The comparison of high and standard definition computed tomography techniques regarding coronary artery imaging

Aktas Aykut[1], Degirmenci Bumin[1], Yilmaz Omer[1], Kayan Mustafa[1], Cetin Meltem[1], Celik Orhan[1], Unlu Nisa[1], Orhan Hikmet[2], Demirtas Hakan[1], Koroglu Mert[3]

1. Suleyman Demirel University, Radiology Dept.
2. Suleyman Demirel University, Biostatistics Dept.
3. Near East University, Radiology Dept.

Abstract

Objectıve: The aim was to compare coronary high-definition CT (HDCT) with standard-definition CT (SDCT) angiography as to radiation dose, image quality and accuracy.

Material and methods: 28 patients with history of coronary artery disease scanned by HDCT (Discovery CT750 HD) and SDCT (Somatom Definition AS). The scan modes were both axial prospective ECG-triggered. The vessel diameters and vessel attenuation values of totally 280 measurements from 140 coronary arteries were analyzed by two experienced radiologists. All data was analyzed by intraclass correlation test. Image quality graded by motion and stair step artifacts (grade 1, poor, to grade 4, excellent), accuracy of vessel inner and outer diameters were compared between the two CT units using the independent samples t-test and Mann-Whitney U test.

Results: The intraclass correlation coefficient (ICC) of measured vessel attenuation values in SDCT between the two radiologists was exceedingly good. The ICC was higher in HDCT. The radiation dose of HDCT was higher than that of SDCT. The mean tube current was 180 (mA) in HDCT and 147(mA) in SDCT with the same tube voltage (kVp). There was no significant difference between image quality.

Conclusion: HDCT has a higher radiation dose but has much more atenuation and the spatial resolution which improve measurement accuracy for imaging coronary arteries.

Key words: Coronary Arteries, Computerised Tomography, Angiography

DOI: http://dx.doi.org/10.4314/ahs.v15i3.29

Cite as: *Aykut A, Bumin D, Omer Y, Mustafa K, Meltem C, Orhan C, Nisa U, Hikmet O, Hakan D, Mert K. The comparison of high and standard definition computed tomography techniques regarding coronary artery imaging. Afri Health Sci. 2015;15(3):925-30. doi: http://dx.doi.org/10.4314/ahs.v15i3.29*

Introduction

In coronary artery disease follow-up, coronary CT angiography (CCTA) is a non-invasive method which becomes very important and useful in the assessment of coronary arteries[1].

CCTA is highly accurate but image quality can be affected by several factors in some patients. As an example, highly calcified vessels, high body mass index, and higher heart rates causing excessive image noise, partial volume and beam hardening artifacts, and limited temporal resolution decrease diagnostic accuracy of CCTA[2].

Recently developed high definition CT(HDCT) allowes high spatial resolution imaging that improves Data Acquisition (DA). X-ray tube with the deflecting focal spot, 2496 sampling per rotation, and a new gemstone detector improved spatial and contrast resolution[3].

Standard definition computed tomography (SDCT) is known to be limited by spatial and contrast resolution in CCTA[4,5].

The purpose of this clinical study was to compare HDCT and conventional 64-row SDCT for the performance of imaging coronary arteries according to image quality, diagnostic performance and radiation exposure.

