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Optimal phase analysis of electrocardiogram-gated computed tomography angiography in patients with Stanford type A acute aortic dissection

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HIGHLIGHTS

- Patients with Stanford type A acute aortic dissection with perfused false lumen.
- We created and randomized 10 cross-sectional images of each phase for 20 patients.
- We scored these images depending on the degree of flap stoppage.
- Image scores were significantly better in the 65 %–100 % R-R interval group.

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ABSTRACT

Objective: To determine the phase that facilitates flap observation of the ascending aorta in Stanford type A acute aortic dissection with perfused false lumen.
Methods: We reconstructed retrospective Electrocardiogram-gated Computed Tomography Angiography images of the ascending aorta of all 20 patients to 20 phases of curved-multiplanar reconstruction in 5% increment. One radiologist created and randomized 10 cross-sectional images of each phase for every patient and two radiologists scored these images on a 5-point scale depending on the degree of flap stoppage. We calculated the average score for each phase of each case and compared them among the three groups.
Results: Image scores were significantly better in the 65 %–100 % R-R interval group than those in the 5%–30 % ($p < 2e\text{-}16$) and 35 %–60 % R-R interval groups($p = 7.2e\text{-}10$). Similar scores were observed in the Heart Rate > 70 group ($p = 0.00039$, 2.2e-14). Moreover a similar tendency was observed in the arrhythmia group ($p = 0.0035$, 0.294). No difference was found in the degree of flap stoppage in the 65 %–100 % R-R interval group between the Heart Rate > 70 and Heart Rate ≤ 70 groups ($p = 0.466$) and between the arrhythmia and non-arrhythmia groups ($p = 0.1240$).
Conclusion: In observing the ascending aorta, We obtained a good image at 65 %–100 % R-R interval and similar tendency was observed in the patients with arrhythmia.

Abbreviations: AAD, acute aortic dissection; CTA, computed tomography angiography; ECG, electrocardiogram; HR, heart rate; bpm, beats per minute; AEC, automatic exposure control; DLP, dose-length-product; E, effective dose; MPR, multiplanar reconstruction; RR, R-R interval; S, systolic phase; D, diastolic phase; IVR, isovolumetric relaxation phase; RF, rapid filling phase; SF, slow filling phase; AC, atrial contraction phase; AR, Aortic Regurgitation.

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1. Introduction

Stanford type A acute aortic dissection (AAD) is a life-threatening condition that requires surgical management. Although various operative methods are performed such as ascending aortic, total arch, and aortic valve replacement, and replacement including entry tear are performed, perfect agreement about the most suitable method has not yet been achieved. At our facility, we usually include the entry site in determining the extent of graft replacement. The assisted circulation apparatus and vascular graft including the prosthetic valve used differs for each surgical procedure; therefore, precise information regarding the location and the size of the entry site can be helpful in deciding the surgical treatment for AAD.

Clear imaging of the affected area is required, and transesophageal and transthoracic echocardiographies are often performed, which are quick and does not expose the patient to radiation [1]. Computed tomography angiography (CTA) is almost simple and suitable for screening for other diseases throughout the body and is mostly performed; however, this is often difficult due to a remarkable motion artifact of the ascending aorta on non-electrocardiogram (ECG)-gated CTA [2]. By transmitting the heartbeat to the ascending aorta, the walls and flaps of these parts are depicted unclear, or in double or multiple on non-ECG-gated CTA. Therefore, some institutions perform ECG-gated CTA to reduce motion artifacts [3,4]. In addition, ECG-gated CTA has been performed in some institutions when aortic disease is suspected as non-ECG-gated CTA may result in misdiagnosis in the absence of aortic dissection [4–6].

ECG-gated CTA is associated with the disadvantage of increased radiation exposure compared with non-ECG-gated CTA. Therefore, prospective ECG-triggering CTA may be used to perform the procedure to obtain similar image quality and with a lower radiation dose. Wenhui et al. reported that the use of prospective ECG-triggering CTA during chest CTA can reduce radiation dose parameters such as CT dose index volume and dose–length product to 1/2–1/3 of those of retrospective ECG-gated CTA [7].

Some studies have investigated flap movement caused by aortic dissection in the descending and abdominal aorta [8–11]. However, there are few studies that have examined the phase in the ascending aorta that is likely to be quiescent, for use in prospective ECG-triggering CTA.

In this study, to perform ECG-triggering CTA for assessing the ascending aorta, we simultaneously examined the phase along with the least flap movement. In addition, in coronary artery CTA, some studies have reported that it can be easily observed in the late systolic phase at heart rate (HR) $>$ 70 beats per minute (bpm) [12–17]. Therefore, we also examined if the tendency in the aorta was similar. In addition, we assessed whether problems occur during flap observation in cases of arrhythmia.

