# Impact of Motion Artifacts on Reproducibility of Repeated Coronary Artery Calcium Measurements

Abstract:

The purpose of this study is, using a 16-section multidetector-row helical computed tomography (MDCT) scanner with retrospective reconstruction, to compare variability in repeated coronary calcium scoring and qualitative scores of the motion artifacts. One hundred and forty-four patients underwent two subsequent scans using MDCT. According to Agatston and volume algorithms, the coronary calcium scores during mid-diastole (the center corresponding to 70% of the R-R cycle) were calculated and the inter-scan variability was obtained. Motion artifacts from coronary artery calcium were subjectively evaluated and classified using a 5-point scale: 1 _ excellent; no motion artifacts; 2 _ fine, minor motion artifacts; 3 _ moderate, mild motion artifacts; 4 _ bad, severe motion artifacts and 5 _ poor, doubling or discontinuity. Each reading was done by vessels (left main, left descending, left circumflex and right coronary arteries) and the motion artifact score (mean of the scales) was determined per patient. The variability in low (1.2 ± 0.2) and high (2.4 ± 0.6) motion artifact score groups was 7 ± 6 (median, 6)% and 19 ± 15 (16)% on Agatston score ($p<0.01$) and 7 ± 7 (6)% and 16 ± 13 (14)% on volume score ($p<0.01$), respectively. In conclusion, motion have a significant impact on reproducibility of coronary calcium scoring.

Introduction:

Low interscan variability and accuracy of coronary artery calcium (CAC) measurement are essential to monitor CAC for the assessment of the progression and regression of coronary atherosclerosis, risk factors and medical interventions [1,2]. Factors influencing inter-scan variability on CAC measurement reported are as follows; partial volume effect [3], the use of the step function in the Agatston method to quantitate calcium [4], coronary artery motion [5], image noise [6], field inhomogeneity [7], lack of calibration [8], total volume of CAC [9], scoring parameters [10], intraobserver and interobserver variations [11], etc. Some more details in the factors above are as follows: The use of a continuous weighting function instead of the step function decreases the variability. The variability is lower in the higher CAC score group. The CAC scoring parameters (four-connected or eight-connected, lesion size threshold and interpolation) affect the CAC score, therefore the parameters should be standardized. However, how important each of these factors is and therefore what should be done to reduce variability is not well understood.

The purpose of this study is, using a 16-section MDCT scanner with retrospective reconstruction, to test the extent to which motion artifacts from CAC have an impact on variability in repeated coronary calcium scoring.

Materials and methods:

The study was approved by our institutional review committee. Written informed consent was received from all patients involved after the nature of the procedure had been fully explained. For 15 months, 144 consecutive subjects (96 males and 48 females,

68±9 years old: range, 44-85 years) who were asymptomatic, with at least one cardiac risk factor (n = 85) or complaints of chest pain (n = 59) were included. Prior to scanning, the technologists trained subjects in breath-hold techniques. Two subsequent volume scans were performed using a 16-section MDCT scanner (LightSpeed Ultrafast 16; GE Healthcare, Waukesha, WI) with no change in subject positioning. The table was advanced by 1mm each time (home position: 0 and +1mm), during the subsequent scans.

16-section MDCT Protocol

Volumetric data of the entire heart were obtained by helical mode with scan parameters of a 1.25mm collimation width x 16 detectors, a gantry rotation speed of 0.5 sec/rotation, 120kV and 100mA. CT pitch factors were variable by the heart rate and were set according to the manufacturer's recommendations for coronary CT angiography protocol, i.e. 0.275 below 45bpm, 0.3 for 45-49bpm, 0.325 for 50-59bpm, 0.3 for 60-74bpm, and 0.275 for over 76bpm. In image reconstruction, single-sector, which is derived from approximately 240 degrees of one 360-degree gantry rotation data, was used when the heart rate was below 60bpm. Due to using half scan weighting, the effective temporal resolution will be: rotation speed x 2/3 (240 degree) x 0.75 = 250msec. Multisector reconstruction was applied when the heart rate was more than 60bpm. Multisector reconstruction uses a retrospective ECG-gating algorithm. With this, by combining some (n=2 to 4, depending on the heart rate) adjacent cardiac cycles (segments), temporal resolution is improved while maintaining image quality [12]. In a recent study, the influence of multisector reconstruction on image quality is only

observed at heart rates above 70 bpm [13]. One should also be aware that image quality does not increase even using multisector reconstruction when the heart rate varies between heart beats.

The center of the temporal window was set to 70% of the R-R interval. To reduce the influence of partial volume averaging, overlapping reconstruction, i.e. 2.5mm thickness images with 1.25mm increment were reconstructed [14-17]. Image reconstruction was performed with a 512 x 512 pixel matrix using a standard kernel. A display field of 26cm was sufficient and yielded a pixel size of approximately 0.5x0.5 $mm^2$.

Calcium Scoring

Agatston and volume scores were determined on a commercially available external workstation (Advantage Windows Version 4.1, GE Healthcare) using CAC-scoring software (Smartscore Version 3.5). In accordance with the Agatston method [18], we defined the ROIs by vessel and slice with the threshold option for pixels greater than 130 Hounsfield units (HU) to measure the area and peak density of plaques. Depending on the peak density of the plaque, an area of at least 0.52$mm^2$ (2 pixels) was multiplied by one of the following cofactors: a factor of 1 for 130-199HU, a factor of 2 for 200-299HU, a factor of 3 for 300-399HU, and a factor of 4 for densities greater than 400HU. The total calcium score was calculated as the sum of the individual lesion scores in all coronary arteries. The calcium volume [19] was calculated using the following equation:

Volume= $\sum$ (area x slice increment)

The calcium mass was not calculated because no calibration phantom was available. To avoid interobserver variability, all CT scans were scored by a radiologist with 6 years experience of CAC measurement. The percentage of variability on Agatston and volume scores was calculated using the following equation:

[absolute (scan1 – scan2 ) / 0.5 x [(scan1 + scan2)]] x 100.

