

**Coronary CT angiography in coronary artery bypass grafts:
Comparison between low concentration Iodixanol 270 and Iohexol
350**

Abstract

Objective:

The aim of this study was to evaluate the feasibility of low concentration iso-osmolar Iodixanol 270 compared with Iohexol 350 in patients with coronary artery bypass grafts (CABG) undergoing coronary CT angiography (CCTA).

Methods:

A total of 80 consecutive patients undergoing CABG follow up with the use of CCTA were prospectively enrolled, with 40 patients assigned to Iodixanol 270 and 40 patients to Iohexol 350. In both groups, contrast medium was injected at an injection rate of 4.5 mL/s in patients with $BMI > 24 \text{ kg/m}^2$ and 3.5 mL/s in patients with $BMI \leq 24 \text{ kg/m}^2$. Image quality score and visualization of bypass grafts were evaluated. Subjective assessment of image quality for each coronary artery segment was determined using a 4-point grading scale by two reviewers, while objective evaluation of image quality was conducted by measuring the mean CT attenuation values (HU) in terms of standard deviation (SD), contrast-to noise ratio (CNR), and signal-to-noise ratio (SNR) in the ascending aorta.

Results:

The mean contrast volume for Iodixanol 270 and Iohexol 350 group was $66.28 \pm 12.00 \text{ ml}$, and $64.98 \pm 12 \text{ ml}$, respectively with no significant difference ($p=0.57$). The mean CT attenuation value in the 270-group was 409.69 ± 98.27 , which was lower than in the 350-group, which was 475.14 ± 104.75 ($p=0.04$). The subjective image quality for 270-group was superior to 350-group in the arterial graft vessels ($p=0.027$), while there was no significant difference between the two groups in the venous graft vessels ($p=0.377$). There was no significant difference in terms of SD_{AO} , SNR, and CNR between the two groups.

Conclusion:

Low concentration iso-osmolar Iodixanol 270 provides image quality comparable to Iohexol 350, allowing diagnostic CCTA follow-up of patients with CABG.

Keywords: Contrast media, Coronary CT Angiography, Bypass Grafts, Cardiac imaging, Low concentration contrast media

Introduction

Coronary CT angiography (CCTA) is a widely used noninvasive diagnostic tool for the detection of coronary artery disease (CAD) and the assessment of coronary artery bypass grafts (CABG) ¹⁻³. The efficacy of CCTA in the detection of significant stenosis in native coronary arteries and bypass grafts has been significantly improved due to increased spatial and temporal resolution of CT imaging techniques. Some studies have demonstrated good diagnostic accuracy of CCTA in the evaluation of significant graft, recipient, and non-grafted vessel stenosis as well as occlusion in patients with prior CABG, but still at the cost of high radiation exposure and contrast media doses ⁴⁻⁶. CCTA-associated radiation exposure and contrast media dose used for patients with prior CABG are generally higher than patients evaluated for the exclusion of CAD, since the greater scan length is needed to ensure coverage of the bypass grafts. Over the past few years, great efforts have been made to reduce radiation dose during CCTA, while the use of iodinated contrast media has increased over the past decades and is a well-known cause of acute renal failure, especially in patients with impaired renal function and/or in those with diabetes mellitus ⁷⁻⁹. Therefore, reducing iodine load during CCTA in patients with prior CABG is necessary, while maintaining diagnostic quality images. The iodine burden during CCTA may be reduced substantially with the use of low concentration contrast medium.

Characteristics of contrast medium, such as osmolality, might also influence the risk of contrast-induced nephropathy (CIN). A meta-analysis indicates that the iso-osmolar Iodixanol reduces the risk of contrast-induced nephropathy in patients with chronic kidney disease or with diabetes mellitus when compared with the low-osmolar Iohexol ⁸. However, the feasibility of CCTA using low concentration iso-osmolar (Iodixanol) contrast agent in patients with prior CABG has not been well investigated, to the best of our knowledge. Thus, the purpose of this study was to

evaluate the feasibility of Iodixanol 270 compared with Iohexol 350 for the assessment of coronary arteries and bypass grafts in patients with prior CABG.