2. Materials and methods

2.1. Patient selection

For this retrospective study, we enrolled patients from a single facility from April 2017 to July 2019. Retrospective ECG-gated CTA was performed for patients suspected of aortic dissection from body examinations and simple CT findings. Patients with a false lumen in the ascending aorta and an image of contrast agent inflow into the false cavity were diagnosed with Stanford type A AAD with perfused false lumen; we analyzed the CTA results of such patients. This study was approved by the ethics committee of the study hospital, and the requirement of informed consent was waived owing to the study's retrospective nature.

2.2. CT acquisition

All CT scans were obtained using the area-detector CT scanner (Aquilion ONE or Aquilion ONE ViSION Edition, Canon, Tokyo, Japan). CT parameters were as follows: tube potential =120 kV, tube rotation = 0.35 s in Aquilion One and 0.275 s in Aquilion One Vision Edition, acquisition mode = 100 × 0.5 mm, reconstruction slice width = 1.0 mm, reconstruction slice interval = 0.8 mm, and kernel = FC13. AEC (automatic exposure control) was used for tube current modulation.

We injected the contrast material through a peripheral intravenous line using a dual-head power injector (Dual Shot GX-V in Aquilion One, Dual Shot GX-7 in Aquilion One Vision, Nemoto Inc., Tokyo, Japan). The flow of non-ionic iodinated contrast material (Iopamidol 370, Fuji Pharma Inc., Tokyo, Japan) was adjusted to 24.0 mg/kg/sec and injected for 21 s. The manufacturer's bolus tracking software was used, with a region-of-interest being the descending aorta. No beta-blockers or other heart rate-altering medications were administered. Pitch factor included the manufacturer's encouragement value for segment chest reconstruction, cardiac apex switching, and fast pitch factor in the abdomen.

2.3. Radiation dose

The DLP (dose-length-product) of each examination was documented by technicians and collected by the study coordinator. The effective dose (E) was calculated approximately using the equation, $E = E_{DLP} \times DLP$, where E_{DLP} is the effective dose estimate. According to the National Radiological Protection Board regarding doses from computed tomography, E_{DLP} is 0.015 mSv/(mGy × cm) for the trunk and we used this value for it [18].

2.4. CT reconstruction and image creation

A radiologist with 4 years of experience in image interpretation performed CT reconstruction and image creation. The obtained data were reconstructed into 20 series of CT images with different cardiac cycles in 5% increments between the R–R interval using segmental image reconstructions. The ascending aorta was reconstructed using Curved- multiplanar reconstruction (MPR) using Ziostation (Ziosoft Inc., Tokyo, Japan). The ascending aorta, from the lower end of the left and right coronary artery origins to the right brachiocephalic artery origin, was divided into 10 equal parts, and cross-sectional images of 10 cross sections at a height including the coronary artery side were obtained in each series(Fig. 1A).

2.5. Image analysis

Created images were randomized regardless of patients and phases. It is because their randomization eliminates information other than the ease of flap stoppage, such as patient and upper and lower cross-sectional information. The observer can particularly evaluate the degree of flap stoppage. Radiologists with 4 and 17 years of experience in image interpretation, who were blinded to patient information, scored the degree of flap stoppage in each image.

Because there was no report mentioning about flap grading system, we have made a new one by referring to the coronary grading system mentioned by Aroz et al. [12]. The image was scored as 5 (highest) when $>$90 % of the flap was not blurred and followed one line. The image was assigned a score of 1–4 in 25 % increments depending on flap visibility (Table 1, Fig. 1B). Final image scores were determined after reaching a consensus between the two assessors.

2.6. Grouping

Despite using segmental image reconstructions, the acquisition time (180° + fan angle) should be equivalent to that of the half reconstruction