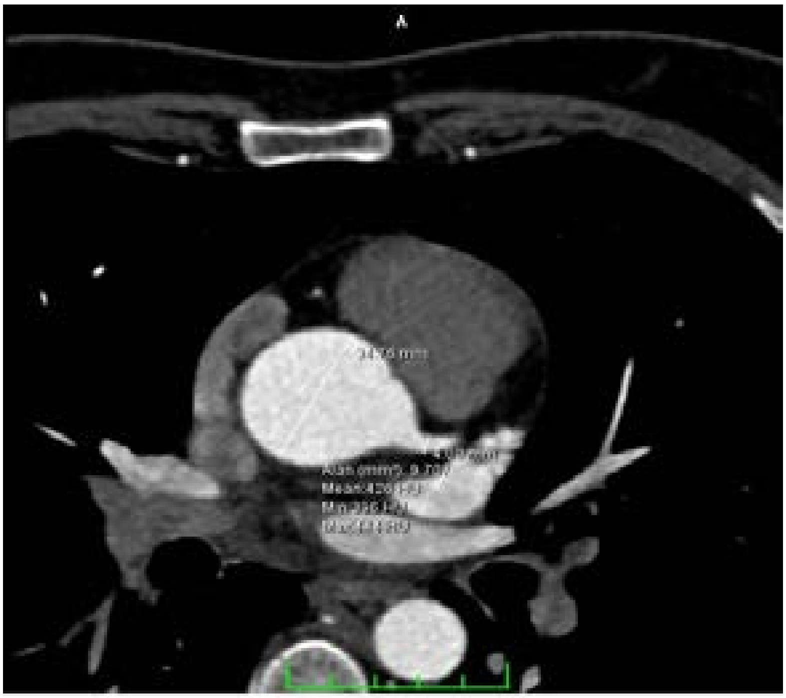
Corresponding author:
Aktas Aykut
Suleyman Demirel University,
Radiology Dept.
Email: aykutraktas@gmail.com

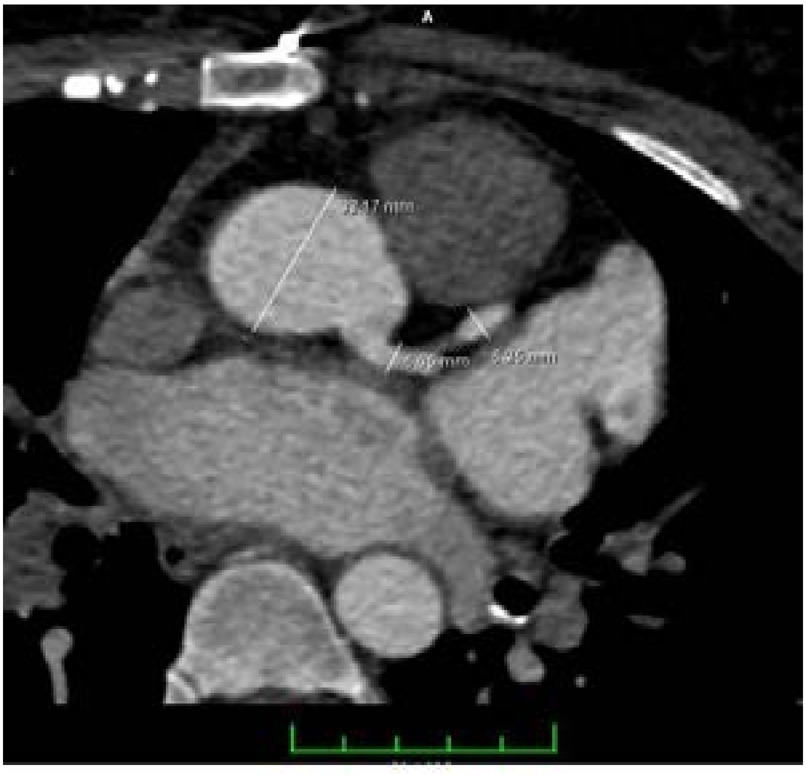
Materials and methods

Patients with coronary heart disease history with stable heart rates of 60-80 beats per minute were selected in different university hospitals by using contrast material iohexol(Omnipaque 350, GE Healthcare, Amersham, UK), prospective ECG-triggered axial scans were performed in the same cardiac phase for both HDCT(120 kV, 180 mA) (Discovery HD 750, GE Healthcare, Waukesha, WI) and SDCT (120 kV, 147 mA) (Somatom Definition AS, Erlangen, Germany) with slice thickness of 0.675 mm and 0.6mm respectively. Patients with unstable and rapid heart rate with motion artefacts and highly calcified coronary arteries were exluded from the study.