Scoring of motion artifacts

Motion artifacts from coronary artery calcium were subjectively evaluated and graded using a 5-point scale: 1 _ excellent; no motion artifacts, sharply delineated; 2 _ fine, minor motion artifacts, blurred lesion margin; 3 _ moderate, mild artifacts, tail-shaped artifacts; 4 _ bad, severe motion artifacts, star-shaped artifacts; and 5 _ poor, doubling or discontinuity of calcium (Fig. 1). In each patient, reading was done vessel by vessel; i.e. left main (LM), left anterior descending (LAD), left circumflex (LCx) and right coronary arteries (RCA) on two subsequent CT scans by two radiologists who were unaware of the CAC measurement results. In case the consensus of the grade was not obtained, a third radiologist participated in the grade determination. The final decision was made on a 2:1 decision. When the grade differed between two subsequent CT scans, the worse grade was assigned to the grade of the coronary vessel. This evaluation of the coronary arteries was mainly performed on eight of the 15 coronary segments according to the American Heart Association classification: LM; the proximal and middle segments of LAD and LCX; and the proximal, middle, and distal segments of RCA. This is due to the fact that small calcium does not have much effect on total CAC scoring. The motion artifact score was defined per patient as the mean of the

grades assigned to 4 parts (LM, LAD, LCx and RCA) of coronary artery burden with calcium.

First, the grades of motion artifacts were compared between LM, LAD, LCx and RCA. Next, the relationship between the motion artifact score and the variability of CAC scoring was assessed. Lastly, dividing the patients (n=144) into two groups (n=72) according to the motion artifact scores (low and high), the heart rate, heart rate change, CAC scores and the variability were compared between the two groups. For statistical analysis, t-tests, Kruskal-Wallis test and ANOVA followed by Bonferroni/Dunn test were used to determine differences.

Results:

All patients were able to hold their breath on two subsequent scans. Median heart rate 66 ± 12 bpm (ranged, 44-99 bpm) on scan1, and 65 ± 13 bpm (ranged, 47-95 bpm) on scan2. Change in heart rate (difference between maximum and minimum of heart rate in the scan) was 7 ± 13 bpm during scan1 and 8 ± 14 bpm during scan2. The number of segments used in the multisector reconstruction was 2 to 4. The number depended on the heart rate and variability, thus varied even during one scan. Almost all MDCT images had a temporal resolution from 100 to 250msec, determined according to the heart rate and the number of segments used for reconstruction.

Mean scores on two subsequent scans were 570 ± 748 (median, 271) and 464 ± 579 (median, 248) on Agatston and volume, respectively. Variability between two subsequent scans were 13 ± 13% (median, 9%) and 12 ± 11% (median, 8%) on Agatston

and volume, respectively.

Among 144 patients, CAC was detected in 72, 130, 94 and 108 patients on LM, LAD, LCx and RCA, respectively. Distribution of the grades of motion artifacts per coronary artery branches is shown (Fig. 2). Per vessel analysis, motion artifacts were graded as 1.4 ± 0.7 (median, 1), 1.6 ± 0.7 (median, 1), 1.7 ± 0.8 (median, 2) and 2.4 ± 1.1 (median, 2) on LM, LAD, LCx and RCA, respectively. When comparing the number of grades, there were statistical differences between the coronary artery branches (Kruskal-Wallis test; $p<0.01$). On ANOVA followed by Bonferroni/Dunn test, the grades of RCA were higher (with more motion artifacts) than those of other coronary branches ($p<0.001$), whereas there were no differences between LM, LAD and LCx.

The motion artifact score, determined per patient by the mean of the grades, was 1.8 ± 0.7 (median, 1.7: ranged 1 to 4). Relationship between the score and variability of repeated Agatston and volume scores are shown (Fig. 3 and 4). Using the median motion artifact score of 1.67, 144 patients were divided into two groups. The heart rate and the variability of both CAC scores between two subsequent scans were lower in the low score group (<0.01, t-test) (Table 1).

Discussion:

Motion artifacts from CAC is one of the important causes of increasing variability; however, how big an effect, has not been well demonstrated before. Results of a previous study have shown that variability of CAC scoring is high at high heart rates on prospective ECG-triggering MDCT [20]. However, according to our knowledge, there have not been many studies published to compare between the intensity of motion

artifacts and the variability of CAC scoring [21].

Variability of Agatston scores using electron beam CT yields 20% to 37% [4,9,19,22]. Although the temporal resolution of MDCT is lower than that of electron beam CT, MDCT with overlapping image reconstruction shows lower variability of 12% compared with 23% with non-overlapping [16] and 13% compared with 22% [23]. We, therefore, believe that partial volume effect is one of the most important factors on influencing variability of CAC scoring, and that the use of overlapping image data sets is suited for validating the effect of motion artifacts. Image noise [6], in other words, standard deviation of images [9], is known as another factor. Our MDCT protocol, using a tube current of 100mA, provides low-noise images [24], therefore is also able to minimize the effect of image noise on variability of CAC scoring.

There have been many studies exploring variability of CAC scoring per coronary arteries. Lu et al. [25] showed that interscan variabilities in individual arterial scores were highest in the LM, followed by the RCA, LCx, and LAD. The finding that the largest score variation occurred in the LM may have been due in part to difficulty in delineating the exact junction between the LM, LAD, and LCx [26]. For example, calcification near the junction of the LM bifurcation into the LAD and LCx may be assigned to the LM, whereas at the second reading or examination, the same lesion may be assigned to the LAD or LCx. The phenomenon is considered to be a major drawback in this kind of analysis. Our approach is limited to being a semi-quantitative analysis, however is not subject to this phenomenon.

