The Usefulness of Multi-detector row spiral CT (16 channel) for Detection of Coronary Artery Stenoses

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The Usefulness of Multi-detector row spiral CT (16 channel) for Detection of Coronary Artery Stenoses

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Abstract

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Background: Contrast-enhanced multi-detector row spiral computed tomography (MDCT) has been introduced as a promising noninvasive method for vascular imaging. We investigated the accuracy of this technique in the detection of significant coronary artery stenoses.

Method: Both MDCT(Sensation 16, Siemens, Germany, 12x0.75mm collimation and 0.42sec rotation speed, 120kV, 500 effective mA, and 2.7 mm/rotation table-feed) and invasive coronary angiography(CAG) were performed in 61 consecutive patients (mean age 59.2±10, 44 men) who were suspected to have coronary artery disease. All patients were treated with atenolol(25-50mg) prior to imaging and heart rate was maintained below 65 beats per minutes during image acquisition. Images were reconstructed in diastole around TI -400ms with 0.5mm increment and 1.0mm thickness. All coronary arteries with a diameter of 2.0mm or more were assessed for the presence of stenosis(> 50% luminal narrowing). MDCT data were evaluated by two independent radiologists who were unaware of the results of invasive CAG and were compared with the results of invasive CAG (interval 1-27, mean 11days).

Result: Evaluation of CT coronary angiogram (CTCA) was possible in 58 of 61 patients (95%). Image acquisition of major coronary arteries including the left main trunk was available in 229 out of 244 arteries. Thirty-five of 58 patients had significant coronary artery stenoses by invasive CAG. By patient analysis in evaluable patients, CT coronary angiography correctly classified 30 of 35 patients as having at least 1 coronary stenoses (sensitivity 85.7%, specificity 91.3%, positive predictive value 93.8%, negative predictive value 80.8%). By each coronary artery analysis, CAG found 62 stenotic coronary arteries in evaluable 229 coronary arteries. MDCT correctly detected 50 of 62 stenotic coronary artery and absence of stenosis was correctly identified in 156 of 167 normal coronary arteries (sensitivity 80.6%, specificity 93.4%, positive predictive value 81.9%, negative predictive value 92.8%). **Conclusion:** The non-invasive technique of MDCT for coronary artery appears to be a useful method for detection of coronary artery stenoses with high accuracy especially to the proximal portion and large arteries.

Keywords: coronary artery stenoses, Computed tomography,

imaging, stent, MDCT

The Usefulness of Multi-detector row spiral CT (16 channel) for Detection of Coronary Artery Stenoses

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I. INTRODUCTION

For nearly 50 years, selective coronary angiography remains the clinical "gold standard" for evaluating coronary anatomy and defining epicardial coronary artery disease. While conventional invasive coronary angiography provides for exceptional spatial resolution and a general map of the coronary system, it is expensive and has a small but definite risk of complications, and requires either a brief hospitalization or a period of observation for several hours after the procedure in a specialized monitoring unit. The replacement of even a fraction of these procedures with noninvasive imaging modalities would constitute an important advance in the care of patients with suspected coronary artery disease. Presently, a number of imaging modalities are employed to study epicardial coronary artery disease; most identify luminal diameter or stenosis, wall thickness, and plaque volume.[1)] Since 1999, multi-detector row spiral computed tomography (MDCT) scanners have been available for coronary artery scanning.[2)] The increased scan speed results in thinner collimated slice widths and an improved spatial and temporal resolution,

Recently, with the introduction of multi-detector spiral computed tomography (MDCT) combined with subsecond rotation and retrospective electrocardographic (ECG) gating, the invasive modalities have been challenged by an additional new method for the noninvasive assessment of coronary artery stenoses[3)]. However, image quality has been insufficient for reliable detection of coronary stenoses in a substantial number of cases. Calcifications often rendered severely diseased coronary segments unevaluable and coronary arteries were frequently affected by motion artifacts[4-8)] and it has been observed that the patient's heart rate during the scan critically influences image quality.[9,10)] So, the heart rate control is one of the most important factor for better image acquisition, therefore current technique for image acquisition with MDCT require pre-medication of beta-blockers[11)].