All images were analyzed by two radiologists(ARA. and BD.) with special training in cardiovascular imaging 3 and 5 years of experience, respectively. They were blinded with the CT protocols on the same viewing programme (Enlil PACS Viewer, Eroglu Yazılım, Eskisehir, Turkey). The observers measured inner and outer vessel diameters of the visible maximum diameter of vascular lumen of ascending aorta(AA), left main coronary artery (LM), left anterior descending coronary artery (LAD), left circumflex artery(Cx), and right coronary artery (RCA) using electronic calipers and attenuation values by using a region of interest (ROI) technique inside the non-stented or calcified lumen of arteries on the plane perpendicular to the long-axis of the vessel (Figure 1).

The luminal diameters obtained at the 1 cm proximal





portions of each coronary vessel and the mean luminal diameters were also calculated. Image quality was graded and attributed in a 4-step scale (grade 4, excellent quality, vessels showing a continuous course, without stair-step artifacts; grade 3, good quality, presence of discrete blurring of vessel margin, minor motion artifacts; grade 2, moderate quality, noticeably blurred vessels or plaque margins, distinctly broader motion artifacts; and grade 1, poor quality, inadequate delineation between the vessel and surrounding tissue). Dose–length product (DLP) was displayed on the dose report on the CT scans, and the effective dose (E = k × DLP, k=0.014 mSv mGy-1cm-1 for the chest) was calculated. All the data was analyzed with the SPSS 11.0 software (Chicago, IL). Intraclass correlation coefficient (ICC) was used to compare the correlation between effects of the scanner within the radiologists' measurements of vascular diameters and attenuation values. Radiation dose in HDCT or SDCT were compared by independent samples t-test and Mann-Whitney U test. A 2-tailed P value less than 0.05 was considered statistically significant.

Results

Totally 280 measurements from 140 coronary arteries of 18 (64%) male and 10 (36%) female patients with a median age of 51(42-76) were analyzed. The intraclass correlation coefficient (ICC) of measured vessel attenuation values in SDCT between the two radiologists was very good.Measurements of Cx, LAD and LM artery were higher in HDCT but Aorta and RCA diameters were higher in SDCT (Table1).

The radiation dose of high definition CT angiography

Table 1: Independent samples t test

	CT type			
Variables	HD (n=11)	SD (n=17)	Test	P
age	51,1±16,7	50,9±13,5	0,036	0,971
dose dlp	1028 (887-1350)	461 (289-676)	-4,399	<0,001
dose mSv1	14,39 (12,42-18,9)	6,45 (4,05-9,46)	-4,399	<0,001
iq1	3 (1-4)	3 (1-3)	-0,857	0,392
Tube curr1	180 (180-200)	147 (67-183)	-4,044	<0,001
Aorta Vod1	37,65±6,87	35,36±5,71	0,956	0,348
Aorta Vid1	32,8 (25,5-46,1)	32,2 (24,8-47,8)	-0,565	0,572
Aorta HU1	373,82±74,36	353,18±94,02	0,613	0,545
LM Vod1	5,86±1,17	5,48±0,94	0,95	0,351
LM Vid1	4,19±0,96	3,81±1,09	0,943	0,354
LM HU1	364,09±66,79	325,94±104,37	1,068	0,296
LAD Vod1	4,75±1,29	4,58±0,73	0,452	0,655
LAD Vid1	3,3 (2,4-6,2)	3,6 (1,7-4,4)	-0,141	0,888
LAD HU1	334 (258-447)	316 (126-952)	-0,753	0,452
Cx Vod1	4,33±0,97	3,94±0,85	1,126	0,270
Cx Vid1	3,10±0,87	2,65±0,91	1,31	0,202
Cx HU1	339,64±77,86	315,00±109,33	0,642	0,527
RCA Vod1	4,79±0,97	4,07±0,71	2,273	0,032
RCA Vid1	3,53±0,84	2,74±0,83	2,458	0,021
RCA HU1	318 (285-432)	316 (178-514)	-0,682	0,495
iq2	2 (1-4)	3 (1-4)	-0,539	0,590
Aorta Vod2	40,3 (31-47)	33 (26,3-53)	-1,863	0,062
Aorta Vid2	35,87±5,98	31,06±3,71	2,391	0,030
Aorta HU2	326,09±97,88	367,18±81,96	-1,201	0,241
LM Vod2	5,95±1,01	4,84±1,27	2,445	0,022
LM Vid2	4,44±1,01	3,83±1,07	1,521	0,140
LM HU2	299 (148-475)	325 (210-550)	-0,612	0,541
LAD Vod2	4,82±1,00	3,74±0,67	3,446	0,002
LAD Vid2	3,65±0,77	2,72±0,51	3,815	0,001
LAD HU2	334 (147-900)	334 (220-925)	-0,26	0,795
Cx Vod2	4,21±0,94	3,25±0,59	3,36	0,002
Cx Vid2	3,29±0,76	2,48±0,50	3,45	0,002
Cx HU2	302,36±102,50	334,38±87,27	-0,873	0,391
RCA Vod2	4,80±1,57	3,65±0,90	2,194	0,045
RCA Vid2	3,51±1,14	2,75±0,81	2,06	0,050
RCA HU2	294,27±77,56	323,88±88,75	-0,904	0,374

