Usefulness of the latest motion artifact correction technology (Cardio StillShot) in coronary CT angiography

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Abstract:

In coronary CT angiography using 64-slice CT, there is an issue that “the success rate decreases as the heart rate rises ” [1)]. In this study, it is important to clarify correction effect of Cardio StillShot[*1](CSS), which is the latest motion artifact correction technology, using a coronary artery phantom and clinical data. In phantom study, half reconstruction images with/without CSS were reconstructed using a coronary artery phantom and the visibility and circularity were compared. In the evaluation for clinical data, segment reconstruction image without CSS and half reconstruction images with/without CSS were reconstructed from data of each heart rate group obtained by coronary CT angiography, and the images were used to create CPR images of the three coronary arteries. The image quality of these CPR images was visually evaluated by two cardiologists. As a result, usefulness with CSS is expected not only for low heart rate but also for HR: 60-69 bpm, HR: 70 bpm or more.

Key word

Coronary CT Angiography Cardio StillShot Motion Artifact Correction High Heart Rate

1 Introduction:

According to the 2014 journal of Japanese circulation society [2)], the number of coronary artery CT examinations has been increasing year by year since 2004, and statistics from Gekkan Shin-Iryo (monthly bulletin of New Medicine) [3)-9)] show that even in these days in which surface detectors are available, coronary artery CT examinations using 64-row CT are still the most common. The reason behind this is that, while area detectors are expensive, 64-row CT is relatively inexpensive and preferred in hospitals of various sizes (Figure 1).

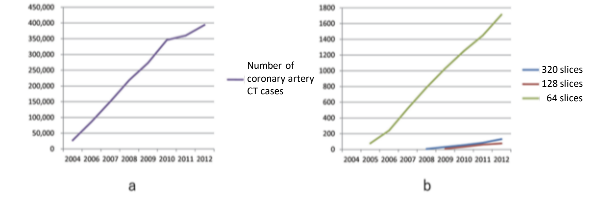

Figure 1: Current status of coronary artery CT in Japan
a: Number of coronary artery CT cases
b: Number of MDCT systems installed

In March 2022, the new findings from "JCS 2018 Guideline on Diagnosis of Chronic Coronary Heart Disease" [10)] and "JCS 2018 Guideline on Revascularization of Stable Coronary Artery Disease" [11)] were summarized and the "JCS 2022 Guideline Focused Update on Diagnosis and Treatment in Patients with Stable Coronary Artery Disease" [12)] was published. A modified pre-examination probability is calculated by adding clinical likelihood to the previous baseline pre-examination probability, and it is now possible to determine whether to perform follow-up or non-invasive examination (Figure 2).

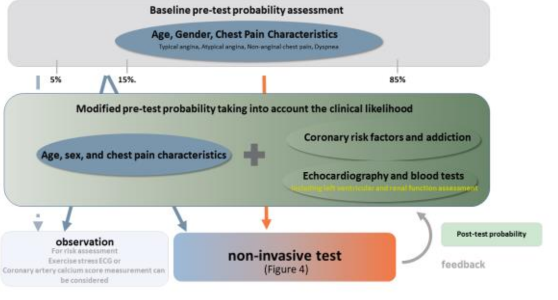

Figure 2: Role of pre-test probability (PTP) and clinical likelihood (CL) assessment in stable CAD

Coronary artery CT examination is recommended for cases of moderate or higher severity if non-invasive examination is judged to be necessary, but it is also stated that it should be avoided if poor image quality is predicted (Figure 3).

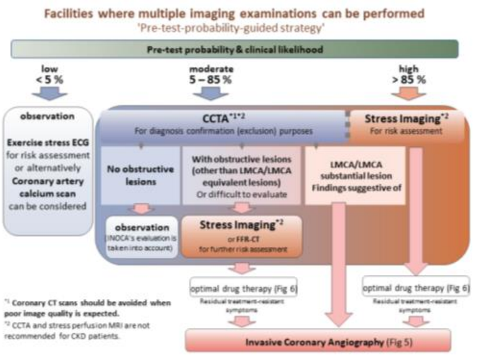

Figure 3: Pre-test probability and staged non-invasive imaging examinations

Therefore, it was necessary to pay close attention to the patient when performing 64-series CT as the heart rate increased.

Figure 4 shows the success rate of coronary artery CT examinations at our hospital between December 15, 2014 and February 15, 2015.

Excellent: Continuity   Good: Less than two discontinuities
Poor: More than 3 discontinuities   Severe: Not stationary

Figure 4: Success rate of coronary artery CT exams at our hospital

It can be seen that as the heart rate (HR) increases, the success rate decreases. In addition, Figure 5 shows the HR histogram, and the percentage of patients with an HR up to 60 bpm is about 80%, and by including the HR up to 70 bpm, the percentage of patients becomes about 90%. When conducting the examinations, it is desirable to increase the success rate of the examinations for patients with HR up to 70 bpm.

