



Assessment of Image Quality for Selective Intracoronary Contrast-Injected CT Angiography in a Hybrid Angio-CT System: A Feasibility Study in Swine

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Purpose: To compare image quality in selective intracoronary contrast-injected computed tomography angiography (Selective-CTA) with that in conventional intravenous contrast-injected CTA (IV-CTA).

Materials and Methods: Six pigs (35 to 40 kg) underwent both IV-CTA using an intravenous injection (60 mL) and Selective-CTA using an intracoronary injection (20 mL) through a guide-wire during/after percutaneous coronary intervention. Images of the common coronary artery were acquired. Scans were performed using a combined machine comprising an invasive coronary angiography suite and a 320-channel multi-slice CT scanner. Quantitative image quality parameters of CT attenuation, image noise, signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR), mean lumen diameter (MLD), and mean lumen area (MLA) were measured and compared. Qualitative analysis was performed using intraclass correlation coefficient (ICC), which was calculated for analysis of interobserver agreement.

Results: Quantitative image quality, determined by assessing the uniformity of CT attenuation (399.06 vs. 330.21, $p < 0.001$), image noise (24.93 vs. 18.43, $p < 0.001$), SNR (16.43 vs. 18.52, $p = 0.005$), and CNR (11.56 vs. 13.46, $p = 0.002$), differed significantly between IV-CTA and Selective-CTA. MLD and MLA showed no significant difference overall (2.38 vs. 2.44, $p = 0.068$, 4.72 vs. 4.95, $p = 0.078$). The density of contrast agent was significantly lower for selective-CTA (13.13 mg/mL) than for IV-CTA (400 mg/mL). Agreement between observers was acceptable (ICC=0.79±0.08).

Conclusion: Our feasibility study in swine showed that compared to IV-CTA, Selective-CTA provides better image quality and requires less iodine contrast medium.

Key Words: Computed tomography angiography, image quality enhancement, percutaneous coronary intervention, contrast media

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INTRODUCTION

Adjunctive coronary atherosclerotic plaque assessment tools, such as intravascular ultrasound (IVUS) or optical coherence tomography (OCT), at the time of invasive coronary angiography have been shown to improve the success of percutaneous coronary intervention and minimize the risk of complications.¹⁻⁵ However, these invasive imaging modalities have inherent limitations associated with their invasive nature, as well as additional costs.⁶⁻¹⁰ In contrast, noninvasive coronary angiography with coronary computed tomography angiography (CTA) facilitates effective assessment of luminal narrowing and atherosclerotic plaque both quantitatively and qualitatively, and has been shown to provide additional information regarding functional parameters, such as myocardial perfusion, fractional flow reserve, and wall shear stress, upon applying computation fluid dynamics techniques.¹¹⁻²³ However, CTA is of less use in patients with pre-existent renal insufficiency because of a high risk of contrast-induced nephropathy, and it cannot be used during revascularization since the device is not mobile.

In order to overcome these limitations, a selective intracoronary contrast-injected computed tomography angiography technique using a state-of-the-art Angio-CT system, Selective-CTA, has been introduced. This technique combines a 320-detector row CT scanner (Aquilion ONE; Canon Medical Systems Corporation, Otawara, Japan) with a coronary angiography system (INFX-8000C; Canon Medical Systems Corporation) allowing CTA scanning during coronary intervention without patient movement. A prior study showed the feasibility of Selective-CTA for the first time by establishing an imaging protocol in a swine model.²⁴ In the current study, we aimed to validate this new technique by comparing its image quality with that of conventional intravenous contrast-injected CTA (IV-CTA).

MATERIALS AND METHODS

Animal preparation

The Institutional Animal Care and Use Committee (IACUC, Yonsei University Health System) approved the study protocol. Six randomly chosen farm female pigs (35 to 40 kg) acclimated for 7 to 10 days in our animal facility (Department of Laboratory Animal Medicine, Medical Research Center, Yonsei University College of Medicine) were used for the evaluation. Prior to CT scanning, intramuscular enrofloxacin (5 mg/kg) and atropine (0.05 mg/kg) were injected. Sedation was achieved using tiletamine (Zoletil 50, Virbac, Carros, France) 5 mg/kg and xylazine (Rompun, Bayer Korea Ltd., Seoul, Korea). Intravenous access was achieved through the ear vein with a 20-gauge catheter. After placing the pigs on the Angio-CT system, mechanical ventilation was applied to maintain respiration during the study while the animal received anesthesia with 2%

isoflurane (Forane, JW Pharmaceutical, Seoul, Korea) and muscle relaxation using 4 mg vecuronium bromide (0.10 mg/kg). Additionally, 40 mg of intravenous esmolol was administered to achieve a target heart rate of 70 to 80 bpm. Coronary artery catheterization was performed using the conventional right (Cordis, JR 5-3.5) and left (Cordis, JL 5-3.5) diagnostic catheters for engagement of the right coronary artery (RCA), left anterior descending artery (LAD), and left circumflex artery (LCx), respectively.