This study evaluates the diagnostic accuracy of MDCT angiography in determining significant coronary artery stenoses (≥50% lumen diameter narrowing in angiography) and occlusions compared with conventional invasive angiography in Korean patients who have controlled heart rate with beta-blockers. And we evaluated the detection rate of computed tomographic coronary angiography (CTCA) in each coronary arterial segment and assessed the detection rate by the location of the stenotic lesion.

II. METHODS AND MATERIALS

1. Patients

CTCA was performed in 61 patients who were suspected of having coronary artery disease (20-76 years, mean 59.3±10.0 years). They consecutively underwent CTCA, as well as invasive coronary angiography, over a six month period. The average time between the two examinations was 11 days (range: 1-27days). All patients were treated with atenolol (25-50mg) and four patients with heart rates higher than 70 bpm received a short-lasting beta-blocker (propranolol 40mg) prior to imaging. Only patients in sinus rhythm, without implanted pacemakers or valve prostheses, and without contraindications to the administration of iodinated contrast agent were included in this study. Hemodynamicaly unstable patients were excluded and all patients were allowed to continue concurrent medications with no additional medications except beta-blockers. The patients who had previously inserted coronary artery stents were included in this study.

2. MDCT scan

CT was performed by using a 16-slice CT (Sensation 16, Siemens, Germany) with 12x0.75mm collimation and 0.42s rotation speed. 120kV, 500 effective mA, and 2.7 mm/rotation table-feed. Images were reconstructed in diastole around TI -400ms with 0.5mm increment and 1.0mm thickness.

3. Quantitative coronary angiography

All the data were compared with the results of invasive coronary angiography. Invasive coronary angiograms were evaluated by a blinded independent observer with the use of quantitative coronary angiography (QCA) and used as a gold standard for stenoses detection. Lesions with a diameter reduction of 50% or more were considered significant stenoses. In addition, the reference diameter of the lesion (vessel diameter in non-diseased artery immediately proximal to the lesion) was documented because only lesions in vessel segments with a lumen diameter ≥ 2.0mm were included in the analysis.

4. Image evaluation and comparison of two examinations.

Evaluation of the coronary arteries and each of the segments was performed according to the classification of the American Heart Aoosciation[12)]. All MDCT data were evaluated by two independent radiologists who were unaware of the results of invasive coronary angiography. We analyzed the result firstly by patients evaluation, how accurately detect the patient who had coronary artery occlusive disease (CAOD). We checked the overall sensitivity and overall specificity by patient analysis. Second we analyzed the results by each coronary artery (LAD, LCx, RCA and Left main trunk) and then calculated sensitivity, specificity, positive predictive value and negative predictive value of each coronary artery. Finally we evaluate the detection rate for stenotic lesion depending on the lesion locations could influence the detection of stenosis.

III. Results

1. Baseline clinical characteristics

The CTCA was performed without complication in all patients (mean age: 59.3±10.0 years, M:F=44:17)(Figure 1). Evaluation of CTCA was possible in 58 out of 61 patients (95%). By invasive coronary angiography, thirty-eight patients had significant coronary artery stenoses (1 vessel disease: 17 cases, 2 vessel disease: 11 cases, 3 vessel disease: 10 cases) and 23 patients had normal coronary artery or minimal coronary artery stenoses (<50% luminal narrowing). The images of three patients were unevaluable due to blurring artifact, which was due to increased heart rate during scanning procedures and motion artifact. The image acquisition of major coronary arteries including the left main trunk was available in 229 out of 244 arteries (Table 1)

Table 1. Baseline clinical characteristics

Age	59.3±10.0
Number(M:F)	**61 (44:17)**
Normal coronary artery by CAG	**23 (37.7%)**
Coronary artery disease by CAG	**38 (62.3%)**
1-vessel disease	**17(27.9%)**
2-vessel disease	**11(18.0%)**
3-vessel disease	**10(16.4%)**
Evaluable image by MDCT	**58 (95%)**

