

## Spiral Flow Tube for Saline Flush in Coronary CT Angiography: Initial Experience

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**Abbreviations:** SNR: signal-to-noise ratio; ROI: region of interest.

### ABSTRACT

**AIM:** To compare the enhancement and visibility of coronary arteries using the spiral flow tube with that of the T-tube during coronary CT angiography.

**MATERIALS AND METHODS:** This retrospective study consisted of 110 patients. The first 55 patients underwent coronary CT angiography with the conventional T-tube, while the last 55 patients used the novel spiral flow tube. Coronary attenuation of proximal and distal segments were measured and the signal-to-noise ratio (SNR) were calculated. To assess the visibility of distal segments, the number of coronary branches of 1 mm at their origin was counted.

**RESULTS:** The spiral flow tube significantly increased the average attenuation of proximal ( $413 \pm 40$  vs  $438 \pm 45$  HU,  $p < 0.005$ ) and distal segments ( $403 \pm 46$  vs  $441 \pm 46$  HU,  $p < 0.0001$ ). The SNR in the spiral tube group tended to be higher than the T-tube group and the difference was significant in distal segments ( $14.0 \pm 2.9$  vs  $15.4 \pm 4.1$ ,  $p = 0.04$ ). The depiction of coronary branches improved with the spiral flow tube ( $16.0 \pm 4.8$  vs  $17.8 \pm 4.4$ ,  $p = 0.04$ ).

**CONCLUSION:** The spiral flow tube increased the enhancement of coronary arteries and improved the visibility of distal segments in coronary CT angiography.

### INTRODUCTION

Coronary computed tomography (CT) angiography has become a promising method for the detection of significant coronary artery disease by its high sensitivity and negative predictive value<sup>[1]</sup>. Optimal enhancement of coronary arteries is necessary to maintain high diagnostic performance<sup>[2]</sup>, while dense contrast medium in the superior vena cava and the right ventricle could limit the diagnosis of the right coronary artery<sup>[3]</sup>. This is why contrast medium is injected at a high flow rate followed by a saline chaser to flush the excessive contrast medium in the right ventricular system<sup>[2-5]</sup>.

A connector with a T-shaped joint is widely used for saline flush during coronary CT angiography. Although this conventional tube could effectively push the contrast medium into the central venous system, some proportion of contrast medium could remain in the tube or the subclavian vein due to the laminar flow generated by the T-shaped joint (Figure 1a)<sup>[5]</sup>. Several studies have shown that a spiral flow could push the contrast medium more effectively than a laminar flow<sup>[6,7]</sup>. Recently, a novel connecting tube which generates a spiral flow became available for CT angiography (Figure 1b). A previous study showed that this spiral flow tube increased the aortic enhancement by approximately 10% during hepatic arterial phase<sup>[5]</sup>. However, the effect of spiral flow tube in CT angiographic studies

using smaller amounts of contrast medium with higher injection speed have not been studied. We hypothesized that spiral flow tube could also improve the enhancement of coronary arteries in coronary CT angiography. Thus the purpose of this study was to compare the enhancement of coronary arteries using the spiral flow tube with that of the T-tube during coronary CT angiography. We also compared the subjective visibility of especially distal coronary segments.

## METHODS

This retrospective study was approved by the local ethics committee, and the requirement for informed consent to participate in this study was waived. Authors who were not employees of Nemoto Kyorindo had control of the data.

### Patients

The spiral flow tube (Nemoto spiral flow; Nemoto Kyorindo, Tokyo, Japan) became available at our institution on March 24, 2015. We initially included 114 coronary CT angiography exams from March 13, 2015 to April 1, 2015 before and after the introduction of the spiral flow tube. These patients underwent coronary CT angiography because coronary artery disease was clinically suspected. A total of 4 patients with known coronary artery disease (post coronary artery bypass surgery or percutaneous coronary intervention) were excluded. The final study group consisted of 110 patients; the first 55 patients used the T-tube (Top injector tube; Top, Tokyo, Japan), and the last 55 patients used the spiral flow tube.