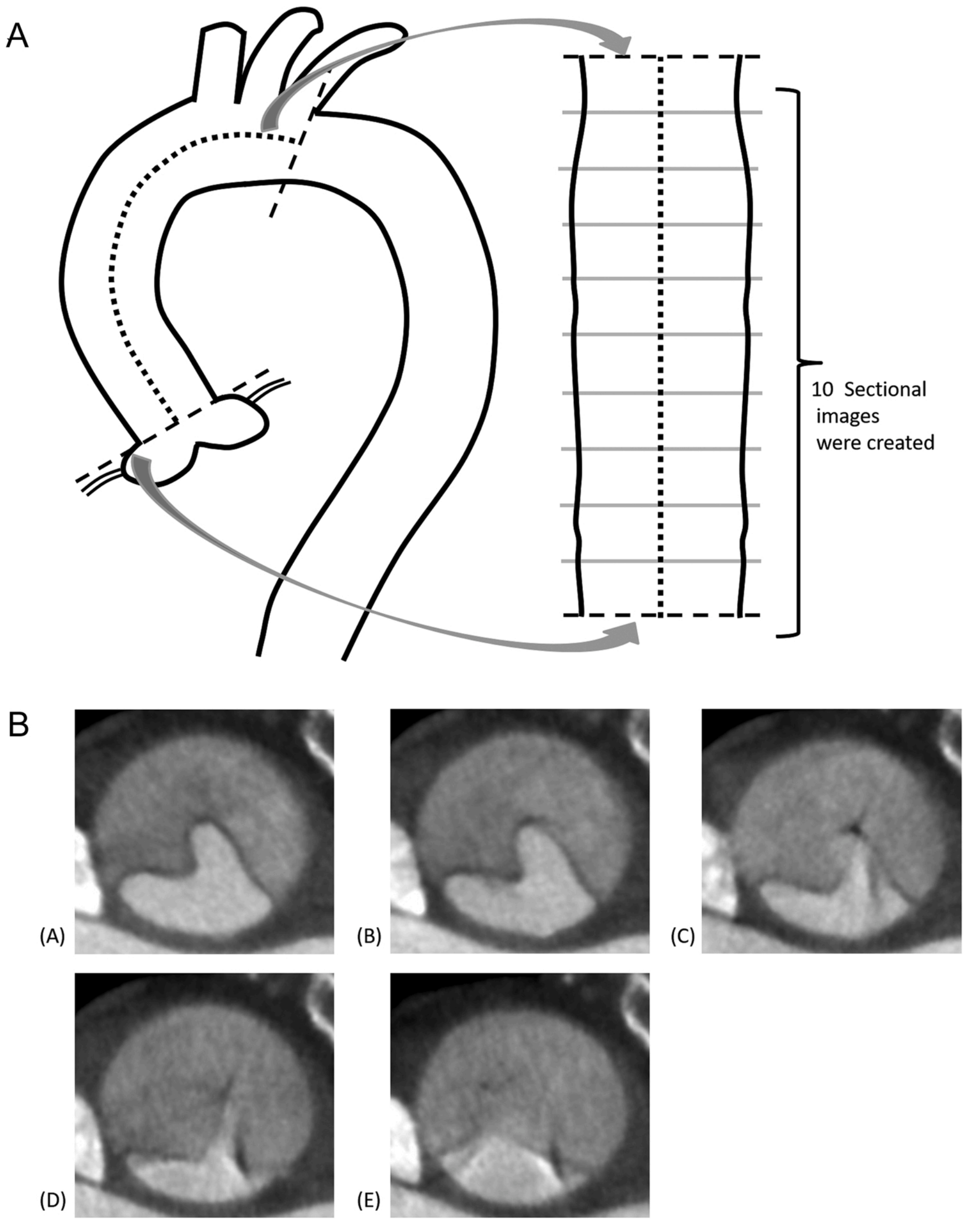

Fig. 1. A) The ascending aorta was reconstructed using Curved-MPR and from the lower end of the left and right coronary artery origins to the right brachiocephalic artery origin, which was divided into 10 equal parts. In each series, cross-sectional images of 10 cross sections at a height including the coronary artery side were created. (B) Sample images corresponding to each score. Cross-sectional images of the ascending aorta of a 92-year-old woman with the image scores of 5, 4, 3, 2, and 1 in.(A) 75 %, (B) 95 %, (C) 10 %, (D) 15 %, and (E) 20 % R–R interval, respectively. The higher the score, the easier it is to observe the flap.

Table 1
Score for the degree of flap observability.

Percentage that we can follow as a single line without blurring the whole flap	Score
90 %–100 % (almost entirely)	5
75 %–90 % (adequately)	4
50 %–75 % (more than half)	3
25 %–50 % (less than half)	2
0%–25 % (not adequate)	1

method to avoid data loss due to arrhythmia. If tube rotation is set at 0.35 s, temporal resolution should be approximately 200 ms. The higher the HR, the higher is the proportion of acquisition time in the R–R interval (RR), e.g., if HR is 100 and RR is 600 ms, acquisition time is 1/3 of RR. We assumed that patients with high HR require approximately 1/3 of the acquisition time. Thus, the 20 series of CT images with different cardiac cycles in 5% increments in R and R were classified into three groups.

Conversely, the cardiac cycle is divided into two phases: systole (S) and diastole (D); diastole is further divided into an isovolumetric relaxation phase (IVR), a rapid filling phase (RF), a slow filing phase (SF), and an atrial contraction phase (AC) (Fig. 2A). Using the formula described by Sano and by predicting the phase of each RR in the cardiac cycle, 5 %–30 %, 35 %–60 %, and 65 %–100 % of RR were considered approximately as the early S, late S and early D, and middle D and late D phase, respectively (Fig. 2B) [19]. The 20 series were divided into three groups: 5%–30 %, 35 %–60 %, and 65 %–100 % RR groups, and differences in image scores were examined.

In addition, we divided the patients into HR $>$ 70 and HR $\leq$ 70 groups to determine the impact of HR. High HR was defined as 70 bpm in two reports [12,13], 80 bpm in 1 [14], and 75 bpm in 1 [16], and low HR was defined as 65 bpm in two reports [14,16]; therefore, 70 bpm was used as a grouping value. We also divided patients into arrhythmia and non-arrhythmia groups according to the presence or absence of arrhythmia to investigate the influence of HR.