iq: image quality, Vod: Vessel outer diameter, Vid: Vessel inner diameter, HU: attenuation value 1: first radiologist measurement 2: second radioligist measurement

(HDCTA) (14,3 mSv) was higher than that of SDCTA (6,5 mSv). The mean tube current was 180 (mA) in HDCT and 147(mA) in SDCT when the same voltage (kVp) were used in both methods (Table 2).

There was no important difference between image quality assesments of radiologists and attenuation values of HDCT and SDCT in stable heart rate up to 75 beats per minute (bpm) when using the minimal X-ray exposure time (table 3).

Table 2: Intraclass Correlation Coefficient (ICC)

	CT type	
Variables	HD (n=11)	SD (n=17)
Aorta Vod	0,337	0,777
Aorta Vid	0,152	0,677
Aorta HU	0,288	0,908
LM Vod	0,665	0,621
LM Vid	0,498	0,571
LM HU	0,080	0,969
LAD Vod	0,741	-0,334
LAD Vid	0,434	0,322
LAD HU	-0,140	0,960
Cx Vod	0,832	0,466
Cx Vid	0,674	0,582
Cx HU	0,327	0,887
RCA Vod	0,684	0,716
RCA Vid	0,592	0,831
RCA HU	0,313	0,916

iq: image quality, Vod: Vessel outer diameter, Vid: Vessel inner diameter, HU: attenuation value 1: first radiologist measurement 2: second radioligist measurement

Table 3: The measurements of two radiologists from both type of CT scanners

	HDCT	SDCT	test	p
Tube curr1	180 (180-200)	147 (67-183)	-4,044	<0,001
dose mSv1	14,39 (12,42-18,9)	6,45 (4,05-9,46)	-4,399	<0,001
iq1	3 (1-4)	3 (1-3)	-0,857	0,392
iq2	2 (1-4)	3 (1-4)	-0,539	0,59
Aorta HU1	373,82±74,36	353,18±94,02	0,613	0,545
Aorta HU2	326,09±97,88	367,18±81,96	-1,201	0,241
Cx HU1	339,64±77,86	315,00±109,33	0,642	0,527
Cx HU2	302,36±102,50	334,38±87,27	-0,873	0,391
LAD HU1	334 (258-447)	316 (126-952)	-0,753	0,452
LAD HU2	334 (147-900)	334 (220-925)	-0,26	0,795
LM HU1	364,09±66,79	325,94±104,37	1,068	0,296
LM HU2	299 (148-475)	325 (210-550)	-0,612	0,541
RCA HU1	318 (285-432)	316 (178-514)	-0,682	0,495
RCA HU2	294,27±77,56	323,88±88,75	-0,904	0,374

iq: image quality, Vod: Vessel outer diameter, Vid: Vessel inner diameter, HU: attenuation value 1: first radiologist measurement 2: second radioligist measurement

Discussion

Coronary artery disease (CAD) is one of the major causes of death and recently the 64-slice multi-detector row computed tomography (MDCT) permits successful evaluation of coronary artery. The diagnostic performance of MDCT for coronary artery evaluation have shown high accuracy for the detection of obstructive coronary artery stenosis in general patient populations[6,7].