Materials and Methods

Patients

The study was approved by the local ethics committee, and written informed consent was obtained from all patients. From April 2013 to November 2013, a total of 82 consecutive patients with prior CABG, who were referred to undergo follow-up CCTA, were prospectively enrolled. The exclusion criteria for CCTA were as follows: allergic to iodine containing contrast medium, renal insufficiency (creatinine clearance less than 60 ml/min/1.73 m²), inability to follow breath-hold instructions, body mass index (BMI) ≥ 30 kg/m² or body weight ≥ 90 kg. Two patients were excluded due to failure of breath-holding. Thus, 80 patients (64 male, 16 female; mean age: 63.35 \pm 10.25 years, age range: 34 – 85 years) were enrolled in the study. Patients were randomly assigned to two groups with 270-group consisting of 40 patients (11 female; mean age 63.40 \pm 9.26 years; range 34 - 78 years) and 350-group 40 patients (5 female; mean age 65.30 \pm 11.17 years; range 37 – 85 years).

In 270-group, lower concentration Iodixanol 270 (Visipaque 270, 270 mg I/ mL, GE Healthcare, Ireland) was used for contrast injection. In 350-group, conventional Iohexol 350 (Omnipaque 350 mg I/mL, GE Healthcare(Shanghai),Co.,Ltd) was administrated.

CCTA data acquisition

All CT examinations were performed on a second generation dual-source 128-slice CT scanner (SOMATOM Definition Flash, Siemens Healthcare, Forchheim, Germany). Patients were instructed to practice breath holding before scanning. Both contrast media were applied using a dual-head power injector (Stellant, Medrad, Indianola, USA). The image acquisition was triggered after a threshold of 120 HU was reached in a region-of-interest placed in the ascending aorta (bolus-tracking technique). None of patients received sublingual nitroglycerine. Data were

acquired in cranio-caudal direction by using the following parameters: detector collimation $2 \times 64 \times 0.6$ mm; slice acquisition $2 \times 128 \times 0.6$ mm by means of a z-flying focal spot; gantry rotation time 0.28 s and temporal resolution 75 msec. The scanning range included the bypass graft, entire heart, and extended to cover the level of the subclavian arteries in patients with internal mammary artery grafts. The field of view was adjusted to encompass the whole heart exactly. Patients with $\text{BMI} > 24 \text{ kg/m}^2$ were examined with a tube voltage of 100 kVp, while patients with $\text{BMI} \leq 24 \text{ kg/m}^2$ were performed with a tube voltage of 80 kVp. Tube current settings were set at 330-370 mA and adjusted according to patients' BMI. Prospectively ECG-triggered sequential scan with padding technique was used in all patients. In patients with $\text{HR} \geq 70$ bpm, data acquisition window was set at 35% to 45% of the R-R interval, and 70% to 80% of the R-R interval for patients with $\text{HR} < 70$ bpm.

Contrast media were preheated in a heating box to 37°C before injection. In both groups, contrast medium was injected at an injection rate of 4.5 mL/s in patients with $\text{BMI} > 24 \text{ kg/m}^2$ and 3.5 mL/s in patients with $\text{BMI} \leq 24 \text{ kg/m}^2$. The contrast volume was calculated as follows: injection rate \times (prior estimate scan time + delay time) + 5 ml. The prior estimate scan time was obtained from the CT scanner. The delay time was set as 5 seconds. And the extra 5 ml contrast media was injection, in case the prior estimate scan time was less than the real scan time. All injections were followed by 30 mL of saline flush.

Data post-processing

CCTA images were reconstructed with a slice thickness of 0.75 mm and increment of 0.5 mm, using a smooth convolution kernel (I26f). All images were reconstructed using sinogram affirmed iterative reconstruction algorithm, level 3 (SAFIRE, Siemens Healthcare, Forchheim, Germany). Images were reconstructed in multiple cardiac phases with 2% interval. After anonymization, images with best quality were transferred to a post-processing workstation (MMWP, Siemens Forchheim, Germany) for further analysis.