2.7. Statistical analysis

We used R (statistics free software) for statistical analysis. P values of $<$0.05 were considered statistically significant. Weighted κ was

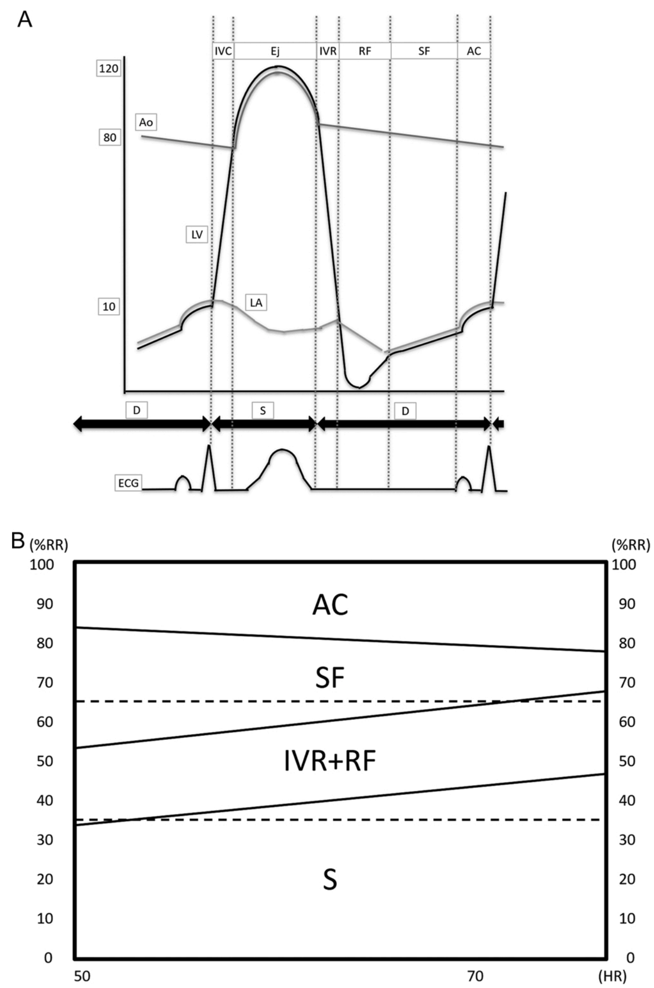

Fig. 2. (A) Changes in the pressure curve of the left heart system, electrocardiogram, and pressure–volume curve with heartbeat. (B) The predicted phase of each cardiac cycle. Approximately 5 %–30 % R–R interval is in the early S phase, 35 %–60 % in the late S and late D phases, and 65 %–100 % in the middle and late D phases. S (systolic phase), D (diastolic phase), IVR (isovolumetric relaxation phase), RF (rapid filling phase), SF (slow filling phase), AC (atrial contraction phase), Ao (aorta), LV(left ventricle), LA(left atrium), and ECG(electrocardiogram).

calculated as the observer index of the observer agreement rate. If κ was more than 0.6, it was considered that the reproducibility between observers was sufficiently high [20].

The average score of each phase in each patient was calculated. Next, these scores were divided into the above-mentioned three groups, and the Friedman test was used to determine a significant difference in the image scores of the three groups because it was considered as repeated measures analysis of variance that does not follow normal distribution. Next, the presence of significant differences between the two groups was examined using Bonferroni correction as a procedure of multiple comparison method.

Furthermore, to investigate whether aortic CTA demonstrated a tendency similar to coronary artery CTA in the HR > 70 group, the average image scores for each phase in the HR > 70 group were divided into the above-mentioned three groups using Friedman test. Next, the presence of significant differences between the two groups was examined using Bonferroni correction.

Furthermore, to investigate whether the image scores differed in a specific phase between the HR > 70 group and HR ≤ 70 group, the Mann–Whitney *U* test was used. To investigate the effects of arrhythmia, the arrhythmia and non-arrhythmia groups were also compared using the aforementioned test.

3. Results

We included 24 patients with Stanford type A AAD with perfused false lumen. Four patients were excluded from evaluation because the flap in two patients did not move due to excessive mural thrombus in the false lumens, the flap in one patient exhibited 3D movement due to all around dissection where the tear is not a part of the tunica media but the whole circumference, and the flap in another patient was too short to be evaluated (specifically less than 2 cm) because the tear was too large. The intimal tear in all the remaining 20 patients was identified and the observability of their flaps was examined.

Of the 20 enrolled patients, 10 had an HR of >70 and 10 had an HR of ≤70. In addition, two patients had 2:1 atrioventricular block, and the remaining 16 had regular rhythm and no apparent arrhythmia. Patients' characteristics with regard to all groups (HR > 70, HR ≥ 70, arrhythmia, and non-arrhythmia groups) have been described in Table 2. Aortic regurgitation (AR) was none in six, trivial in three, trivial-to-mild in one, mild in four, mild-to-moderate in two, and moderate in one. In addition, the severity of AR was unknown in three patients. There was no clear difference in flap stoppage with or without AR.