2. Comparison of CTCA and invasive coronary angiography.

Table 2 shows comparison between MDCT and invasive coronary angiography. CTCA correctly classified 30 of 35 evaluable patients who had significant coronary artery stenoses as having coronary artery stenoses. Five patients who were incorrectly classified by CTCA had only one vessel stenosis. Among the rest 5 cases, one case had a lesion of total occlusion in the proximal RCA, which was interpreted as diminutive RCA. A second case with stenotic lesion in the PL (posterolateral) branch was not detected because it was located far distal. Misdiagnosis of the third case with proximal LAD lesion was attiributable to motion artifact. Stenotic lesion at the proximal edge of previous RCA stent and lesion of diagonal branch ostium adjust to the previous proximal LAD stent were not correctly assessed in the fourth and fifth case, respectively. In the last 2 cases, the previously inserted stent interfered with the detection of coronary artery lesions, known as metallic stent artifact in CTCA. So, by patient analysis CTCA correctly classified 30 of 35 patients who were evaluable as having at least one coronary artery stenoses (overall sensitivity 85.7%, overall specificity 91.3%, overall positive predictive value 93.8%, overall negative predictive value 80.8% and accuracy 87.9%)(Table 2)

Table 2. Comparison of CTCA and invasive CAG by patients analysis

		Invasive CAG		total
		Normal	CAOD	
CTCA	Normal	21(91.3%)	5(14.3%)	26
	CAOD	2(8.7%)	30(85.7%)	32
Total		23	35	58*

*** this value was calculated in evaluable patients by MDCT(n=58), CAOD: coronary artery occlusive disease (>50% stenoses). overall sensitivity 85.7%, overall specificity 91.3%, overall positive predictive value 93.8%, overall negative predictive value 80.8% and accuracy 87.9%**

3. Accuracy of CTCA

We compared sensitivity, specificity, positive predictive value and negative predictive value by coronary vessel analysis on Table 3. Image acquisition of major coronary arteries (LAD, LCx, RCA, Left main trunk) was available in 229 out of 244(61x4) arteries. CTCA correctly detected 50 of 62 stenotic coronary artery and absence of stenosis was correctly identified in 156 of 167 normal coronary arteries (sensitivity 80.6%, specificity 93.4%, positive predictive value 81.9%, negative predictive value 92.8%). In LAD artery there was a relatively high level of unevaluable coronary vessel at 8.2%. On the other hand, it was lowest in LCx artery at 4.2%. It may be due to the coronary artery calcifications, which were more frequently founded in LAD artery than other arteries. Other values showed relatively similar levels. Only one case had significant stenosis in Left main trunk in invasive coronary angiography.

Table 3. Accuracy of MDCT for stenotic vessels by vessel analysis in the evaluable vessels

	LAD(%)	LCx(%)	RCA(%)	Lt. main(%)
Sensitivity	86.3	81.2	73.9	100
Specificity	85.2	92.8	94.1	98.2
PPV*	79.1	81.2	89.5	50
NPV*	90.6	92.8	84.2	100
Accuracy	85.7	89.6	86.0	98.0
unevaluable	8.2%	4.9%	6.6%	4.9%

*** PPV: positive predictive value, NPV: negative predictive value**

4. Accuracy of CTCA for stenoses in regards to lesion location

Table 4 showes the comparison of detection rates in each stenotic segment in regards to lesion locations. Whereas relatively proximal portion were frequently detected, distal lesions and side branches were less detected.