The reported sensitivity was between 86-99% and specificity 93-97%. The negative predictive value was 95–99% that suggests coronary CT angiography (CTA) has the potential to rule out the presence of coronary stenosis[8,9].

But MDCT has a limited temporal and spatial resolutions compared with catheter angiography that reduced diagnostic performance of coronary CTA. The accuracy for detection of coronary stenosis is lower in the presence of severe calcification[10,11].

HDCT scanner with high sampling rate data acquisition system, X-ray tube with the deflecting focal spot and a gemstone detector, improved the in-plane spatial resolution to 0.23 mm and a contrast resolution to 3 mm. The gemstone detector is made from a complex rare earth particle which has a garnet crystal structure. The Gemstone detector has the direct effect of decreasing in-plane spatial resolution[12].

While spatial and temporal resolution increase, there is an increase in radiation dose[13]. The exposure to radiation has to be as low as reasonably achievable (ALARA). In our study, the effective dose is higher than that for diagnostic coronary angiography reported that is 2.1/2.5 mSv (male/female)[14]. The radiation dose varies with the square of the kilo voltage. For reduction of radiation dose, we should have used lower tube voltage such as 80 kV or 100 kV. Furthermore, the decreased tube voltage leads to increased opacification of vascular structures during contrast-enhanced CTA owing to an increase in the photoelectric effect and a decrease in Compton scattering[15].

Limitation

The first limitation of our study, 120 kVp was mainly used although no tube voltage value had been widely accepted as standard for coronary artery imaging . We have found that HDCT has also more tube current so that the effective dose was higher. Second, since we focus on spatial resolution on coronary artery imaging, the impact of temporal resolution was not mentioned, and no specific heart rate had been used. Third, we studied different patients from different hospitals so that there was no physical unity. The patients had wider AA and RCA in the SDCT compared to HDCT. Last and the most important limitation was the hardware problem so we could not be able to use a novel ASIR method to reconstruct CT images.

HDCT has a higher radiation dose than SDCT but has much more attenuation, and the spatial resolution was estimated to be 0.71 mm on SDCT and 0.50 mm on HDCT which improve measurement accuracy for imaging coronary arteries.

ASIR techniques are theoretically more accurate in the modeling of physical noise and tissue geometries. Prior in vitro studies have shown improved image quality for enhanced image resolution as well as lower image noise by use of these Bayesian iterative algorithms[16].

Conclusion

There are few clinical studies comparing HDCT with SDCT. Because it is hard to find both devices in the same center and the radiation dose is much higher when applying both scans to one patient. We compared the radiologist image quality assessment and correlations of vascular diameter measurements. HDCT offers a little improved measurement accuracy for imaging coronary arteries compared to conventional SDCT. The diagnostic performance of HDCT for coronary artery imaging compared to SDCT is better, but ASIR is mandatory for a lower radiation dose.