Scan protocols of IV-CTA and Selective-CTA

The Angio-CT system, which consists of a 320-detector row CT scanner with a 16-cm detector width (Aquilion ONE) and a coronary angiography system (INFX-8000C), was used in this study. The CT scan parameters were as follows: tube voltage, 120 kVp; tube current, 550 mA; rotation time, 0.35 s; collimation, 320×0.5 mm; slice thickness, 0.5 mm; and reconstruction increment, 0.3 mm. The reconstruction parameters were as follows: iterative reconstruction algorithm (Adaptive Iterative Dose Reduction 3D; AIDR3D standard), convolution sharp filter kernel (FC43), and images reconstructed from 70% to 80% of the R-R interval in 5% increments. The CT scan was performed automatically with prospective ECG-gating, when the CT value at the level of the ascending aorta reached 180 HU.

The contrast injection method differed between IV-CTA and Selective-CTA. The conventional timing-bolus contrast injection method was used in IV-CTA; 60 mL of contrast agent (Iomeron 400, Bracco, Milano, Italy) was injected at a flow rate of 5 mL/s, followed by 30 mL of saline bolus using a dual-head power injector (CT Stellant; Medrad, Inianola, IA, USA). The Selective-CTA contrast injection protocol, which was proposed in our previous study, was chosen based on the findings in that study: diluted 20 mL of mixed contrast medium [we acquired continuous volume set over the 10 second scan duration; 1% (0.2 g) of IV-CTA (24 g) iodine contrast, Iomeron 400 mixed with saline] was injected at 2 mL/s using the same dual-head power injector, through the pre-engaged diagnostic catheter directly into the right or left coronary artery, respectively (Table 1).²⁴

We acquired continuous volumes (average 6-7 sets of volumes) over the 10-second scan duration. Both methods were scanned using prospective ECG gating (70% to 80% phase). After each scan, arteries were washed out with adequate saline flushing.

Table 1. Comparison of the Amount of Iodine Used in IV-CTA and Selective-CTA Experiments

	IV-CTA	Selective-CTA
Volume of contrast medium (mL)	60	20
Ratio of contrast medium (mg/mL)	400	13.13
Mass of contrast medium (mg)	24000	262.6
The ratio of two variables (%)	91.6 : 1.0	

CTA, computed tomography angiography.

Image quality assessment

Since the image quality was dependent on vessel and segment properties, all data were analyzed both on a per-vessel and on per-segment basis. For assessments on a per-vessel basis, all three major coronary arteries (RCA, LAD, and LCx) were analyzed. When the catheter was located on the left ostium, we measured contrast enhancement for the LAD and LCx. Analyses based on a per-segment basis, which takes the length of the vessel and the location of the branch into account, were performed by obtaining measurements for the proximal, mid, and distal segments of each coronary artery according to SCCT guidelines.²⁵ The proximal RCA is the segment from the ostium of the RCA to one-half the distance to the acute margin of heart, the mid RCA is from the end of the proximal RCA to the acute margin of heart, and the distal RCA is from the end of the mid RCA to the margin. The proximal LAD is from the end of the left main coronary artery (LM) to the first large septal, the mid LAD is from the end of the proximal LAD to one-half the distance to the apex, and the distal LAD is from the end of the mid LAD to the end of the LAD. The proximal LCx is from the end of the LM to the origin of the first ob-

tuse marginal (OM). The mid and distal LCx's travel in the AV groove, with the distal LCx from the first OM branch to the end of the vessel. All datasets from both protocols were analyzed with a commercially available software workstation (QAngioCT, version 2.0.2, Medis Medical Imaging Systems, Leiden, the Netherlands) by two radiologists with experience of 10 years. All segmentations were produced by the automatic segmentation function of the QAngioCT workstation (Fig. 1). The initial window width and window level for measurements were set to 800 Hounsfield units (HU) and 300 HU, respectively, and the window level was adjusted in the range of 250 to 400 HU according to the status of the measured image.²⁵

Quantitative image quality assessment

In order to analyze image quality, we measured contrast homogeneity, contrast noise, signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR), mean lumen diameter (MLD), and mean lumen area (MLA). MLD and MLA were measured from cross-sectional vessels in the quantitative analysis of the coronary artery, and the inner and outer borders of the coronary arteries were blurred depending on image quality. Therefore, quantita-