In a previous study, Lu et al. [27] measured coronary motion and found that the rest periods in the cardiac cycle for the LAD artery, LCx, and RCA were 439.4–1,060.4

msec, 101.9–258.8 msec, and 87.2–167.7 msec, respectively, at heart rates lower than 70 bpm. Temporal resolution of 250 msec, which is a fixed value by single-sector when heart rates are below 60bpm in our study, is considered insufficient especially when imaging the RCA. Hong et al. [20] using prospective ECG-triggering MDCT with temporal resolution of 250 msec, interacquisition variability in the low heart rate group (70 bpm or lower) was lower than that in the high heart rate group (higher than 70 bpm). We used multisector reconstruction when the heart rate was more than 60bpm. It is known that changes in heart rate or cardiac rhythm may alter the duration or location of the components in the cardiac cycle, and thus, acquisition may be disturbed by systole or atrial contraction. This retrospective ECG gating algorithm does not rely on prospective estimations of the duration of the R-R interval. Image reconstruction can be performed at arbitrary or multiple cardiac phase(s) according to the real R-R interval, therefore is able to minimize the influence of heart rate variation. In addition, by combining some adjacent cardiac cycles segments, temporal resolution is improved. These factors are advantageous for reducing motion artifacts, however we were often unable to suppress motion artifacts especially on high heart rate patients. The result in our study that RCA was most difficult to suppress motion artifacts is well understandable when we relate the motion speed of individual coronary arteries [27,28,29] with the motion artifacts. For better imaging of CAC using MDCT, further reduction of gantry rotation time is considered mandatory despite when multisector reconstruction is used.

One limitation of our study is that we chose 70% for reconstruction of all heart rates, although we used retrospective-gated technique without dose modulation.

Determination of the data acquisition window is also a vital factor as the optimal ECG-triggering point for minimizing motion artifacts differs between heart rates, lengths of acquisition windows and of course, individuals [30]. The rest period is located in diastasis for low heart rates and in end-systole for high heart rates or atrial fibrillation [31]. Recently, a dynamic model called the ‘delay algorithm’ which enables us to capture the same physiological phase or ‘state’ of the anatomy during the cardiac cycle as the instantaneous heart rate varies during the spiral scan has been introduced [32]. Hoffmann et al have introduced a clinical evaluation of the motion map, which will allow to measure low motion phases after scan acquisition automatically [33]. The other limitation is that we did not perform calcium mass scoring which has been proposed to be used as the standard measurement of CAC.

If we are able to reduce motion artifacts as to the level of the low motion artifacts score group with variability of 7 ± 7 (6)% on Agatston scores and of 7 ± 7 (6)% on volume scores, monitoring coronary atherosclerosis on MDCT will be very promising. The level of variability is far superior to that on electron beam CT and is recommendable in consideration of normal progression of CAC score per year; 14-27% [34] and accelerated level with significant coronary disease; 33-48% [35,36].

Although not the focus in this study, lowering radiation exposure is vital for CAC scoring using MDCT especially retrospective ECG-gated technique. ECG-controlled modulation [37] or/and the use of low-dose (low milliampere) [24] will contribute to this. In conclusion, motion artifacts have a significant impact on variability of CAC scoring. Reducing motion artifacts by improving temporal resolution and optimization of the data acquisition window, such as the reconstruction of multiple phases, enables

MDCT to be a further useful tool for monitoring coronary atherosclerosis.

References:


1. Callister TQ, Raggi P, Cooil B, Lippolis NJ, Russo DJ (1998) Effect of HMG-CoA reductase inhibitors on coronary artery disease as assessed by electron-beam computed tomography. N Engl J Med 339:1972-1978
2. Budoff MJ, Lane KL, Bakhsheshi H, et al (2000) Rates of progression of coronary calcium by electron beam tomography. Am J Cardiol 86:8-11
3. Kajinami K, Seki H, Takekoshi N, Mabuchi H (1993) Quantification of coronary artery calcification using ultrafast computed tomography: reproducibility of measurements. Coron Artery Dis 4:1103–1108
4. Yoon HC, Greaser III LE, Mather R, Sinha S, McNitt-Gray MF, Goldin JG (1997) Coronary artery calcium: alternate methods for accurate and reproducible quantitation. Acad Radiol 4:666-673
5. Mao S, Bakhsheshi H, Lu B, Liu SCK, Oudiz RJ, Budoff MJ (2001) Effect of electrocardiogram triggering on reproducibility of coronary artery calcium scoring. Radiology 220:707-711
6. Bielak LF, Kaufmann RB, Moll PP, McCollough CH, Schwartz RS, Sheedy PF II (1994) Small lesions in the heart identified at electron beam CT: calcification or noise? Radiology 192:631-636
7. Detrano R, Kang X, Mahaisavariya P, et al (1994) Accuracy of quantifying coronary hydroxyapatite with electron beam tomography. Invest Radiol 29:733-738
8. McCollough CH, Kaufmann RB, Cameron BM, Katz DJ, Sheedy PF II, Peyser PA (1995) Electron-beam CT: use of a calibration phantom to reduce variability in calcium quantification. Radiology 196:159-165