The effective dose ECG-gate CTA was 44.9 ± 18.6 (19.8–83.2) mSv.

A good value for weighted κ of 0.985 was obtained in all groups.

The average image score for each phase was calculated, and the transition was graphed for all 20 patients (Fig. 3A). Majority of the patients had an image score of >4 corresponding to the 65 %–100 % RR group, and the lowest image score was noted in the 5%–30 % RR group. The image score in the 35 %–60 % RR group was higher than that in the 5 %–30 % RR group but was lower than that of the 65 %–100 % RR.

The average image score of 20 patients was calculated for each phase, and the transition was graphed. Every average image score in the 65 %–100 % RR group was >4.5, which was higher than that in the other groups (Fig. 3B).

The Friedman test showed significant variation among the three groups (p < 4.862e-16). The Bonferroni correction showed a significantly better image score in the 65 %–100 % RR group than in the 5%–30 % and 35 %–60 % RR groups (p < 2e-16, 7.2e-10, Fig. 3C).

In the HR > 70 group, results of the Friedman test exhibited significant differences among the three groups (p = 4.072e-11). The Bonferroni correction showed a significantly better image score in the 65 %–100 % and 35 %–60 % RR groups than in the 5 %–30 % RR group (p = 0.00039, p = 2.2e-14, Fig. 4A).

No statistically significant difference was noted for the image scores of the 65 %–100 % RR group between with the HR > 70 and HR ≤ 70 groups (p = 0.466, Fig. 4B).

In the arrhythmia group, the Friedman test did not show significant differences with regard to the image score among the three groups (p = 0.0917); however, the image score was the highest in the 65 %–100 % RR group, followed by the 35 %–60 % and 5 %–30 % RR groups. The Bonferroni correction showed a significantly better image score in the 65 %–100 % RR group than in the 5 %–30 % group (p = 0.0035). The image scores did not significantly differ between the 65 %–100 % and 35 %–60 % RR groups (p = 0.294, Fig. 5A).

The Mann–Whitney *U* test revealed that the image score in the 65 %–100 % RR group was not statistically significant between with the arrhythmia and non-arrhythmia groups (p = 0.1240, Fig. 5B).

4. Discussion

It is often difficult to identify the location of the intimal tear due to a remarkable motion artifact of the ascending aorta on non-ECG-gated CTA [2]. Transthoracic and transesophageal echocardiographies may be used together, but CTA is frequently performed, so it is necessary to improve the image quality of CTA [1].

In middle D and late S phases, the left ventricular wall movement is

Table 2
Background data of 20 patients.

	All patients	HR > 70 group	HR ≤ 70 group	Arrhythmia group	Non-arrhythmia group
Number of patients	20	10	10	2	18
Age mean (±SD)	69.4 ± 14.5 (37–92)	69.2 ± 13.4 (48–92)	69.6 ± 16.3 (37–88)	67.0 ± 4.2 (64–70)	73.1 ± 12.3 (51–92)
Male ratio	50.0 % (10 cases)	50.0 % (5 cases)	50.0 % (5 cases)	0.0 %	44.4 % (8 cases)
HR	70.9 ± 14.0 (47.7–98.2)	81.4 ± 9.7 (70.1–98.2)	60.3 ± 8.6 (47.7–69.8)	58.8 ± 15.7 (47.7–68.9)	71.5 ± 14.0 (49.5–98.2)
Arrhythmia ratio	10.0 % (2 cases)	0.0 %	0.0 %	100 % (2 cases)	0.0 %
Part of tear					
-Aortic root	10.0 % (2 case)	0.0 %	20.0 % (2 case)	0.0 %	11.1 % (2 case)
-Ascending aorta	70.0 % (14 cases)	60.0 % (6 cases)	80.0 % (8 cases)	100.0 % (2 cases)	66.7 % (12 cases)
-Bifurcated arches	20.0 % (4 cases)	40.0 % (4 cases)	0.0 % (0 case)	0.0 %	22.2 % (4 cases)

SD: standard deviation, HR: heart rate.