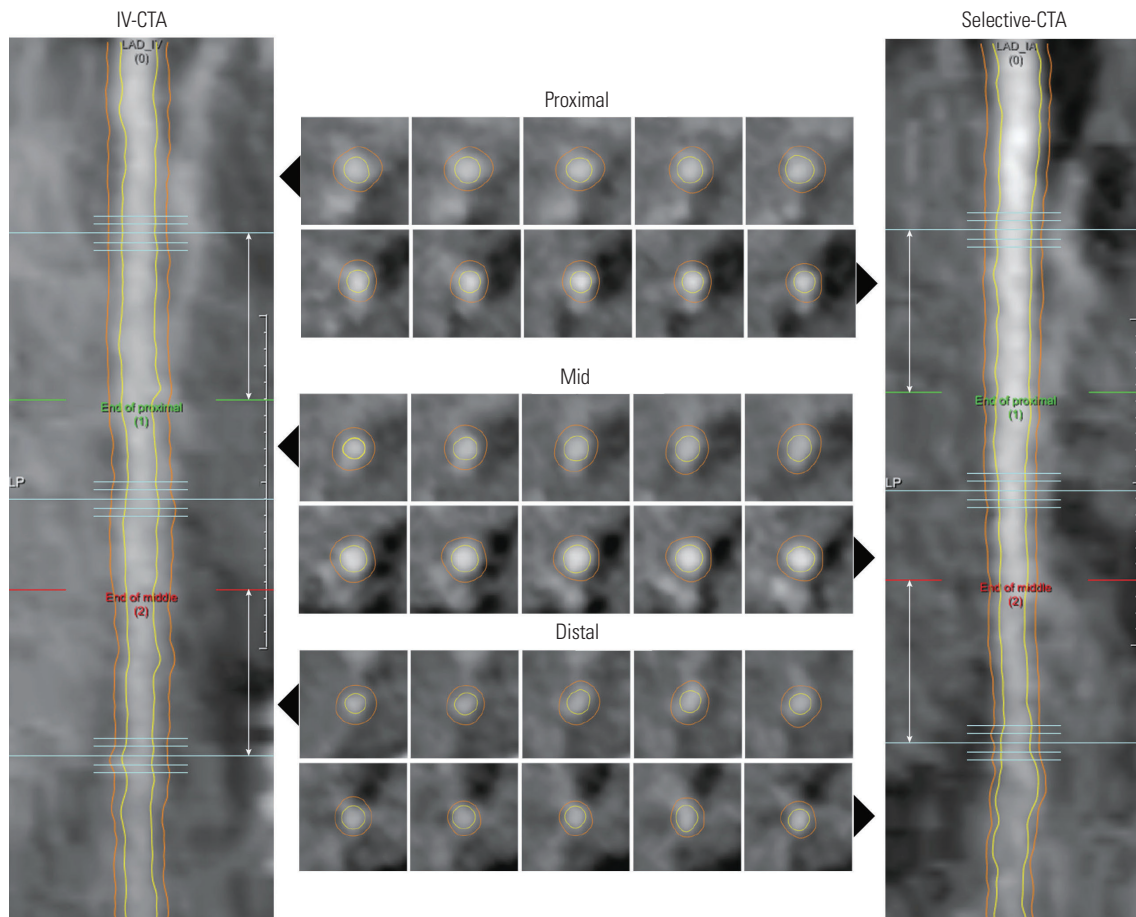


Fig. 1. Coronary CTA images from the IV-CTA and Selective-CTA protocols for quantitative and qualitative measurements. To set the measurement positions as close as possible between both protocols, the proximal, mid, and distal segments of the s-MPR were divided based on the branch. The measurements were performed at a total of five cross-sectioned positions for each segment (Inner yellow line: lumen area). Proximal, segmented proximal artery; Mid, segmented mid artery; Distal, segmented distal artery; CTA, computed tomography angiography; MPR, multiplanar reconstruction.

tive image quality comparison was possible by measuring the diameter and area in the coronary artery. Contrast homogeneity was determined by the mean intensity (HU) in the regions of interest (ROIs) of the possible largest area that ranged from 2.6 to 15.5 mm² within a cross-section of the coronary artery lumen (Fig. 1). Contrast noise was the standard deviation (SD) of the HU values within the ROI. SNR was defined as the ratio of the mean intensity to the SD within the ROI, as calculated in equation 2.

$$SNR = \frac{Mean_{lumen}}{SD_{lumen}} \quad Eq 2$$

CNR was defined as the difference between the mean intensity within the ROI in the vessel lumen and the mean intensity within the ROI in the adjacent non-enhanced pericardial fat tissue divided by the image noise of the lumen ROI, as calculated in equation 3.²⁶

$$CNR = \frac{(Mean_{lumen} - Mean_{fat})}{SD_{lumen}} \quad Eq 3$$

MLD and MLA, respectively, were measured in the placed ROIs.