9. Achenbach S, Ropers D, Mohlenkamp S, et al (2001) Variability of repeated coronary artery calcium measurements by electron beam tomography. Am J Cardiology 87:210-213
10. van Ooijen PM, Vliegenthart R, Witteman JCM, Oudkerk M (2005) Influence of scoring parameter settings on Agatston and volume scores for coronary calcification. Eur Radiol 15:102-110
11. Kaufmann RB, Sheedy PF II, Breen JF, et al (1994) Detection of heart calcification with electron beam CT: interobserver and intraobserver reliability for scoring quantification. Radiology 190:347–352
12. Horiguchi J, Nakanishi T, Ito K (2001) Quantification of coronary artery calcium using multidetector CT and a retrospective ECG-gating reconstruction algorithm. AJR 177:1429-1435
13. Greuter MJW, Dorgelo J, Tukker WGJ, Oudkerk M (2005) Study on motion artifacts in coronary arteries with an anthropomorphic moving heart phantom on an ECG-gated multidetector computed tomography unit. Eur Radiol 15:995-1007
14. Achenbach S, Meissner F, Ropers D, et al (2001) Overlapping cross-sections significantly improve the reproducibility of coronary calcium measurements by electron beam tomography: a phantom study. JCAT 25:569-573
15. Kopp AF, Ohnesorge B, Becker C, et al (2002) Reproducibility and accuracy of coronary calcium measurements with multi–detector row versus electron-beam CT. Radiology 225:113-119
16. Ohnesorge B, Flohr T, Fischbach R, et al (2002) Reproducibility of coronary calcium quantification in repeat examinations with retrospectively ECG-gated

multisection spiral CT. Eur Radiol 12:1532-1540

17. Mahnken AH, Wildberger JE, Sinha AM, et al (2002) Variation of the coronary calcium score depending on image reconstruction interval and scoring algorithm. Invest Radiol 37:496–502
18. Agatston AS, Janowitz WR, Hildner FJ, Zusmer NR, Viamonte M, Detrano R (1990) Quantification of coronary calcium using ultrafast computed tomography. J Am Coll Cardiol 15: 827-832
19. Callister TQ, Cooil B, Raya SP, et al (1998) Coronary artery disease: improved reproducibility of calcium scoring with an electron-beam CT volumetric method. Radiology 208:807-814
20. Hong C, Bae KT, Pilgram TK, Zhu F (2003) Coronary artery calcium quantification at multi–detector row CT: influence of heart rate and measurement methods on interacquisition variability-initial experience. Radiology 228:95-100
21. Detrano RC, Anderson M, Nelson J, et al (2005) Coronary calcium measurements: effect of CT scanner type and calcium measure on rescan reproducibility—MESA study. Radiology 236:477–484
22. Wang S, Detrano RC, Secci A, et al (1996) Detection of coronary calcification with electron-beam computed tomography: evaluation of interexamination reproducibility and comparison of three image-acquisition protocols. Am Heart J 132:550-558
23. Horiguchi J, Yamamoto H, Akiyama Y, et al (2005) Variability of Repeated coronary artery calcium measurements by 16-slice spiral CT with retrospective reconstruction. AJR 184:1917-1923

24. Horiguchi J, Yamamoto H, Akiyama Y, et al. Variability of repeated coronary artery calcium measurements by low-dose ECG- gated 16-slice spiral CT. AJR in press
25. Lu B, Zhuang N, Mao SS, et al (2002) EKG-triggered CT data acquisition to reduce variability in coronary arterial calcium score. Radiology 224:838–844
26. Shields JP, Mielke CH Jr, Watson P (1996) Inter-rater reliability of electron beam computed tomography to detect coronary artery calcification. Am J Card Imaging 10:91–96
27. Lu B, Mao SS, Zhuang N, et al (2001) Coronary artery motion during the cardiac cycle and optimal ECG triggering for coronary artery imaging. Invest Radiol 36: 250–256
28. Achenbach S, Ropers D, Holle J, Muschiol G, Daniel WG, Moshage W (2000) In-plane coronary arterial motion velocity: measurement with electron-beam CT. Radiology 216:457–463
29. Hofman MB, Wickline SA, Lorenz CH (1998) Quantification of in-plane motion of the coronary arteries during the cardiac cycle: implications for acquisition window duration for MR flow quantification. J Magn Reson Imaging 8:568–576
30. Mao S, Budoff MJ, Bin L, Liu SC (2001) Optimal ECG trigger point in electron-beam CT studies: three methods for minimizing motion artifacts. Acad Radiol 8:1107–1115
31. Hoffmann MHK, Shi H, Manzke R, et al (2005) Noninvasive coronary angiography with 16-detector row CT: effect of heart rate. Radiology 234:86-97
32. Vembar M, Garcia MJ, Heuscher DJ, et al (2003) A dynamic approach to identifying desired physiological phases for cardiac imaging using multislice spiral CT. Med

Phys 30:1683-1693

33. Hoffmann MHK, Lessick J, Manzke R, et al (2005) Automatic determination of minimal cardiac motion phases for computed tomography imaging: initial experience. Eur Radiol
34. Maher JE, Bielak LF, Raz JA, Sheedy PF II, Schwartz RS, Peyser PA (1999) Progression of coronary artery calcification: a pilot study. Mayo Clin Proc 74:347-355
35. Janowitz WR, Agatston AS, Viamonte M Jr (1991) Comparison of serial quantitative evaluation of calcified coronary artery plaque by ultrafast computed tomography in persons with and without obstructive coronary artery disease. Am J Cardiol 68:1-6
36. Fischbach R, Heindel W (2000) Detection and quantification of coronary calcification: an update. Rofo 172:407-414
37. Jakobs TF, Becker CR, Ohnesorge B, et al (2002) Multislice helical CT of the heart with retrospective ECG gating: reduction of radiation exposure by ECG-controlled tube current modulation. Eur Radiol 12:1081-1086

Legends for Illustrations

Fig. 1 Grading intensity of motion artifacts from CAC

A: Grade 1_ excellent; no motion artifacts from CAC

B: Grade 2 _ fine, margin of CAC blurred

C: Grade 3 _ moderate, CAC with tail-shaped artifacts

D: Grade 4 _ bad, CAC with star-shaped artifacts

E: Grade 5 _ poor, doubling or discontinuity of CAC

Fig. 2 The grade of motion artifacts from CAC per branch

The motion artifacts from RCA were more intense than those from LM, LAD and LCx.