Table 4. Accuracy of CTCA in regards to lesion locations

	Location	True Positve	False Negative	Detection rate(%)
LAD lesion	p-LAD	8	0	100
	m-LAD	9	1	90
	d-LAD	2	1	66.7
	Diagonal br.	5	4	55.5
	Intermedius br	1	0	100
LCx lesion	P-LCx	6	2	75
	d-LCx	7	0	100
	OM br.	3	2	60
RCA lesion	p-RCA	6	3	66.7
	m-RCA	9	0	100
	d-RCA	6	1	85.7
	PD br.	2	1	66.7
	PL br.	0	2	0
Lt. main		1	0	100
Total		65	17	75.6

Figure1. Normal coronary artery in MDCT and CAG

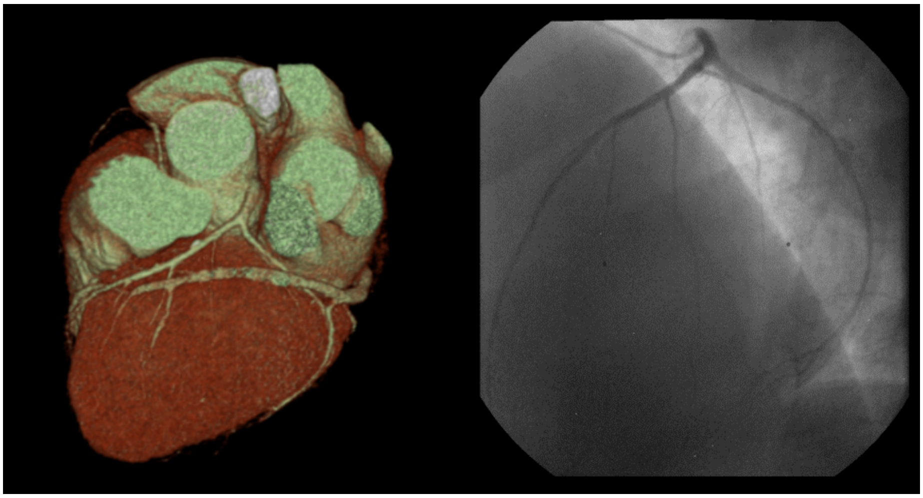


Figure 2. Significant stenoses at proximal RCA

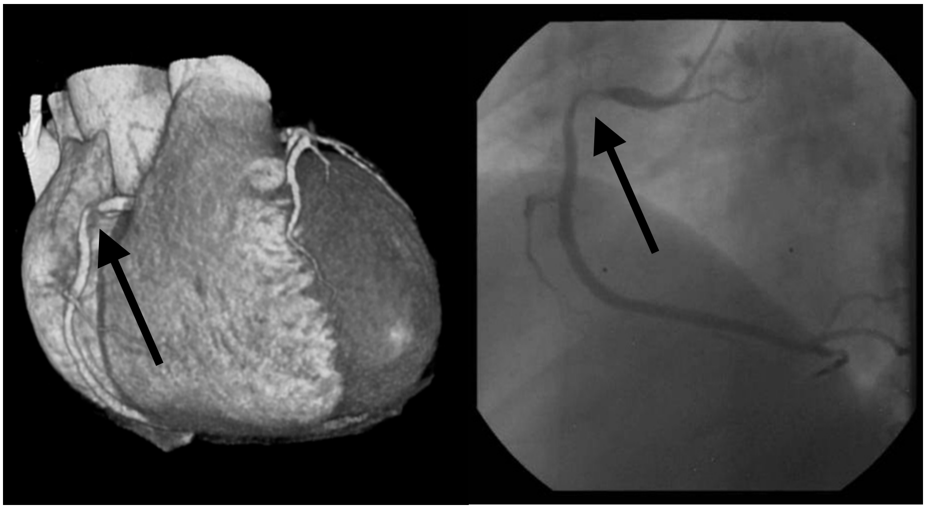


Figure3. Detection of significant stenosis at Left main trunk by MDCT

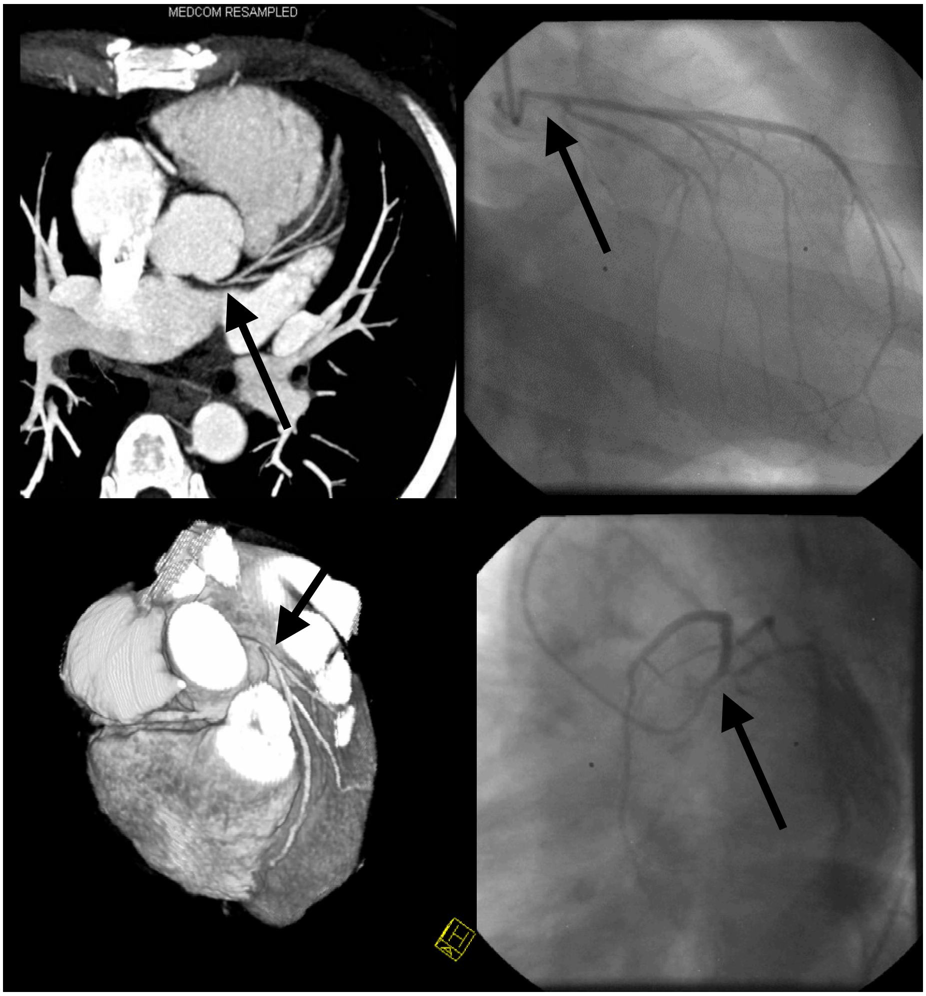
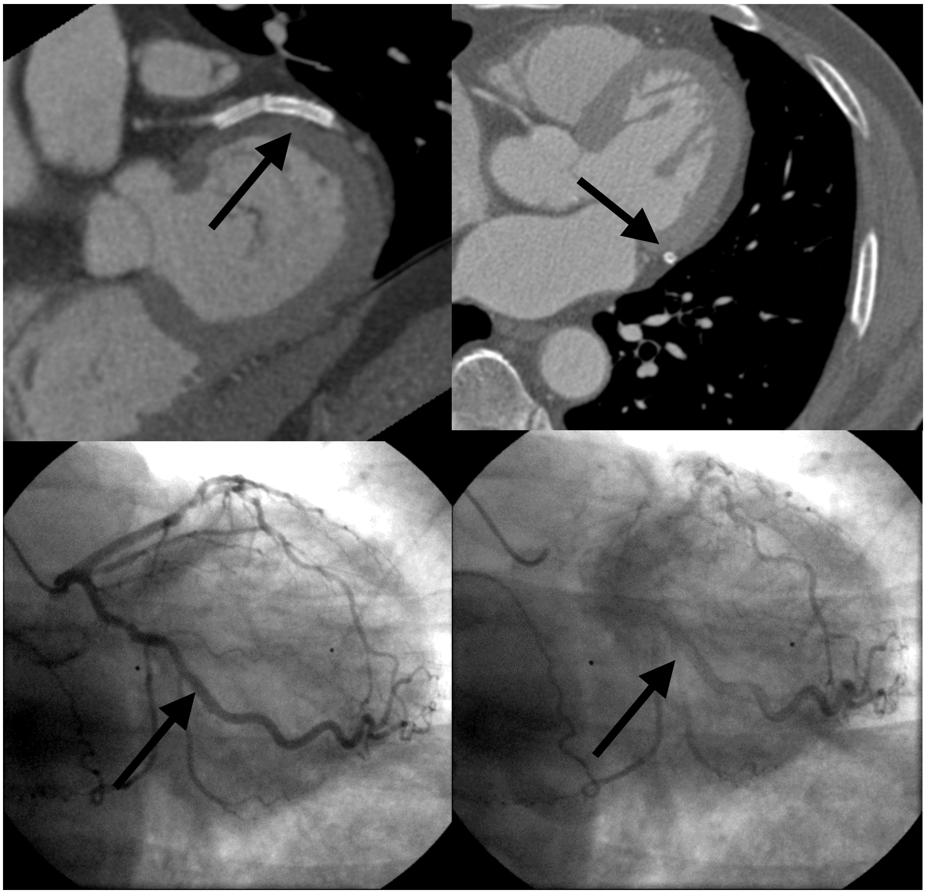