### CT data acquisition

All patients underwent CT angiography with a 64-row CT (Brilliance 64; Philips, Tokyo, Japan). The scanning parameters were as follows: detector configuration,  $64 \times 0.625$  mm; tube potential, 120 kVp; tube current-time product, 800-1050 mAs, depending on the body weight; gantry rotation time, 420 ms; and helical pitch, 0.2.

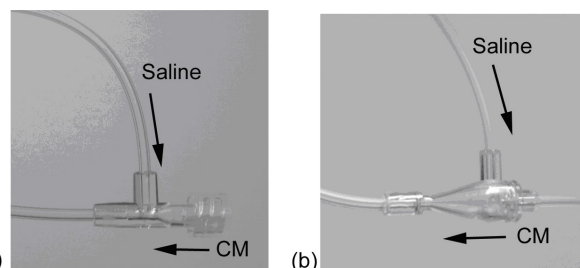
The patients received 21.0 mg/kg/s of iopamidol 370 mgI/mL (Iopamiron 370; Bayer, Osaka, Japan) with a maximum injection speed of 5.0 mL/s. Contrast medium was injected for acquisition duration plus 7 s, followed by a 30 mL saline flush. Bolus tracking method was performed to determine the scan timing. The scan started 6 s after the descending aorta reached 100 Hounsfield unit (HU). The injection and scanning protocol were kept unchanged after the introduction of the spiral flow tube.

Patients with heart rate  $> 65$  beats per minute took an oral  $\beta$ -blocker (20mg of metoprolol) 1 h prior to CT. If the heart rate was  $>65$  beats per minute on site, as much as 12.5 mg of landiolol (Corebeta; Ono Pharmaceutical, Tokyo, Japan) was given intravenously. All patients received 0.3 mg of sublingual nitroglycerin (Nitrophen; Nippon Kayaku, Tokyo, Japan) before imaging.

For each patient, a senior technologist determined the phase with minimum artifacts at the CT console. Multiple phases were reconstructed when artifacts resisted in the image. The reconstructed slice thickness was 0.67 mm, and the increment was 0.33 mm. For processing, images were transferred to a workstation (Synapse Vincent; Fuji Medical, Tokyo, Japan). Further analysis was performed in a randomized order blinded to the date of acquisition.

### Objective Analysis of coronary CT angiography

A cardiovascular radiologist with 8 years of coronary CT angiography experience collected the values. Regions of interest (ROIs) for the left main and the proximal and distal segments of the right coronary (#1 and #3), left anterior descending (#6 and #8) and the left circumflex



**Figure 1** The joint of the conventional connecting tube is T-shaped (a) which produces a laminar flow during saline flush. The joint of the novel spiral flow tube is shaped as a chamber (b) and spiral flow is generated during saline flush. This spiral flow pushes the contrast medium more effectively than the laminar flow. CM: contrast medium.

(#11 and #15) arteries were drawn on a cross-sectional image of the vessel lumen. The average CT number (in HU) was recorded for each ROI. An ROI was also placed on the aortic root, and the standard deviation of this ROI was defined as noise. The signal-to-noise ratio (SNR) was calculated as the CT number of the lumen divided by the image noise.

### Subjective analysis of coronary arteries

In order to assess the visibility of distal coronary segments, a cardiovascular radiologist and a senior radiation technologist counted the number of coronary branches of at least 1 mm at the origin using the volume rendering image and the axial image. The total number of posterior descending and atrioventricular branches of the right coronary, main branch and diagonal branches of the left anterior descending and high lateral, obtuse marginal and posterolateral branches of the left circumflex was counted (Figure 2). When the numbers differed between the readers, the final number was determined by consensus.

### Statistical analysis

Continuous variables were shown as mean  $\pm$  standard deviation and categorical variables as number unless otherwise described. The Student's t test was used to compare continuous variables. The Chi square ( $\chi^2$ ) test was used to compare categorical variables. We averaged the values of left main and proximal right coronary, left anterior descending and left circumflex arteries as proximal segments and distal right coronary, left anterior descending and left circumflex arteries as distal segments when comparing proximal and distal segments.