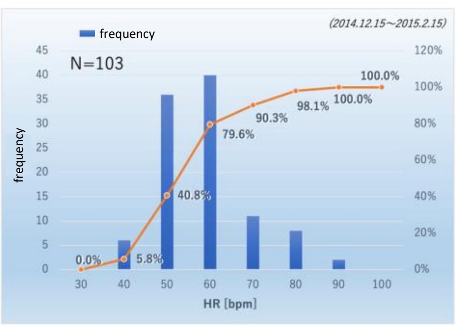

Figure 5: Percentage of HR in our hospital

2 Purpose:

One of the issues with coronary artery CT examination using 64-row CT is that the success rate decreases as the heart rate increases. In this study, we applied Cardio StillShot*1 (hereinafter referred to as CSS), the latest motion artifact correction technology. We will clarify the correction effect at each heart rate and verify its usefulness.

3 Cardio Still Shot, Cardiac Motion Correction Function:

CSS is a half-reconstruction method that performs motion correction processing on raw data. Specifically, it consists of three functions: partial angular image reconstruction, motion estimation, and motion correction. In partial angular image reconstruction, images are intentionally reconstructed within an angular range of less than 180 degrees in order to increase the temporal resolution of images for motion estimation, and images at angular positions 90 degrees away from the center angular position of the correction target image in each direction are used as images for motion estimation.

In motion estimation, shape changes between motion estimation images in opposing positions are extracted as 4-dimensional vectors (hereinafter referred to as motion vectors) containing 3-dimensional space data and time using non-rigid registration technology.

In motion correction, an image is reconstructed from raw data using motion vectors, and since each pixel and each view has a motion vector, backprojection can be performed while motion correction is performed for each view. The above principle makes it possible to reduce image blur caused by heartbeats (Figure 6).

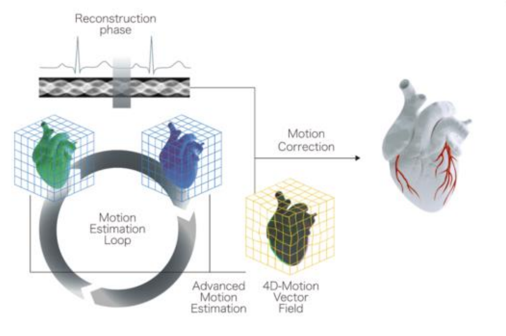

Figure 6: Cardio StillShot Schematic

4 Evaluation:

4.1 Scan and reconstruction

CSS of SCENARIA View Plus*3 was applied to the coronary artery phantom images and clinical images, which were scanned by SCENARIA View*2, a 64-row CT device manufactured by FUJIFILM Healthcare Co., Ltd., .

4.2 Fundamental Evaluation using Coronary Artery Phantom

4.2.1 Method

Fundamental evaluation on CSS was conducted using a coronary artery phantom (MOCOMO phantom manufactured by Fuyo Corporation).

The coronary artery phantom and imaging protocols are shown in Figure 7.

Figure 7: Coronary phantom and imaging protocol

Two types of simulated blood vessels were prepared: a homogeneous one with no internal structure (hereinafter referred to as blood vessel A), and one with a simulated stenosis and calcified structure inside (hereinafter referred to as blood vessel B). The coronary artery phantom was scanned while adjusting the HR of the phantom to 0 bpm, 60 bpm, 70 bpm, and 80 bpm, and half-reconstructed CSS ON/OFF images were reconstructed for each image. Then, using the CEV-CPR function, we created a straight CPR image, an orthogonal cross-sectional image and a circularity graph, and compared to evaluate the image quality and circularity, using the still image (HR: 0 bpm) as the true value.

4.2.2 Results and Consideration

Regarding 60 bpm and 70 bpm, the motion of both straight CPR and orthogonal sections was corrected from the image of blood vessel A (Figure 8), and the results of the circularity graph also showed that the circularity was maintained.

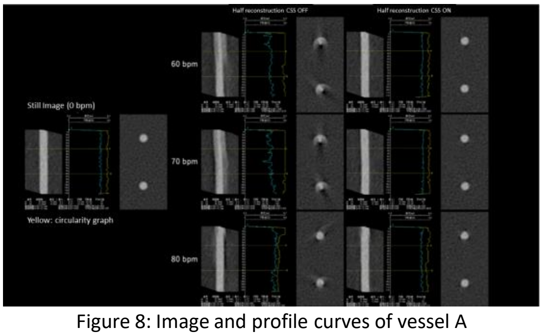

Figure 8: Image and profile curves of vessel A

In addition, in blood vessel B (Figure 9), soft plaques and calcifications that had been difficult to visualize due to motion were clearly visualized due to the correction effect, and the circularity graph was similar to 0 bpm.

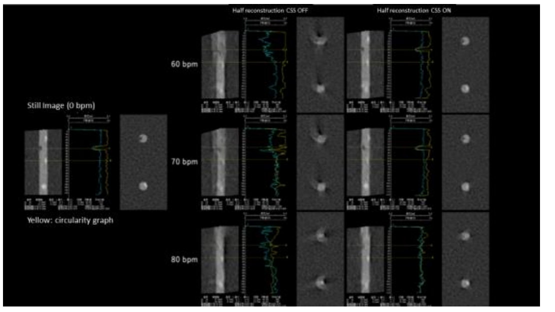

Figure 9: Image and profile curves of vessel B

At 80 bpm, some motion effects remained depending on the cross section, making it difficult to evaluate the soft plaque, but an improvement in calcification was observed.