Qualitative image quality assessment

Two independent level-III readers measured the qualitative image quality in a blinded fashion by considering both the multiplanar reconstruction and cross-sections of the lumen. For the analysis, we used a five-point Likert scale: 1=non-diagnostic (severe artifacts, such as discontinuity or double contour of

vessel), 2=suboptimal (severe motion artifacts or blurring and poor opacification of vessel), 3=acceptable (some degree of motion artifact or blurring and fair opacification of vessels), 4=good (minor motion artifacts or blurring and good opacification of vessel), 5=excellent (no motion artifacts or blurring and excellent opacification of vessel). All scores other than 1 were classified as diagnostic.

Statistical analysis

Continuous variables are expressed as a mean and SD. Quantitative measurements of the two methods (i.e., MLD and MLA) were compared using the independent t-test and Bland-Altman plots. Consistency was assessed between two radiologists by inter-rater agreement (Kappa). The reliability was quantified by intraclass correlation coefficient (ICC) values, which were interpreted as follows: 0.81 to 1.00 indicated excellent reliability, 0.61 to 0.80 indicated good reliability, 0.41 to 0.60 indicated moderate reliability, 0.21 to 0.40 indicated fair reliability, and values under 0.2 indicated poor reliability. In consideration of a two-tailed probability, a *p* value less than 0.05 was considered to indicate a statistically significant difference. Statistical analysis was performed using MedCalc software (version 14; MedCalc, Mariakerke, Belgium).

RESULTS

Quantitative image quality

With the 270 segments (six pigs×three vessels×three segments× five repetitions) and 90 vessels (six swine×three vessels×five

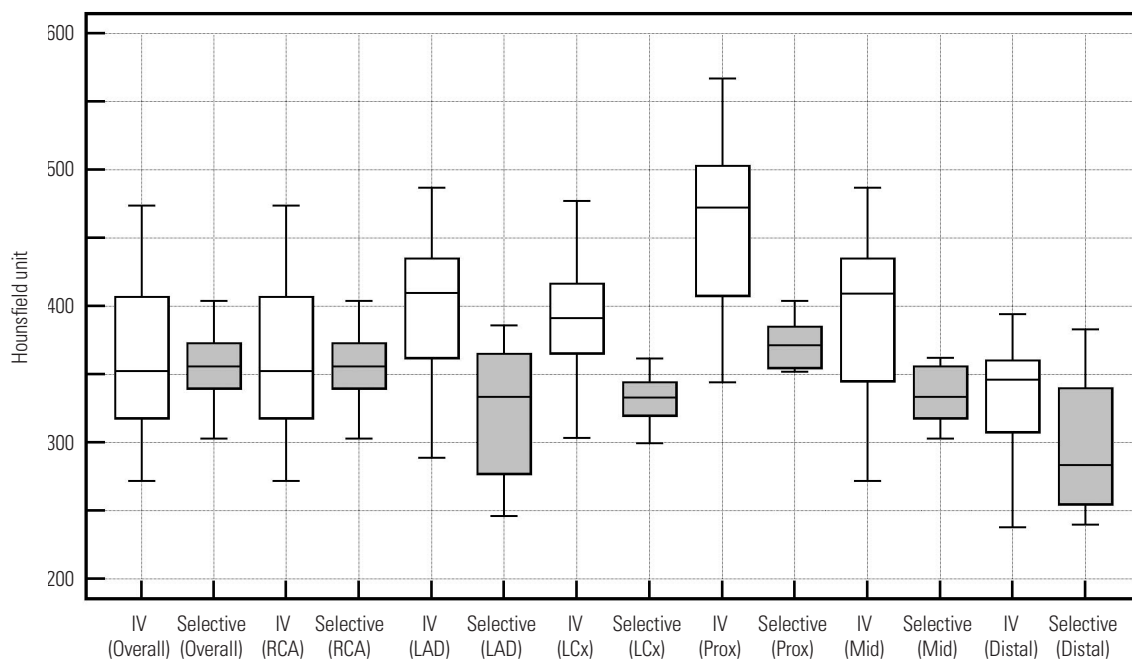


Fig. 2. The box plot indicates the intensity for each vessel and segment. The white box is the IV-CTA protocol, and the gray box is the Selective-CTA protocol. RCA, right coronary artery; LAD, left anterior descending artery; LCx, left circumflex artery; Proximal, segmented proximal artery; Mid, segmented mid artery; Distal, segmented distal artery; CTA, computed tomography angiography.