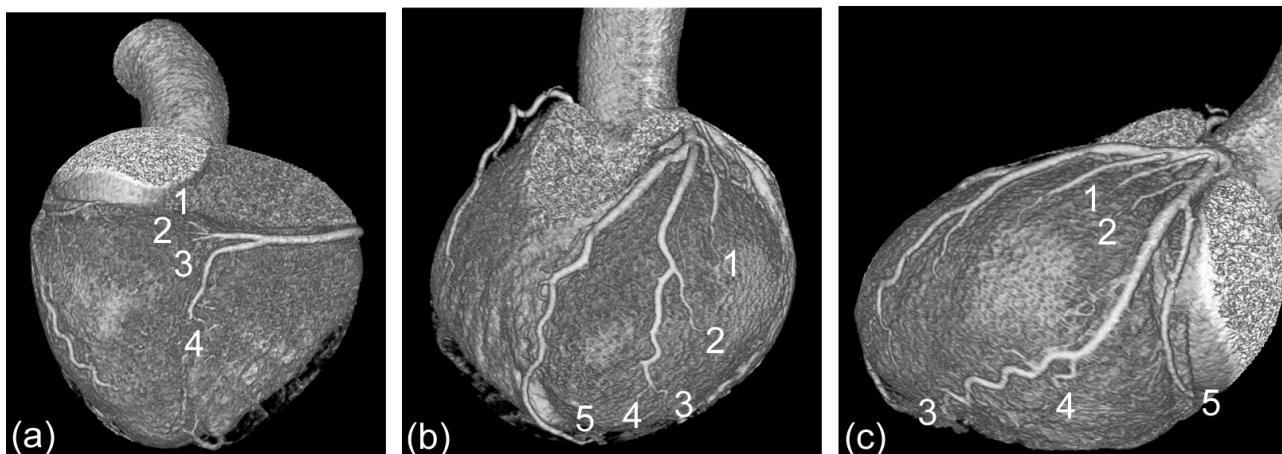
All statistical analyses were performed using JMP software (version 12.0; SAS, Cary, NC). A  $p$ -value  $< 0.05$  was deemed to indicate significance.

## RESULTS

The patient demographics showed no significant difference between the two groups. The heart rate and contrast medium dose and speed were also identical (Table 1).

### Objective analysis

The attenuation of coronary segments significantly increased in the spiral flow tube group compared with the T-tube group (Table 2). The differences were significant ( $p < 0.05$ ) in all segments. The spiral flow tube increased the average attenuation of proximal segments by 25 HU (T-tube vs spiral tube,  $413 \pm 40$  vs  $438 \pm 45$  HU,  $p < 0.005$ ) and distal segments by 38 HU (T-tube vs spiral tube,  $403 \pm 46$  vs  $441 \pm 46$  HU,  $p < 0.0001$ ) (Figure 3a).



**Figure 2** The number of coronary branches of at least 1 mm at the origin was counted using the volume rendering image. The number for right coronary artery was 4, left anterior descending was 5 and left circumflex was 5, thus the total number was 14 for this patient.

**Table 1** Patient demographics and scanning parameters.

	T-tube	Spiral tube	P
Number of patients	55	55	
Male/female	23/32	31/24	0.18
Age (y)	68.5 ± 10.5	69.0 ± 10.4	0.79
Body weight (kg)	59.3 ± 10.8	62.7 ± 15.0	0.17
Body mass index (kg/m <sup>2</sup> )	23.4 ± 3.4	23.7 ± 4.0	0.61
Heart rate (bpm)	58.8 ± 7.7	60.2 ± 8.9	0.37
Contrast medium (mL)	57.5 ± 10.2	60.6 ± 11.9	0.14
Injection speed (s)	3.4 ± 0.5	3.6 ± 0.7	0.10

Numbers are reported as average ± standard deviation.  
bpm: beats per minute.