Fig. 3 Scatterplots of motion artifact score and the variability of Agatston scores

Variability of Agatston score

= [-0.052+0.099 x (Score of motion artifacts)] x 100% R=0.573

Fig. 4 Scatterplots of motion artifact score and the variability of volume scores

Variability of volume scores

= [-0.012+0.073 x (Score of motion artifacts)] x 100% R=0.480

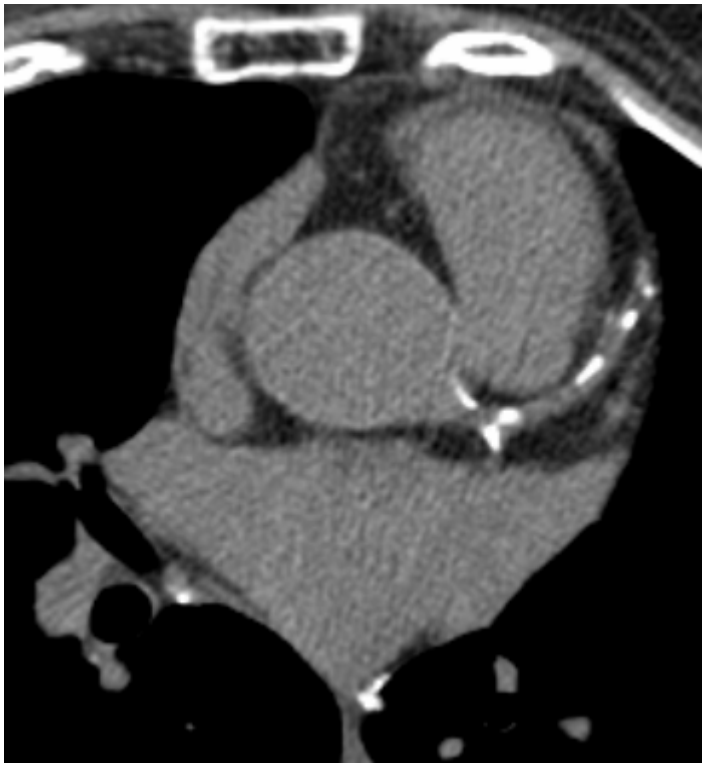

Fig. 1-A

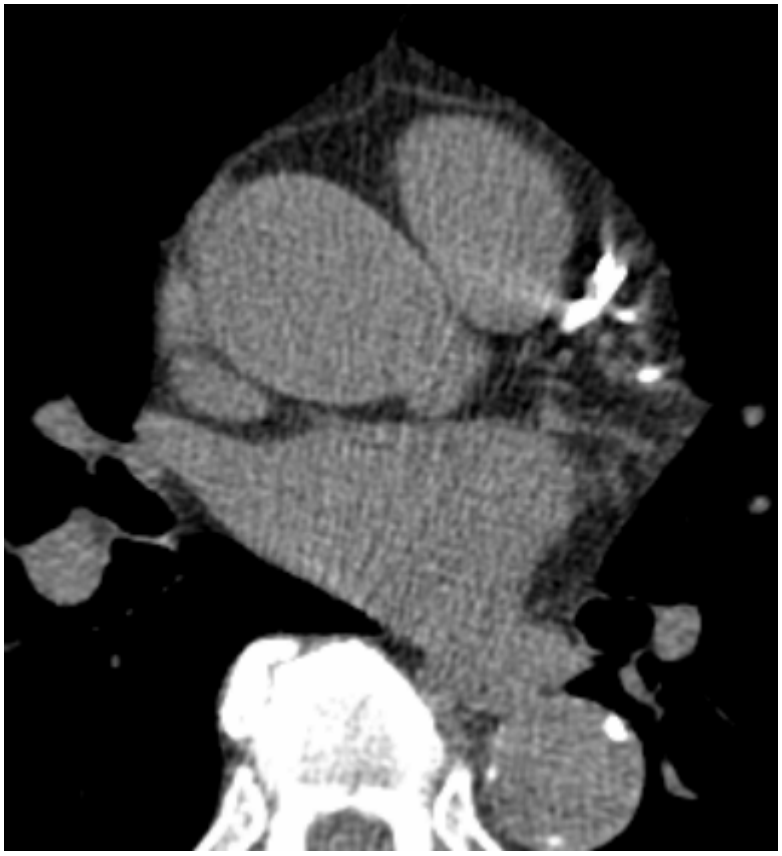

Fig. 1-B

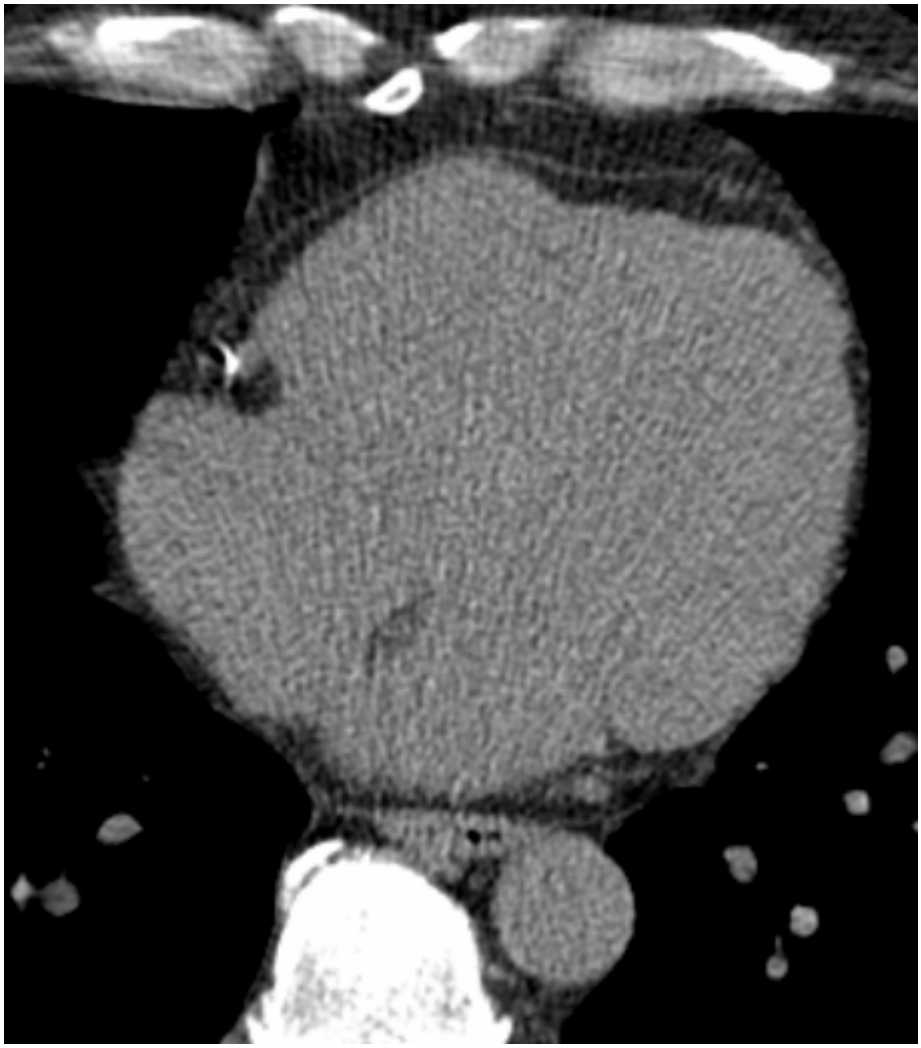