repetitions), we found significant differences between the conventional IV-CTA and Selective-CTA protocols in overall measurements of the uniformity of CT attenuation (399.06 vs. 330.21, $p < 0.001$), image noise (24.93 vs. 18.43, $p < 0.001$), SNR (16.43 vs. 18.52, $p = 0.005$), and CNR (11.56 vs. 13.46, $p = 0.002$) (Fig. 2). On the other hand, no significant difference was observed in MLD (2.38 vs. 2.44, $p = 0.068$) or MLA (4.72 vs. 4.95, $p = 0.078$). When CT attenuation was measured, RCA did not show significant differences (365.38 vs. 355.94, $p = 0.135$), and image noise was significantly different between per-vessel and per-segment assessments. When SNR was measured, there were no significant differences in the LAD (18.07 vs. 18.07, $p = 0.998$) or the distal region (14.34 vs. 16.01, $p = 0.137$). There was also no significant difference in the CNR of LAD (12.63 vs. 12.89, $p = 0.710$), although significant differences were observed in other vessels and segments. The differences between the two protocols in the MLD of RCA (2.47 vs. 2.58, $p = 0.001$) and LCx (2.44 vs. 2.53, $p = 0.042$) were insignificant, while there was a significant difference in the MLA of RCA (5.14 vs. 5.55, $p = 0.001$) (Table 2 and 3). The agreement in MLD and MLA between the two proto-

cols is visualized with Bland-Altman plots in Fig. 3.

Qualitative image quality

Qualitative image quality in the per-vessel and per-segment analyses are shown in Table 4. The results for observer 1 were 3.27 ± 1.13 in IV-CTA and 3.66 ± 0.95 in Selective-CTA, while those for observer 2 were 3.22 ± 1.17 in IV-CTA and 3.33 ± 0.95 in Selective-CTA. Overall, the qualitative scores were acceptable for IV-CTA (suboptimal to acceptable) and Selective-CTA (acceptable to good) (Fig. 4). Two independent observers showed good agreement in their evaluations using IV-CTA and Selective-CTA (κ of mean = 0.79 ± 0.08). According to the observers, there was a good correlation between IV-CTA and Selective-CTA (ICC score: 0.70 to 0.93, 0.75 to 0.86).

DISCUSSION

In a previous study, we were able to demonstrate the feasibility of Selective-CTA by testing various scan protocols and es-

Table 2. Comparison of the Quantitative Measures of Image Quality (Intensity, Image Noise, and SNR) between IV-CTA and Selective-CTA

	IV-CTA	Selective-CTA	p value
Intensity (HU)			
Overall	399.06±78.45	330.21±41.84	<0.001
RCA	365.38±58.26	355.94±26.01	0.135
LAD	407.25±86.48	313.27±52.40	<0.001
LCx	410.61±75.04	335.64±19.02	<0.001
Proximal	453.38±73.14	357.70±31.74	<0.001
Mid	410.70±58.86	325.64±32.71	<0.001
Distal	333.11±49.01	307.29±44.23	0.047
Noise			
Overall	24.93±5.95	18.43±3.48	<0.001
RCA	28.56±6.45	21.72±3.83	0.001
LAD	23.33±5.61	17.97±3.15	<0.001
LCx	25.41±3.14	16.85±2.02	<0.001
Proximal	26.10±5.24	17.73±3.57	<0.001
Mid	24.80±4.37	17.85±3.01	<0.001
Distal	24.66±6.65	19.71±3.60	0.001
SNR			
Overall	16.43±4.19	18.52±4.15	0.005
RCA	13.35±3.46	16.89±3.52	0.008
LAD	18.07±4.31	18.07±4.78	0.998
LCx	16.31±3.30	20.23±2.98	<0.001
Proximal	18.09±4.54	20.91±4.38	0.024
Mid	16.87±3.03	18.67±3.26	0.007
Distal	14.34±4.07	16.01±3.26	0.137

CTA, computed tomography angiography; HU, Hounsfield unit; RCA, right coronary artery; LAD, left anterior descending artery; LCx, left circumflex artery; Proximal, segmented proximal artery; Mid, segmented mid artery; Distal, segmented distal artery; SNR, signal-to-noise ratio. Data expressed as means±standard deviations.

Table 3. Comparison of the Quantitative Measures of Image Quality (CNR, MLD, and MLA) between IV-CTA and Selective-CTA

	IV-CTA	Selective-CTA	p value
CNR			
Overall	11.56±3.51	13.46±3.40	0.002
RCA	9.19±2.65	12.27±3.01	0.005
LAD	12.63±3.60	12.89±3.89	0.710
LCx	11.70±3.23	15.02±2.32	<0.001
Proximal	13.33±3.91	15.63±3.47	0.031
Mid	12.02±2.51	13.28±2.58	0.004
Distal	9.33±2.79	11.18±2.56	0.025
MLD (mm)			
Overall	2.38±0.55	2.44±0.57	0.068
RCA	2.47±0.65	2.58±0.64	0.001
LAD	2.30±0.53	2.27±0.53	0.491
LCx	2.44±0.49	2.53±0.48	0.042
Proximal	2.75±0.53	2.78±0.53	0.163
Mid	2.40±0.51	2.46±0.52	0.543
Distal	2.00±0.34	2.12±0.43	0.057
MLA (mm ²)			
Overall	4.72±2.31	4.95±2.39	0.078
RCA	5.14±2.84	5.55±2.76	0.001
LAD	4.39±2.02	4.27±2.11	0.505
LCx	5.01±2.06	5.19±1.94	0.323
Proximal	6.18±2.42	6.27±2.39	0.193
Mid	4.72±2.08	4.96±2.17	0.683
Distal	3.24±1.16	3.66±1.55	0.114