**Table 2** Attenuation of coronary segments.

	T-tube	Spiral tube	P
RCA			
Proximal	413 ± 51	437 ± 51	0.01*
Distal	422 ± 66	451 ± 61	0.02*
LMT	407 ± 48	426 ± 49	0.04*
LAD			
Proximal	410 ± 39	440 ± 49	0.0006*
Distal	396 ± 51	442 ± 57	<0.0001*
LCX			
Proximal	424 ± 43	448 ± 51	0.009*
Distal	392 ± 50	431 ± 51	0.0001*

Numbers are reported as average ± standard deviation. \* Statistically significant,  $p < 0.05$ . LAD: left anterior descending; LCX: left circumflex; LMT: left main trunk; RCA: right coronary artery.

The image noise showed no significant difference between the two groups (Table 3). The SNR in the spiral flow tube group tended to be higher than the T-tube group and the difference was significant in distal left anterior descending and distal left circumflex segments ( $p < 0.05$ ). The average SNR of proximal and distal segments increased by 6% (T-tube vs spiral tube,  $14.4 \pm 3.1$  vs  $15.3 \pm 4.2$ ,  $p = 0.18$ ) and 10% (T-tube vs spiral tube,  $14.0 \pm 2.9$  vs  $15.4 \pm 4.1$ ,  $p = 0.04$ ), respectively using the spiral flow tube and the difference was significant in the distal segments (Figure 3b).

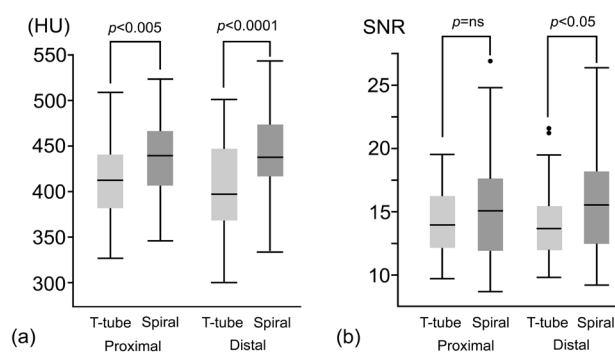
**Subjective analysis**

The spiral flow tube significantly increased the depiction of coronary branches by 10%, approximately 2 more branches using the spiral tube compared with the T-tube (T-tube vs spiral tube,  $16.0 \pm 4.8$  vs  $17.8 \pm 4.4$ ,  $p = 0.04$ ). Figure 4 shows a volume rendering image of a 73 year-old female suspected of angina who underwent coronary CT

**Table 3** Signal-to-noise ratio of coronary segments.

	T-tube	Spiral tube	P
Noise	29.7 ± 5.6	30.2 ± 7.3	0.67
RCA			
Proximal	14.4 ± 3.2	15.4 ± 4.3	0.18
Distal	14.7 ± 3.6	15.8 ± 4.3	0.16
LMT	14.2 ± 3.1	15.0 ± 4.3	0.25
LAD			
Proximal	14.3 ± 3.1	15.4 ± 4.2	0.12
Distal	13.7 ± 2.9	15.5 ± 4.4	0.02*
LCX			
Proximal	14.8 ± 3.6	15.7 ± 4.1	0.24
Distal	13.6 ± 2.7	15.1 ± 4.1	0.03*