4.3 Visual Evaluation using clinical images

4.3.1 Method

Based on the clinical data obtained from coronary artery CT examination, 10 cases each excluding arrhythmia were selected for the HR<60 bpm group, 60 bpm≦HR<70 bpm group, and HR≧70 bpm group, and segment reconstruction CSS OFF, and half reconstruction were performed and we searched for each optimal cardiac phase. CPR images of three coronary arteries (LAD, LCX, RCA) were created using SYNAPSE*4 VINCENT*5 Ver.3.3 manufactured by FUJIFILM. And two cardiologists evaluated the continuity of blood vessels using a 5-point scale (Figure 10), and the Wilcoxon signed-rank test was performed on the obtained results.

SCORE	Description
5: Excellent	The boundaries of the blood vessels are clearly discernible, and continuity is maintained with no disconnected areas.
4: Good	Areas where blood vessels are not stationary (unclear boundaries of blood vessels) or are interrupted is only one location, and continuity is maintained for the rest of the area.
3: Fair	Areas where blood vessels are not stationary (unclear boundaries of blood vessels) or are interrupted are only two locations, and continuity is maintained for the rest of the area.
2: Poor	Areas where blood vessels are not stationary (unclear boundaries of blood vessels) or are interrupted are only three locations and continuity is not maintained.
1: Bad	Areas where blood vessels are not stationary (unclear boundaries of blood vessels) or are interrupted are at least four locations and continuity is not maintained.

Figure 10: Scoring criteria

4.3.2 Results and Consideration

From figure 11, in the HR < 60 bpm group, significant differences were observed only in LAD and LCX, and in the 60 bpm ≦ HR < 70 bpm group, significant differences were observed in all three vessels only in half reconstruction.

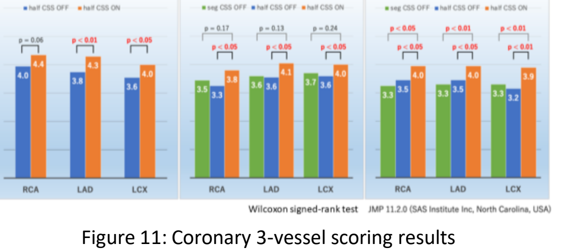

Figure 11: Coronary 3-vessel scoring results

Furthermore, for the HR ≧ 70 bpm group, a significant difference was obtained in CSS compared with segment reconstruction.

Figure 12 shows an example of the 60 bpm ≦ HR < 70 bpm group.

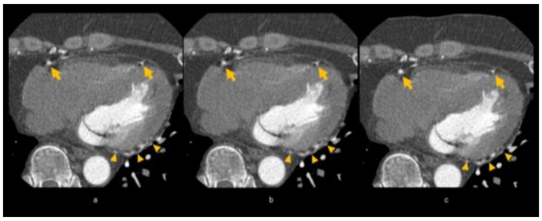

Figure 12: 60 bpm ≦ HR ＜ 70 bpm
a: Segment reconstruction CSS OFF
b: Half reconstruction CSS OFF
c: Half reconstruction CSS ON

In half reconstruction and segment reconstruction, it is not possible to obtain a phase that suppresses blur due to movement of three coronary arteries simultaneously, whereas in CSS, due to the correction effect, the motion correction effect of the coronary artery (arrows) and myocardium (arrowheads) was improved.

Figure 13 shows an example of the HR ≧ 70 bpm group, in half reconstruction and segment reconstruction, it is not possible to obtain a phase that suppresses blur due to movement of three coronary artery branches (arrowheads), and while the RCA is discontinuous in the CPR image. In the CSS, the movement and blood vessel shape were corrected, improving clinical superiority.

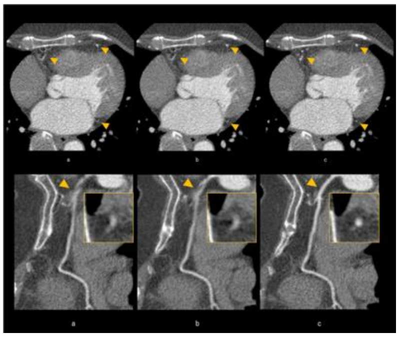

Figure 13: HR ≧ 70 bpm
a: Segment reconstruction CSS OFF
b: Half reconstruction CSS OFF
c: Half reconstruction CSS ON

5 Conclusion:

By using CSS, it was confirmed that the correction effect on movement was useful not only for cases of low heartbeat rate but also for cases of 60 bpm ≦ HR < 70 bpm and HR ≧ 70 bpm. Especially at HR ≥ 70 bpm, the score of visual evaluation of clinical data by cardiologists was higher with CSS than with segmental reconstruction. It was suggested that CSS may be able to improve the decreased success rate due to increased heartbeat rate, which was an issue with 64-row CT.

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