CTA, computed tomography angiography; RCA, right coronary artery; LAD, left anterior descending artery; LCx, left circumflex artery; Proximal, segmented proximal artery; Mid, segmented mid artery; Distal, segmented distal artery; CNR, contrast-to-noise ratio; MLD, mean lumen diameter; MLA, mean lumen area. Data expressed as means±standard deviations.

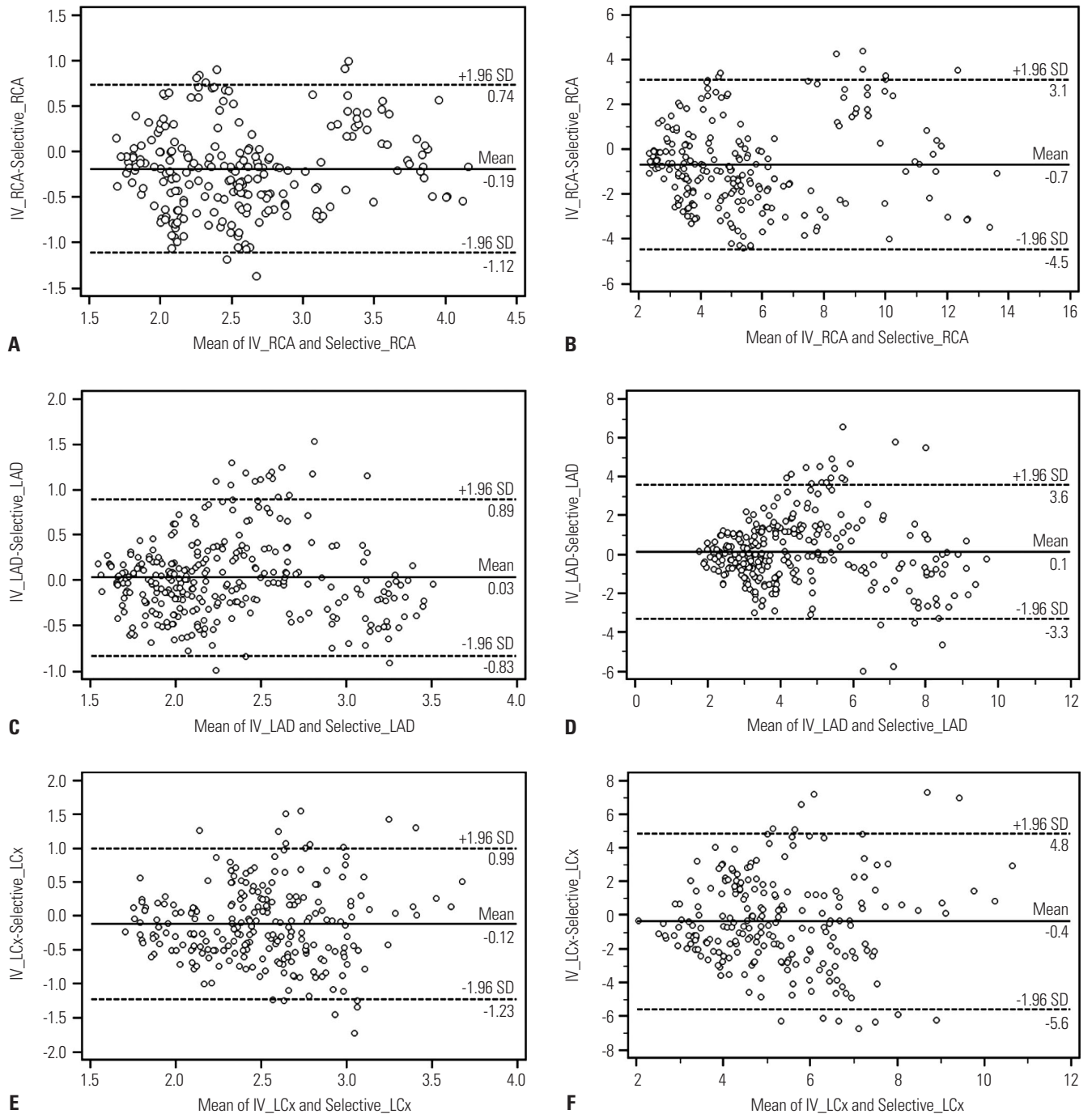


Fig. 3. Bland-Altman plots showing the relationship between MLD and MLA in per-vessel analyses (RCA, LAD, and LCx) of IV-CTA and Selective-CTA. (A) MLD of RCA's. (B) MLA of RCA's. (C) MLD of LAD's. (D) MLA of LAD's. (E) MLD of LCx's. (F) MLA of LCx's. RCA, right coronary artery; LAD, left anterior descending artery; LCx, left circumflex artery; MLA, mean lumen area; MLD, mean lumen diameter; CTA, computed tomography angiography.