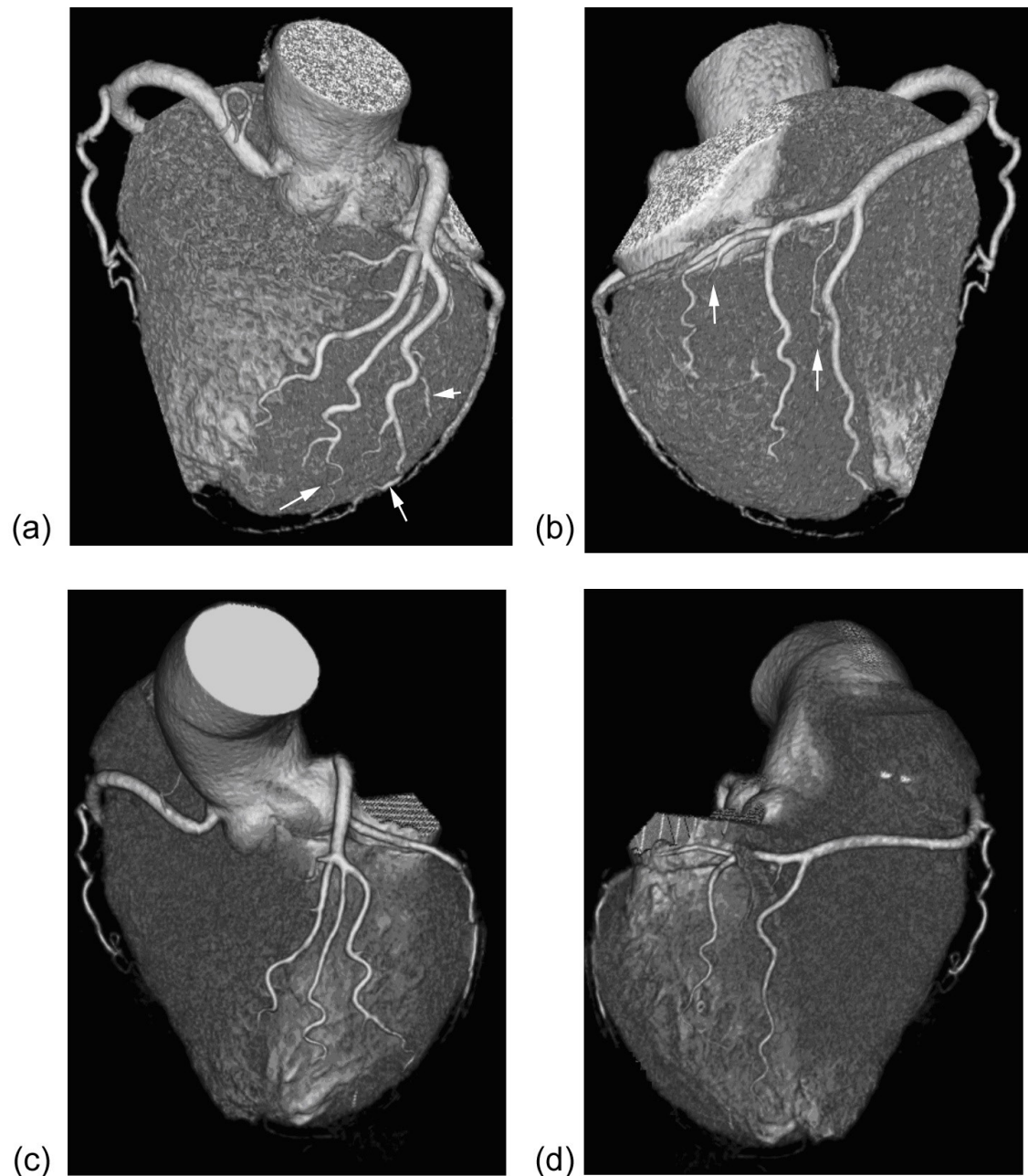
Numbers are reported as average ± standard deviation. \* Statistically significant,  $p < 0.05$ . LAD: left anterior descending; LCX: left circumflex; LMT: left main trunk; RCA: right coronary artery.



**Figure 3** Comparison of attenuation (a) and signal-to-noise ratio (SNR) (b) between T-tube and spiral flow tube. The spiral flow tube significantly increased the average attenuation of proximal and distal segments by 24 HU ( $p < 0.005$ ) and 38 HU ( $p < 0.0001$ ), respectively. The SNR of proximal and distal segments tended to be higher using the spiral tube, and the difference reached significance in the distal segments ( $p < 0.05$ ). Note: Box, 1st-3rd quartiles; bold line, median; whiskers, minimum and maximum values; filled circle, outlier.

angiography using the spiral flow tube (Figure 4a, b). This exam was also performed 4 years before due to suspicion of coronary artery disease with the T-tube (Figure 4c, d). Although the injected contrast medium and speed (47 mL and 3.0 mL/s) were the same, the spiral flow tube depicted the distal segments more clearly than the T-tube.