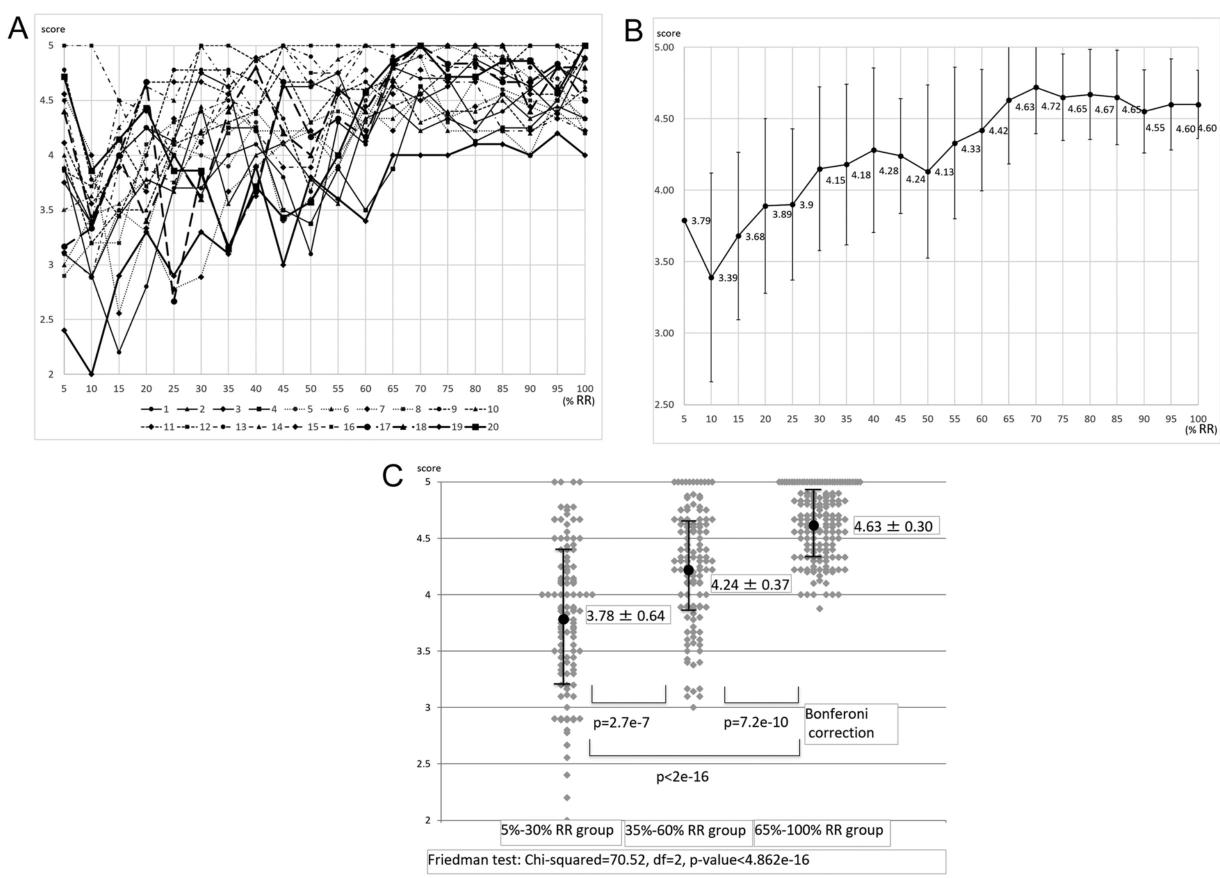

Fig. 3. (A) Among the 20 patients, the average image score for each phase was calculated, and the transition was graphed. In most cases, a high score (>4) was recorded in the 65 %–100 % R-R interval, and no such trend was noted in the 5%–60 % R-R interval. (B) The average image score for each phase of the 20 patients was calculated, and the transition was graphed. In the 5 %–60 % R-R interval, the average image scores were <4.5, whereas in the 65 %–100 % R-R interval range they scored >4.5. (C) The obtained image scores were divided into three groups, and the Friedman test and Bonferroni correction were performed. Significant differences were observed among the three groups, and the image score in the 65 %–100 % R-R interval group was better than that in the other two groups.

slow, and these phases are easily observed in coronary artery CTA [12–17]. In the present study, for the ascending aorta, the 65 %–100 % RR group (middle and late D phases) had the highest image scores, followed by the 35 %–60 % RR group (late S and early D phases) and the 5 %–30 % RR group (early S phase). Therefore, we inferred that flap movement is intense when the aortic valve is opened and the movement of the flap is slow when the aortic valve is closed.

Yang S. et al. reported that the maximum intimal flap movement was observed at 15 % RR in the abdominal aorta [8]. The ascending aorta examined at this time is expected to be slightly earlier than that because it is more central than the abdominal aorta, and the lowest image score is actually observed in 10 %, 5 %, 15 %, 25 %, and 35 % RR in 11,3,3,2 and 1 patients,respectively. In 14 cases, the lowest value was seen earlier than 15 % RR, and in the other five cases, the lowest value was observed within systole.

Additionally, a valley-like reduction in score was observed at 50 % RR in Fig. 3B. In Fig. 3A, a valley-like score reduction (one or two consecutive points that were ≥0.3 lower than the two values before and after) were observed in 12 of 20 cases between 35 % RR and 60 % RR. It was possible that these phases coincided with the timing of blood regurgitation at the time of aortic valve closure called dicrotic notch in the aortic pressure waveform [21–23]. Thus, it seemed that CTA at these timings was likely to result in low image quality.