Figure4. Stent patency evaluation by MDCT Stent patency evaluation was possible by density measurement and direct visual assessment in the lumen of stent



V. Discussion

The high spatial resolution with contrast-enhanced multi-detector row coronary CT angiography may provide many information on coronary artery stenotic lesions and noninvasive image of the coronary artery wall.[13)]

Recently, Achenbach et al.[6)] reported a sensitivity of 85% in detecting significant stenotic coronary artery with contrast-enhanced MDCT in interpretable native coronary arteries (luminal diameter ≥2mm vessels were assessed) and only 68% of all coronary arteries were interpretable. Ropers et al.[11)] reported a sensitivity of 92% in detecting significant stenotic coronary artery with contrast-enhanced MDCT in interpretable coronary arteries (luminal diameter ≥1.5mm vessels were assessed). In this study group, 88% of coronary arteries were evaluable with beta-blocekade pre-medication. Our study demonstrates that CTCA permits the detection of coronary artery stenoses and occlusions with high sensitivity (80.6%) and specificity (93.4%) if an image quality sufficient for evaluation is obtained. In our study, 93.8% of all coronary arteries were evaluable with beta blocker pre-medication. The values of sensitivity and specificity were similar to the results of CTCA in other research center[6-8,11,16-18)] but the value of interpretable arteries portion were relatively higher than other results.

As opposed to previous studies, we verified our CTCA results by QCA and included all vessel segments, proximal and distal segments, including side branches, in the analysis if the vessel diameter measured over 2.0 mm. The cut off value of 2.0mm means that stenoses in vessels with a diameter <2.0mm rarely constitute targets for revascularization.[14,15)]

Our study demonstrates that in the proximal and mid segments of all 3 major arteries and Left main trunk, CTCA permits high accuracy in the exclusion of coronary artery disease and determination of significant stenoses, but CTCA is relatively limited in the diagnosis of distal arteries, side branches and near the previous stent legion. These finding implies that the relative large vessels stenoses were more easily detected by CTCA, suggesting the usefulness of MDCT as a feasible diagnostic modality and noninvasive technique for the selection of revascularization target.

The limitation of CTCA was calcification of coronary arteries. In our study, some patients have severe coronary calcification and accurate evaluation of CTCA image was difficult, so theses lesions were often misdiagnosed as being severe stenoses. But in theses group, some patients had only minimal luminal narrowing or did not have severe coronary stenoses in invasive coronary angiography. Other studies reported that although this finding was the limitation of the accurate diagnosis of MDCT, the presence of any amount of calcium was strongly suggestive of the presence of atherosclerosis in the coronary artery.[19)] Hence, patients with no significant stenoses in invasive coronary angiograpy but with detectable calcification in MDCT can be said to have coronary artery disease. These facts can be one of the advantages of CTCA.