Fig. 1-C

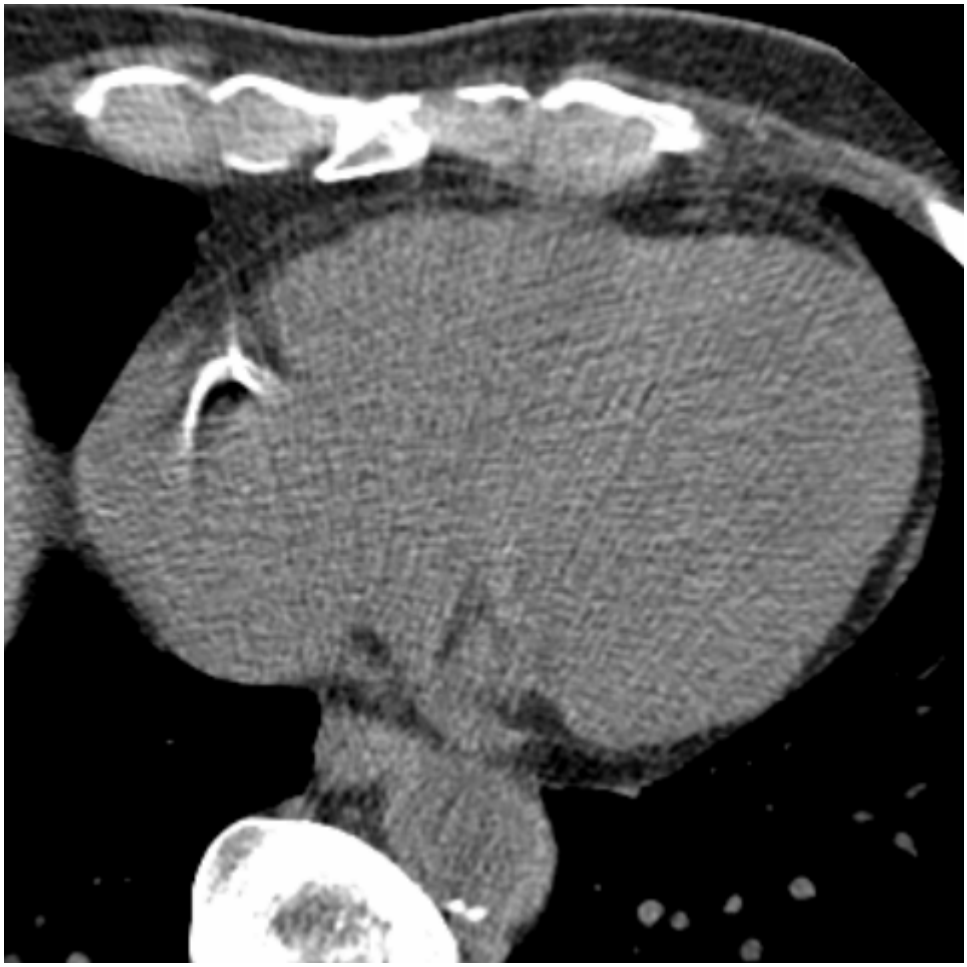

Fig. 1-D

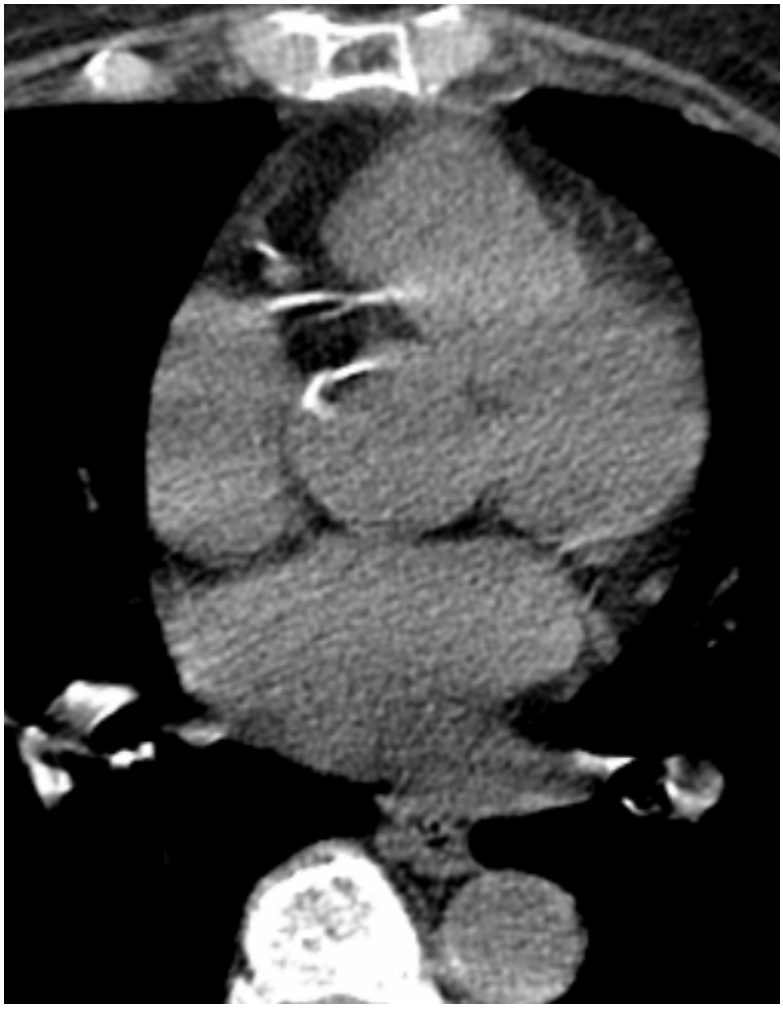

Fig. 1-E

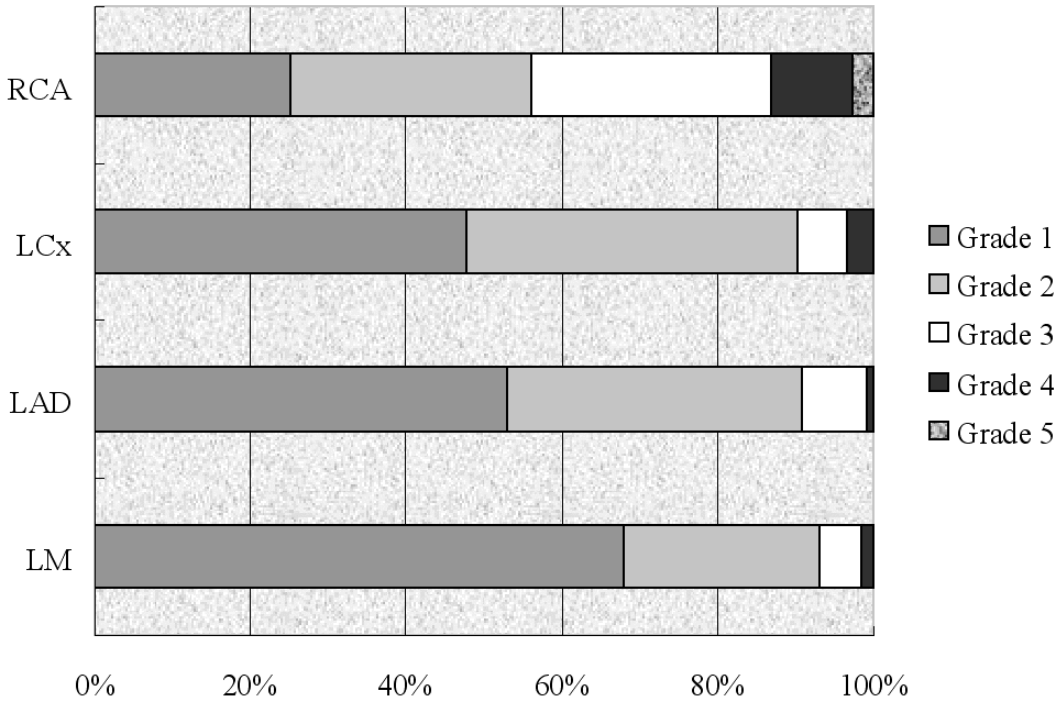
RCA
LCx
LAD
LM
0%
20%
40%
60%
80%
100%
Grade 1
Grade 2
Grade 3
Grade 4
Grade 5

