/reperfusion models of myocardial infarction. These results indicate that the addition of hypoenhanced and hyperenhanced myocardial regions best reflects the extent of myocardial injury. Small scale of subendocardial infarctions could also be detectable in our study because of the higher spatial resolution of 64 slice MSCT.

In addition to its high temporal and spatial resolution, MSCT is superior to all other image tools owing to its unique advantage of coupling myocardial viability assessment with MSCT coronary angiography. This will be useful in evaluating myocardial enhancement, which may serve as a predictor of changes in wall motion, myocardial viability and left ventricular remodeling, and myocardial viability after PCI in patients with STEMI, as patient prognosis after STEMI is directly related to the extent of myocardial injury produced during coronary occlusion.

In our study, additional contrast media injection following coronary intervention within one week showed its safety on serum creatinine level. In real world, additional 80 mL contrast injection should be careful. Patients with moderate or severe renal impairment is not uncommon in elderly, in these cases, dual phase MSCT shortly after coronary angioplasty without contrast re-injection might be valuable.

The most important limitation of this study is the relatively small number of patients. The main Infarct volume in our study was less than 10%, most of them had preserved left ventricular function. Some clinical unstable patients with large infarction were rolled out. They may suitable for MSCT scan in subacute phase. The standard reference modalities for the assessment of myocardial perfusion and delayed enhancement were in short. Comparing the two phases contrast-enhanced MSCT with cardiac MR imaging or nuclear imaging techniques will be ongoing in our future study. The second scan increased the radiation dose to the patient, Paul et al. lowered the tube voltage to 80 kV for delayed acquisition and they obtained better contrast enhancement on the delayed contrast enhanced. In our future study, we will try to lower dose in the second scan in order to reduce the radiation.

In conclusion, variable abnormal myocardial enhancement patterns were seen on dual phase MSCT in elderly patients with STEMI after primary PCI. Assessment of myocardial attenuation on MSCT gives additional information of the location and extent of infarction after reperfusion, and it could be useful in planning appropriate therapeutic strategies and prognosis prediction for elderly patients with STEMI.

References