**Figure 4** Coronary CT angiography of a 73 year-old female suspected of angina who underwent the exam twice in a duration of 4 years. Although the injection protocol was the same (47 mL of contrast medium at 3.0 mL/s), the spiral flow tube (a,b) depicted the distal segments more clearly (arrows) than the T-tube (c,d).

## DISCUSSION

The present study was the first study to evaluate the effects of the novel spiral flow tube in coronary CT angiography and showed that the spiral flow tube improved the enhancement of coronary arteries by approximately 30 HU and the improvement was higher in distal segments compared with proximal segments than the conventional T-tube. The spiral flow tube also increased the SNR and it depicted 2 more distal branches than the T-tube.

There are two implications from this study. Firstly, the spiral tube might improve the image quality of coronary arteries in obese patients. Because the maximum injection speed was 5.0 mL/s in the present study, patients with a body weight over 88 kg received contrast medium lower than 21.0 mg/kg/s. The SNR of these patients

would decrease by the reduced enhancement and the increased image noise. The 10% increase in the SNR would be beneficial for obese patients. Secondly, patients with chronic kidney disease are at risk of acute renal failure in using contrast medium. Thus, contrast medium should be restricted to the minimal dose necessary for diagnosis<sup>[8]</sup>. This spiral flow tube could potentially maintain the image quality while reducing 10% dose of contrast medium. However, further studies are necessary to confirm these issues.

Saline flush is commonly used in coronary CT angiography to push the contrast medium in the injection tube and the peripheral veins<sup>[3,9]</sup>. Saline flush is also used in imaging the aorta<sup>[10-12]</sup> and carotid arteries<sup>[13]</sup>. A previous study showed that approximately 10 to 20 mL of contrast medium remained in the brachial vein or the superior vena cava without saline flush<sup>[14]</sup>. By pushing this residual contrast

medium into the central venous system, a saline flush could achieve a reduction of 12 mL<sup>[15]</sup> or 10% dose of contrast medium<sup>[3,11]</sup> with maintained arterial enhancement in the arterial phase. Other studies showed that saline flush increased the enhancement of coronary arteries<sup>[3]</sup> and aorta<sup>[10]</sup> by 10%. Saline flush could also reduce streak artifacts from the superior vena cava by washing out the excessive contrast medium<sup>[3,12]</sup>. The results of the present study adds to the previous knowledge that laminar flow still leaves a small amount of contrast medium in the dead space and the effect of saline flush would be further enhanced by the spiral flow.

A phantom study using this novel spiral flow tube resulted in 50 to 70 HU increase in peak enhancement<sup>[5]</sup>. The study also showed that the aortic enhancement during the hepatic aortic phase increased by 30 HU using the spiral flow tube compared with the T-tube<sup>[5]</sup> and this was in concordance with the present study. However, the enhancement of the liver during the portal venous phase did not change with the spiral flow tube<sup>[5]</sup>. These results suggest that this novel tube would benefit in arterial phase imaging but not with parenchymal enhancement during the delayed phase.

There were some limitations with this study. Although we showed that the enhancement of coronary arteries improved by the spiral flow tube, the clinical impact is yet to be resolved. We believe that the increased enhancement would improve the diagnostic ability of especially obese patients and it would be maintained with a reduction of contrast medium in non-obese patients. Secondly, the contrast medium dose needed using the latest CT system is much lower compared to the 64-row CT used in the present study. Further study is necessary to assess the effects of the spiral flow tube using the new generation machines, but we believe that the increase in the enhancement of coronary arteries would also be reproduced using these machines. Finally, the patients were included sequentially, not randomly. Although there might be some unknown bias between the groups, we believe that the results would not change because the patient demographics showed no significant difference.

In conclusion, enhancement of coronary arteries significantly increased with the spiral flow tube compared with the T-tube and the difference was greater in the distal segments. The depiction of distal segments improved using this tube. This tube might benefit obese patients or patients with chronic kidney disease.

## CONFLICT OF INTEREST

One author (SU) is an employee of Nemoto Kyorindo. The other authors have nothing to disclose.

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