In the patients examined in the present study, the flaps rapidly

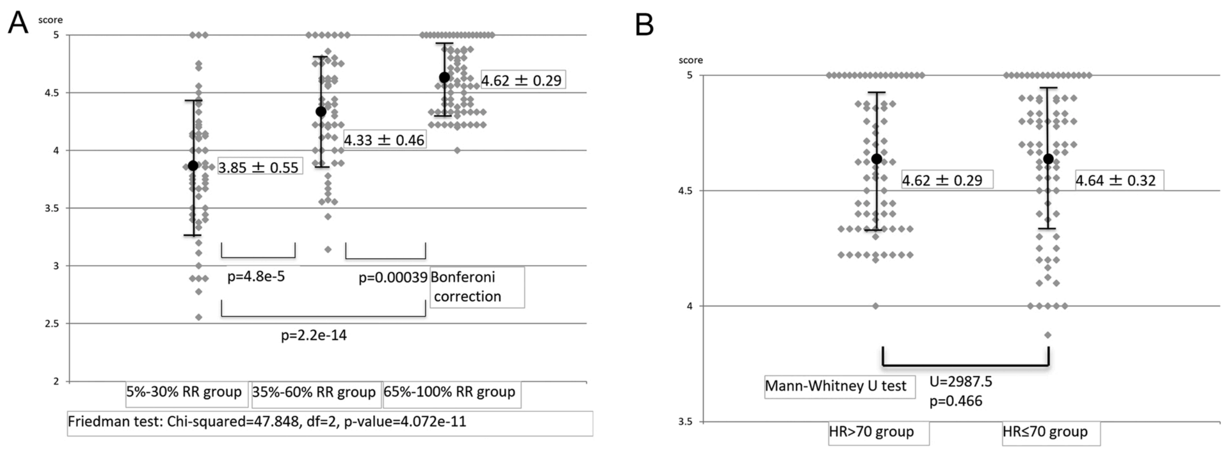

Fig. 4. (A) The image scores for the heart rate > 70 group were categorized into three groups, for which the Friedman test and Bonferroni correction were performed. Significant differences were noted among the three groups, and the image score in the 65 %–100 % R-R interval group was better than that in the 5%–30 % R-R interval group. (B) The Mann–Whitney test showed no significant difference in the average image score in the 65 %–100 % R-R interval between the heart rate > 70 and heart rate ≤ 70 groups. It seems that the difference in heart rate does not affect the readability of flap.

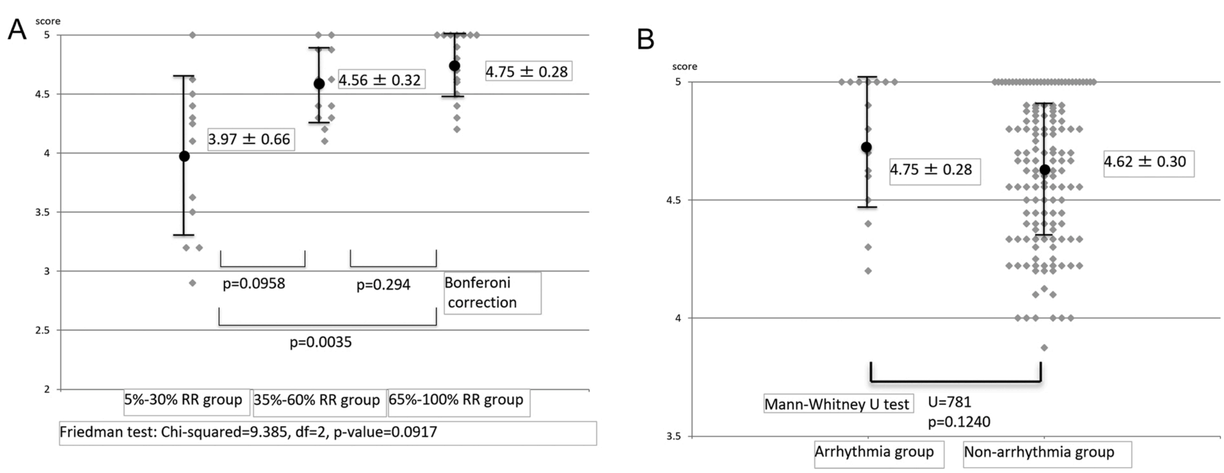

Fig. 5. (A) The image scores obtained in the three R-R interval groups in the heart rate > 70 group were assessed using the Friedman test and Bonferroni correction. We found variations among the three groups and a better image score in the 65 %–100 % R-R interval group than that in the 5 %–30 % R-R interval group. (B) Mann–Whitney test revealed no significant different in the average image score of the 65–100 % R-R interval group in the arrhythmia and non-arrhythmia groups. It seems that the presence or absence of arrhythmia may not affect the readability of flap.

shifted to the false lumen owing to increased pressure in the true lumen during the early S stage, moved slowly to the true lumen in the late S and early D phases, and almost stopped moving in the middle D and late D phases according to the cardiac cycle. When considering the flap movement according to the cardiac cycle, the flap in the middle D and late D phases was assumed to stop better than that in the other phases.