Fig. 2

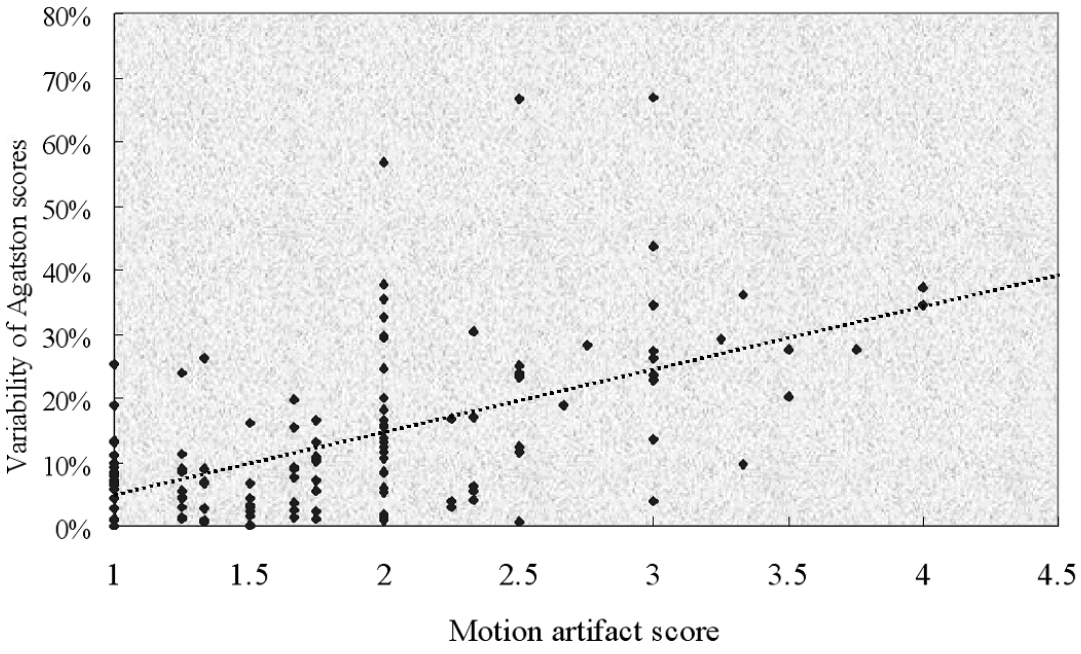
Variability of Agatston scores
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
1.5
2
2.5
3
3.5
4
4.5
Motion artifact score

Fig. 3

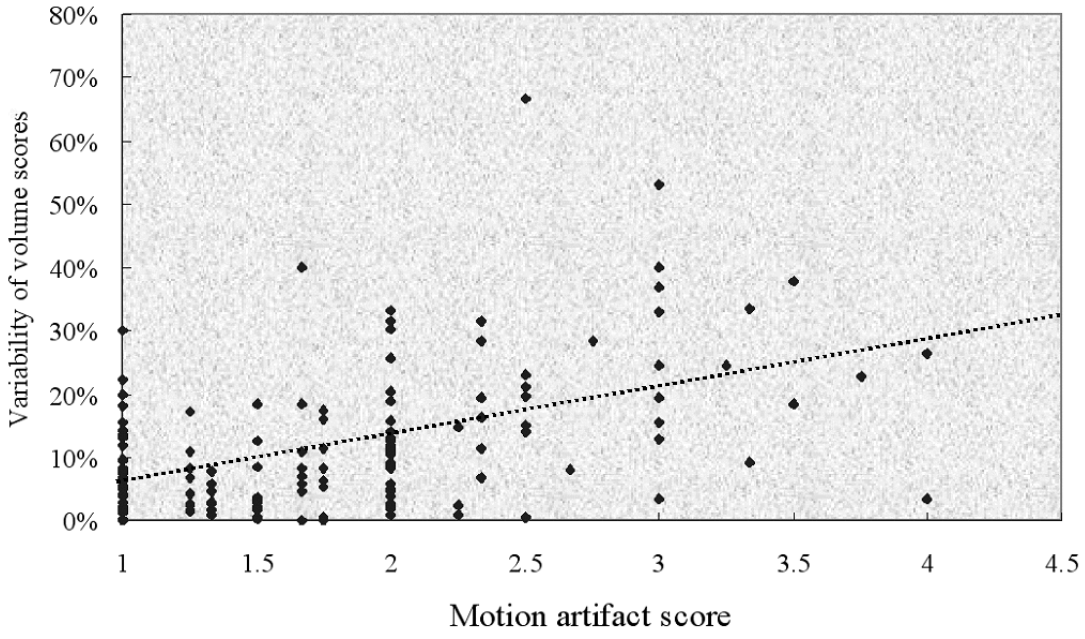
80%
70%
60%
50%
40%
30%
20%
10%
0%
Variability of volume scores
1
1.5
2
2.5
3
3.5
4
4.5
Motion artifact score

Fig. 4

Table 1: Characteristics of parameters in the two groups divided by motion artifact score

| | Artifact score | Heart rate | HR change | Agatston score | Variability of AS | Volume score | Variability of VS |
|---|---|---|---|---|---|---|---|
| Low score group | 1.2 ± 0.2 | 63 ± 12 (62) | 6.3 ± 9.3 (4.0) | 572 ± 749 | 7 ± 6 (6)% | 462 ± 574 | 7 ± 7 (6)% |
| High score group | 2.4 ± 0.6 | 69 ± 11 (69) | 8.0 ± 16.0 (4.0) | 567 ± 752 | 19 ± 15 (16)% | 466 ± 588 | 16 ± 13 (14)% |
| t-test | <0.01 | <0.01 | n.s. | n.s. | <0.01 | n.s. | <0.01 |

Data are expressed as mean ± standard deviation (median)

Artifact score: motion artifact score per patient

Heart rate: mean of heart rate in the scan

HR change: difference between maximum and minimum heart rate in the scan

Variability of AS: variability of Agatston scores between the 2 scans

Variability of VS: variability of volume score between the 2 scans

Statistics are performed using t-test. P-values $< 0.05$ were considered to identify significant differences.

n.s.: not significant