The other limitation was stent imaging. Coronary artery stenting is currently the predominant form of nonsurgical myocardial revascularization. But the stent restenosis remains a clinical problem. Therefore a noninvasive assessment of stented segment in these patients would be highly desired. It is reported that EBCT (Electron Beam Computed Tomography) has been successfully used for stent patency evaluation. But the stent lumen itself cannot be accurately visualized to assess in-stent restenoses.[20-22)] In our study, twenty four of patients previously underwent coronary stenting in 38 lesion. The previous stented segments were often misdiagnosed by radiologists and the luminal narrowing could not be accurately measured. Although the stent lumen could not be visualized in most stents, a reliable evaluation of stent patency was possible by visualized distal flow and the measurement of attenuation changes in the visible stent lumen and outside stent. In our study, 33 of 38 coronary stents was evaluable by these method (86.8%) and MDCT correctly classified 31 of 33 stents as being patent (28 stents) or occluded (3 stents) and the only two stents were misdiagnosis. Some cases of in-stent restenosis but patent distal flow were also classified as being patent by MDCT. Since the stent lumen could be partly visualized in most stents, a reliable evaluation of in-stent restenoses remains to be assessed in the future.

It is clear that the CTCA was feasible diagnostic methods for detection of coronary artery stenoses with high sensitivity and specificity under appropriate heart rate controls. Especially CTCA showed high accuracy in detection of proximal lesion stenoses. However, because most of the unevaluable segments were affected by coronary motion and coronary artery stents, further shortening the image acquisition window and technical advances seems mandatory.

V. Conclusion

The non-invasive technique of MDCT for coronary artery appears to be a useful method for detection of coronary artery stenoses with high accuracy especially to the proximal lesions and large arteries. And MDCT angiography is a rapidly developing imaging modality so further technical advances to improve diagnostic accuracy and clinical usefulness are expected in the future. The MDCT angiography can be replaced for the invasive coronary angiography.

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Multi-detector row spiral CT (16 channel)scan을 통한

관상동맥 질환의 진단 및 진단적 유용성

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문재연

최근 들어 관상동맥질환의 진단에 있어서 Multi-dector row spiral computed tomography(이하 MDCT)는 관상동맥질환 진단의 비침습적인 방법으로 도입되고 있다. 물론 현재까지도 관상동맥질환의 확진을 위한 진단적인 방법으로는 관상동맥 조영술이 가장 정확한 방법일 것이지만, 침습적인 관상동맥 조영술의 위험성 및 합병증을 고려할 때 MDCT의 역할은 관상동맥 조영술을 대체하거나 혹은 보조할 수 있을 것으로 생각된다.

MDCT를 통해 비침습적 심장영상을 얻는 것은 죽상반에 의한 관상동맥의 협착 정도를 파악할 수 있을 뿐만 아니라 관상동맥의 기형등과 같은 다른 관상동맥 질환을 발견할 수도 있으며 또한 관상동맥의 석회화 정도를 평가할 수 있다는 점은 큰 매력이나, 심장이나 호흡에 의한

움직임에 의해 이미지를 얻는데 방해를 받을 수도 있으며 또한 관상동맥 석회화에 따른 artifact 또한 고려해야 한다는 문제점 및 비교적 내경이 작은 혈관의 평가에서는 정확성이 떨어진다는 어려움 또한 있다.