establishing an optimal protocol with an extremely low dose of iodine contrast medium [amount of iodine contrast medium, approximately 1% (0.2 g) of IV-CTA (24 g)] in a pig model.²⁴ In this serial Selective-CTA study, we validated this technique and demonstrated its better quantitative image quality, including more optimal and homogeneous CT attenuation patterns (Fig. 1), lower image noise, higher SNR and CNR over conventional IV-CTA, as well as comparable MLD and MLA.

Bland-Altman plots (Fig. 3) also demonstrated comparable agreement in measurements of diameter and area between the two protocols and qualitative image quality with IV-CTA. These image quality improvements can be attributed to the fact that contrast medium is mixed less extensively with blood and does not enhance adjacent coronary veins or myocardium in the Selective-CTA protocol.

In coronary CTA, the homogeneous opacification of the

Table 4. Comparison of Qualitative Image Quality between IV-CTA and Selective-CTA

	Observer 1			Observer 2		
	IV-CTA	Selective-CTA	ICC	IV-CTA	Selective-CTA	ICC
RCA	3.58±1.31	4.00±1.13	0.93	3.33±1.23	3.25±1.06	0.86
LAD	3.50±1.17	3.83±0.72	0.75	3.17±1.27	3.33±0.89	0.80
LCx	2.75±0.75	3.17±0.83	0.73	3.17±1.11	3.42±1.00	0.81
Proximal	3.83±0.93	4.16±0.57	0.97	3.83±1.11	3.83±0.93	0.80
Mid	3.16±1.02	3.75±0.86	0.70	3.00±0.95	3.33±0.88	0.75
Distal	2.83±1.26	3.08±1.08	0.72	2.83±1.26	2.83±0.83	0.77

CTA, computed tomography angiography; ICC, intraclass correlation coefficient; RCA, right coronary artery; LAD, left anterior descending artery; LCx, left circumflex artery; Proximal, segmented proximal artery; Mid, segmented mid artery; Distal, segmented distal artery. Data expressed as means±standard deviations.

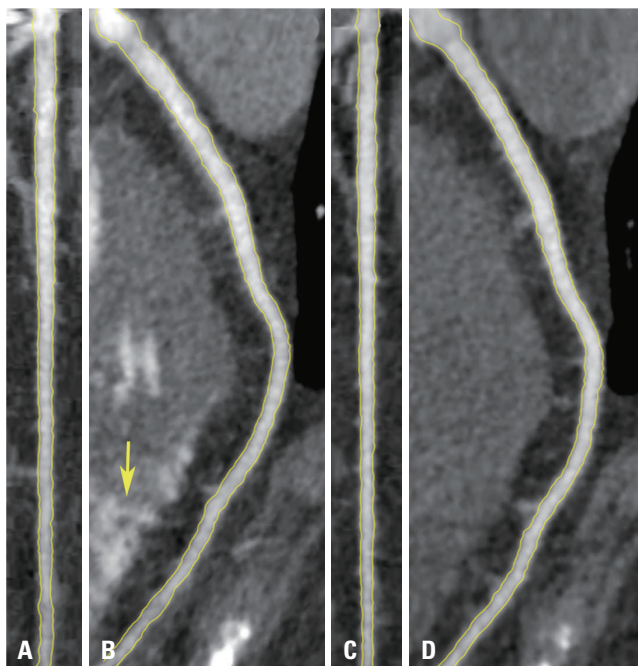


Fig. 4. Representative straightened MPR images. Stretched MPR images of an RCA with IV-CTA (A and B) and Selective-CTA (C and D). The yellow arrow of IV-CTA indicates contrast-enhanced myocardium, because contrast medium was injected intravenously (B). On the other hand, Selective-CTA does not show contrast-enhanced myocardium, because the contrast medium was injected directly into the vessel (D). MPR, multi-planar reconstruction; RCA, right coronary artery; CTA, computed tomography angiography.

proximal and distal regions of the coronary artery has clinical significance, as it facilitates evaluations of the degree of coronary stenosis by measuring the linear regression coefficient between luminal attenuation and axial distance.²⁷ The Selective-CTA method provided more homogeneous images with optimal luminal enhancement (250 to 400 HU) than the IV-CTA method. Additionally, unlike LAD and LCX, RCA showed significant differences in MLD and MLA values between IV-CTA and Selective-CTA. This might be related to the fact that RCA is more susceptible to motion than the other two coronary arteries.²⁸ Therefore, there is a possibility that Selective-CTA provides more accurate measurements than IV-CTA by providing

more homogeneous luminal enhancement than IV-CTA, particularly in actively moving coronary arteries, such as RCA. However, our inference needs to be proven through accurate coronary artery phantom study in the future.