Flap movement was not intense in some patients in this study. Murayama and Williams et al. classified flap movement as "dynamic" and "static" and reported that aortic branch occlusion is more frequently observed in dynamic movement [9,24,25].This may be related to the different anatomical configurations of the intimal tear size, number, and location [8,26,27].This dynamic movement of the flap was observed when the intimal tear was large or the intimal tear was in a position where it was directly hit by the flow. In both the cases, the image scores were good at 65 %–100 % RR group compared with the other groups.

Sano and Philip et al. reported that coronary artery CTA conducted in the late S phase in patients with high HR was considered to have relatively good image quality due to shortening of the middle D phase [12–17,19].However, in the ascending aorta, the flap's easy-to-stop phase occurred in both the middle and late D phases; as these are long enough, we considered that the effect of shortening of the middle D phase would not affect the flap stoppage in these phases. This shows that even in case of high HR, it is possible to obtain images with similar quality at 65 %–100 % RR without performing rate control.

In addition, although the number of cases was as small as two, which had almost no statistical efficacy, patients with arrhythmias even had a good image score in the middle and late D phases and had a comparable score to patients without arrhythmias. Because the time from the previous R was different in the area with arrhythmia, image data collected from different pulse locations is likely to be different, which may result in degradation of the reconstructed image quality. However, it is considered that the image quality was not extremely low because both patients had bradyarrhythmias and the duration of late D phase in which flaps are easy to stop is greatly extended.

The radiation exposure was about twice as high as the previously reported ECG-triggering CTA [4]. As noted in 2.6 Grouping, it is estimated that approximately one-third of the acquisition time is required, especially for patients with high HR, to avoid data loss due to arrhythmias. Based on this experience, if a prospective ECG-triggering CTA is performed during the middle and late D phases, which is about 1/3 of the cardiac cycle, it might be possible to maintain the same image quality with about 1/3 exposure dose compared with the retrospective ECG-gated CTA [7].

This study has several limitations. First, the image score could not be examined in case of tachycardia with HR > 100 and tachyarrhythmia such as that observed in atrial fibrillation and in high frequencies and sinus tachycardias due to the lack of such patients. Especially in case of tachyarrhythmia, the image score is expected to decrease owing to the shortening of the middle and late D phases. Therefore, whether a good image will be obtained using prospective ECG-triggering CTA could not be clarified in tachycardia and tachyarrhythmia.

Second, flap blurring was subjectively evaluated; this may potentially result in bias. However, this bias may have been reduced as two radiologists assessed the images and when images were differently scored, a representative value was determined by consensus.

Third, the flap grading system has been independently created with reference to the coronary grading system, and it has not been examined whether it is an appropriate evaluation method. However, this is a simple method that goes down by 1 point for every 25 % of the line that can be drawn as one line without blurring, therefore, can be said to be objective.

Fourth, the presence or absence of AR may affect the flap stoppage. There were no obvious differences among the cases examined; however, the number of patients included was small, and there was little discussion.

Fifth, this was a single-facility study involving a small number of patients. A multicenter study should be conducted in the future to validate the applicability of our findings.

5. Conclusion

It has been known that motion artifacts can be reduced by performing ECG-gated CTA in patients with AAD, but it has not been investigated in which phase the flap is most stopped. This time, we examined that the flap can be significantly observed at diastolic phase, especially 65 %–100 % RR. Therefore, we believe a prospective ECG-triggering method can be adapted without rate control, but a multicenter and bigger sample size study should be conducted in the future to validate the applicability of our findings. Although this tendency is also noted in patients with bradyarrhythmia, further investigation should be conducted due to the small number of cases. Therefore, in the case of tachycardia with HR > 100 and tachyarrhythmia, we have not examined at which phase the flap can be observed significantly, therefore, a retrospective ECG-gated CTA or other method should be performed.

Ethical statement

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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CRediT authorship contribution statement

Kenji Nishida: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization, Supervision, Project administration. **Yuki Yokoi:** Investigation, Resources, Data curation. **Ayumi Yamada:** Investigation, Resources, Data curation. **Nobuhiro Takaya:** Investigation, Resources, Data curation. **Ken Yamagiwa:** Investigation, Resources, Data curation. **Shuichi Kawada:** Investigation, Conceptualization, Methodology, Resources, Data curation, Writing - review & editing. **Koichi Mori:** Investigation, Conceptualization, Methodology, Resources, Data curation, Writing - review & editing. **Susumu Manabe:** Conceptualization, Methodology, Resources, Data curation, Writing - review & editing. **Eiichiro Kanda:** Methodology, Formal analysis. **Tomoyuki Fujioka:** Supervision, Project administration. **Mitsuhiro Kishino:** Supervision, Project administration. **Ukihide Tateishi:** Supervision, Project administration.

Declaration of Competing Interest

The authors reported no declarations of interest.

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