본 연구에서는 이러한 관상동맥질환의 진단에 있어서의 MDCT 의 진단적인 유용성을 평가하기 위해 진행되었다. 관상동맥질환이 의심되는 총 61명의 환자(59.2±10.0 M:F=44:17)들이 관상동맥조영술과 MDCT scan을 동시에 시행하였다. 연구대상자들은 심박동수를 조절하기 위해 모두 atenolol 을 복용하였으며 MDCT의 Image를 scan하는 동안 심박동수가 65 bpm 이하로 유지하였다. MDCT Image의 결과는 두명의 방사선과 의사들에 의해 검토되었으며, 이들은 관상동맥조영술의 결과를 모르는 상태에서 판독을 진행하였다. 관상동맥조영술의 결과는 각각의 관상동맥 및 관상동맥 분지 별로 QCA 를 통해 분석되었으며 50% 이상의 협착을 의미 있는 협착으로 평가하였다. MDCT 조영술을 시행한 총 61명중 58명에게서 평가가 가능한 Image를 얻어냈으며(95%) 좌주간지를 포함한 총 244개의 관상동맥에서 229개의 관상동맥에서 평가가 가능했다. 결과를 살펴보면, 고식적 관상동맥조영술에서 관상동맥질환이 있는 것으로 분류된 35명의 관상동맥질환자 중에서 30명을 적어도 한군데 이상의 관상동맥의 협착이 있는 관상동맥질환으로 분류했으며, 관상동맥 질환이 없는 23명중 21명에서 관상동맥 협착이 없는 것으로 분류해냈다 (sensitivity 85.7%, specificity 80.8%, positive predictive value 93.8%, negative predictive value 80.8%). 각각의 관상동맥별로 분석한 결과

MDCT 조영술은 평가가 가능했던 229개 중 62개의 협착이 있었던 관상동맥 중 50개를 정확히 판독해 냈으며 협착이 없었던 167개의 관상동맥 중 156개에서 협착이 없었던 것으로 평가했다 (sensitivity 80.6%, specificity 93.4% positive predictive value 81.9%, negative predictive value 79.3%). 각 협착 병변에 따른 분석을 살펴보면 MDCT조영술은 판독 가능했던 82개의 협착 병변 중 65개의 병변을 정확히 판독해냈다. (detection rate 79.3%)

MDCT조영술의 판독 불가능했던 경우는 대부분은 원위부 협착 또는 작은 가지들의 병변이 많았으며 근위부 협착이나 직경이 큰 관상동맥에서는 훨씬 높은 발견율을 나타냈다. 이는 관상동맥질환에서 관상동맥중재시술을 고려할 때 MDCT가 더 효과적임을 나타내 주는 결과라 할 수 있겠다. 마지막으로 기존에 스텐트를 삽입했던 환자들에게서도 스텐트의 개존성을 평가하는데도 도움이 될 수 있는데 스텐트의 내부를 직접 눈으로 확인함과 동시에 스텐트 내부 및 스텐트 바깥 부위와의 density 의 차이를 통해 스텐트의 개존성을 평가해 낼 수 있었다. 이러한 점은 향후 스텐트 개존성 및 스텐트 재협착을 평가해내는 방법으로서의 MDCT가 쓰일 수 있음을 시사한다고 할 수 있으며 이에 대한 연구는 차후에도 필요하리라 생각된다.

베타 차단제의 전처치를 통한 심박동수의 조절, 기술적인 측면의 발전을 통해 더욱 더 좋은 영상을 얻음과 동시에 짧은 시간에 많은 영상들을 얻어내는 일들이 가능해짐에 따라 MDCT조영술의 단점으로 생각되었던

영상의 해상도 및 관상동맥의 움직임에 따른 잘못된 영상등의 문제들이 해결 되어 가고 있는 상황이다. 본 연구를 통해 관상동맥질환의 진단적인 유용성을 확인하였으며, 향후 기술의 발전 등을 통해 더욱 나은 MDCT가 나오게 된다면 고식적인 관상동맥조영술을 통한 관상동맥질환의 진단은 이제 MDCT조영술에게 자리를 양보해야 하는 상황이 될 수도 있을 것이다.

핵심 되는 말: 관상동맥질환, Computed tomography, 관상동맥영상, 스텐트, MDCT