To our knowledge, our study was the first to carry out serial selective intracoronary catheter-directed contrast-injected CTA. Several prior trials had studied catheter-directed selective contrast injection methods in pig models to reduce contrast amounts by placing the catheter in the superior vena cava or aortic root.^{29,30} However, in these previous studies, only 50% and 80% reductions in contrast medium dosages were achieved, respectively.²⁹ In contrast, our Selective-CTA was able to achieve a 99% reduction in contrast medium dosage. Therefore, Selective-CTA might be an alternative method for coronary artery disease in patients with decreased renal function and those who cannot tolerate invasive coronary angiography or conventional CTA due to the risk of developing contrast-induced nephropathy. In addition, the radiation dose of the selective-CTA (2.71±1.10 mSv) was significantly lower than that of conventional CTA (3.52±2.50 mSv), in comparison with a tube voltage of 100 kV in patients with a body mass index <30 kg/m² and 120 kV otherwise.

Furthermore, our scan was performed on-site during the procedure by pre-engaging the coronaries with conventional diagnostic catheters, thereby avoiding the need to move the subject to the CT room or use additional specialized catheters for imaging. Coronary atherosclerotic plaque characterization has recently been established as an effective tool for prediction of future acute coronary events. Therefore, invasive IVUS or OCT, as well as non-invasive CTA plaque characterization, have been actively studied in a qualitative and quantitative manner.^{11-13,31-33} Furthermore, as the spatial and temporal resolution of CTA continues to improve, computed fluid dynamics can be applied to assess the detailed coronary anatomy in order to provide physiologic information, such as fractional flow reserve and wall shear stress, with the help of sophisticated automated or semi-automated analysis software.^{19-21,34}

However, these novel techniques can currently only be applied to the patients with stable angina in whom CTA has been performed prior to catheterization due to the computerized

processing time.²² On the other hand, CTA scans are not recommended prior to cardiac catheterization in patients with unstable angina or those with a high pretest probability based on positive exercise treadmill test results.³⁵ Selective-CTA, even for this high-risk patient population, may serve as a non-invasive adjunctive tool, which can similarly perform invasive IVUS and OCT. It could potentially allow detailed anatomical and plaque characterization, as well as establish the hemodynamic significance of the lesion, while requiring extremely low amounts of contrast agent at a relatively low cost due to the lack of need for additional devices.²⁴ On the other hand, IVUS and OCT frequently require expensive specialized catheters and necessitate coronary wiring, as well as guiding catheter engagement. These invasive techniques may potentially cause complications, such as coronary spasm, rupture, dissection, and thrombosis, and require additional contrast medium.⁷⁻¹⁰ In addition, the image acquisition time of approximately 5 minutes is similar between Selective-CTA and IV-CTA. Only the contrast injection line needs to be replaced with a dual head injector when utilizing the Selective-CTA method. In the near future, as CTA technology continues to improve and post processing algorithms continue to evolve, Selective-CTA could possibly emerge as a robust non-invasive tool that can potentially allow instantaneous comprehensive plaque analysis and provide physiologic information on-site.

This study has limitations. We evaluated the Selective-CTA technique only in a swine model using a relatively small number of animals. In addition, the analyzed vessels were free of atherosclerosis, and the study was conducted under normal heart function. Therefore, these results could not be generalized to clinical conditions where heart rate can vary and is difficult to control during the procedure. Furthermore, an optimal contrast injection protocol has not been established in a human study. Therefore, Selective-CTA needs to be validated in a clinical study. Another limitation is that the conventional radio-opaque diagnostic catheter tip can cause significant beam hardening artifacts, which may compromise accurate assessment of the ostium of RCA and left main coronary artery. Therefore, in future clinical studies, development of a radiolucent diagnostic catheter tip needs to be considered. In this study, a comparison was performed with IV-CTA, which is a non-invasive method; however, a gold standard comparison between the Selective-CTA method and invasive approaches (IVUS, OCT, etc.) is needed.

In conclusion, our feasibility study in swine showed that compared to IV-CTA, Selective-CTA is effective for reducing iodine contrast medium, as well as improving image quality. However, further clinical evaluation is required in order to confirm the effectiveness thereof.

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