References

1. Schuijf JD, Pundziute G, Jukema JW, Lamb HJ, Tuinenburg JC, van der Hoeven BL, et al. Evaluation of patients with previous coronary stent implantation with 64-section CT. Radiology.2007;245:416– PubMed ;423.
2. G.L. Raff, M.J. Gallagher, W.W. O'Neill, J. Goldstein Diagnostic accuracy of noninvasive coronary angiography using 64-slice spiral computed tomography. *J Am Coll Cardiol* 2005;46: 552– PubMed ;557
3. Vartuli JS, Lyons RJ, Vess CJ et al (2008) GE Healthcare's New Computed Tomography Scintillator—Gemstone. Symposium on Radiation Measurement and Applications, June 2–5, Berkeley, California
4. Wykrzykowska JJ, Arbab-Zadeh A, Godoy G, Miller JM, Lin S, Vavere A, et al. Assessment of in-stent restenosis using 64-MDCT: analysis of the CORE-64 Multicenter International Trial. *AJR Am J Roentgenol.* 2010;194:85– PubMed ;92.
5. Wen Jie Yang, Ke Min Chen, Li Fang Pang, Ying Guo,

Jian Ying Li, Huang Zhang, Zi Lai Pan. High-Definition Computed Tomography for Coronary Artery Stent Imaging: a Phantom Study. *Korean J Radiol.* 2012 ; 13: 20–26.

6. M.J. Budoff, D. Dowe, J.G. Jollis, M. Gitter, J. Sutherland, E. Halamert, M. Scherer, R. Bellinger, A. Martin, R. Benton, A. Delago, J.K. Min Diagnostic performance of 64-multidetector row coronary computed tomographic angiography for evaluation of coronary artery stenosis in individuals without known coronary artery disease: results from the prospective multicenter ACCURACY (Assessment by Coronary Computed Tomographic Angiography of Individuals Undergoing Invasive Coronary Angiography) trial. *J Am Coll Cardiol* 2008;52:1724– PubMed ;1732

7. M. Hamon, G.G. Biondi-Zoccai, P. Malagutti, P. Agostoni, R. Morello, M. Valgimigli, M. Hamon Diagnostic performance of multislice spiral computed tomography of coronary arteries as compared with conventional invasive coronary angiography: a meta-analysis. *J Am Coll Cardiol* 2006;48:1896– PubMed ;1910

8. Ropers D, Rixe J, Anders K, et al. Usefulness of multidetector row computed tomography with 64-× 0.6-mm collimation and 330-ms rotation for the noninvasive detection of significant coronary artery stenoses. *Am J Cardiol* 2006 ;97 : 343–348

9.Fine JJ, Hopkins CB, Ruff N, Newton FC. Comparison of accuracy of 64-slice cardiovascular computed tomography with coronary angiography in patients with suspected coronary artery disease. *Am J Cardiol* 2006; 97:173 –174

10. Hoffmann U, Moselewski F, Cury RC, et al. Predictive value of 16-slice multidetector spiral computed tomography to detect significant obstructive coronary artery disease in patients at high risk for coronary disease: patient versus segment-based analysis. Circulation 2004;110:2638& PubMed nbsp;–2643

11. Cordeiro MA, Miller JM, Schmidt A, et al. Noninvasive half millimetre 32 detector row computed tomography angiography accurately excludes significant stenoses in patients with advanced coronary artery disease and high calcium scores. Heart 2006;92:589– PubMed ;597

12. Yang, W.Chen, K.Pang, L.Pan, High-Definition Computed Tomography for Coronary Artery Stent Imaging: a phantom study. *Korean J Radiol.* 2012; 13: 20– PubMed ;26.

13. Hausleiter J, Meyer T, Hadamitzky M, et al. Radiation dose estimates from cardiac multislice computed tomography in daily practice: impact of different scanning protocols on effective dose estimates. *Circulation* 2006;113:1305– PubMed ;1310

14. Coles DR, Smail MA, Negus IS, et al. Comparison of radiation doses from multislice computed tomography coronary angiography and conventional diagnostic angiography. *J Am Coll Cardiol* 2006; 47:1840 –1845

15. Ertl-Wagner BB, Hoffmann RT, Bruning R, et al. Multi-detector row CT angiography of the brain at various kilo voltage settings. *Radiology* 2004; 231: 528–535

16. J.B. Thibault, K.D. Sauer, C.A. Bouman, J. Hsieh A three-dimensional statistical approach to improved image quality for multislice helical CT. Med Phys 2007; 34: 4526– PubMed ;4544