Subjective assessment of image quality

On a per-segment level, venous and arterial grafts as well as distal runoffs were evaluated. Five segments (proximal, middle, distal course of graft body, anastomosis, and distal runoff) were

classified for in-situ arterial grafts. For the venous grafts, five segments (proximal, middle, distal course of graft body, proximal anastomosis, and distal runoff) were classified for general venous grafts or six segments (proximal, middle, distal course of graft body, proximal anastomosis, distal anastomosis, and distal runoff) were classified for the jump venous grafts. The anastomosis refers to the stomas between the graft vessel and the coronary artery. In the general venous grafts, there was only one anastomosis between the graft vessel and the coronary artery. We defined it as the proximal anastomosis to keep consistent with the jump venous grafts. The graft segment closer to the heart was defined as “Distal Course”. Extensive, calcified, and atherosclerotic plaque may influence the subjective assessment of native coronary artery and thus was not performed in this study¹⁰. The occluded graft bodies were excluded, while the distal runoff segments supplied by occluded grafts were included. In addition, distal runoffs with a lumen diameter < 1.5 mm were excluded.

Volume-rendered images were initially generated to visualize the course of the grafts in relation to the coronary arteries. Original 2D transverse images and curved planar reformations were used for evaluation of image quality. Two radiologists, each with more than 5 years of experience in cardiovascular imaging, were blinded to the CT protocols and independently assessed all graft segments and distal runoff segments. CT images obtained from the two groups were randomly presented during each reading session. Any discrepancy between the two reviewers was resolved during a third session, through which the reviewers read images together to reach a consensus.

Image quality for each coronary artery segment was evaluated with a 4-point grading scale¹¹. Segments that could not be evaluated (non-diagnostic) were given a score of 4, corresponding to poor vessel opacification, lack of vessel wall definition due to marked motion artefacts, severe image noise-related blurring, and prominent structural discontinuity. Segments that could be evaluated (being diagnostic) were scored as follows: A score of 3 corresponded to fair vessel opacification, some motion artefacts or noise-related blurring, or moderate structural discontinuity, but sufficient delineation of the individual segments; a score of 2, good vessel opacification, minor motion artefacts or noise-related blurring, and minimal vessel discontinuity; and a score of 1,

excellent vessel opacification, absence of motion artefacts or noise-related blurring, and no structural discontinuity (Fig.1). Segments with coronary stent were not included.

Objective analysis of image quality

The mean CT attenuation values in HU, noise, i.e., standard deviation (SD) of the mean CT attenuation values of the ascending aorta, contrast-to noise ratio (CNR) and signal-to-noise ratio (SNR) were measured in the ascending aorta¹². Attenuation was measured in a circular region of interest (ROI) in the ascending aorta (100 mm²) and the perivascular fatty tissue (10 mm²). ROIs were placed avoiding the possible influence of partial volume effects and outside visible image artefacts. Attenuation was assessed in three adjacent slices, and the attenuation values were averaged for the vessels and the perivascular fatty tissue. All measurements were performed by an experienced radiologist (with more than 5 years of experience in cardiovascular imaging). The CNR was calculated for the ascending aorta (ao) as: $CNR = (HU_{ao} - HU_{fat})/image\ noise$, while the SNR was calculated as: $SNR = HU_{ao}/image\ noise$.

Radiation dose estimation

Parameters relevant to radiation dose were recorded from the CT system after each CCTA study. These parameters included the volume CT dose index (CTDI_{vol}) and dose length product (DLP). The effective dose (ED) measured in millisieverts of CCTA was calculated by multiplying the DLP by a conversion coefficient weighting factor for the chest in adults (0.014)¹³

Statistical analysis

Statistical analysis was performed with statistical software SPSS version 16.0 for Windows (SPSS Inc, Chicago, IL, USA). Quantitative variables were expressed as mean \pm SD, and categorical variables were expressed as frequencies or percentages. Since the continuous variables were normally distributed (according to Kolmogorov–Smirnov test results), the age, weight, BMI, heart rate, and scanning range were compared between the two groups by using the Student's *t*-test. Wilcoxon signed rank test was used to evaluate the difference in the subjective image quality between 270 and 350 mg I/mL groups for all segments together. Objective imaging quality parameters between the 270 and 350 mg I/mL protocols, such as CT attenuation and image noise, were compared using the *t*-test. Inter-observer agreement in subjective image quality grading was

evaluated by Kappa statistics. A Kappa value of 0 indicates poor agreement; 0.01–0.20, slight agreement; 0.21–0.40, fair agreement; 0.41–0.60, moderate agreement; 0.61–0.80, good agreement; and 0.81–1.00, excellent agreement. The rate of diagnostic segments was compared by using the non-parametric Chi-square test. A value of $p < 0.05$ indicated a statistically significant difference.

Results

Patients' characteristics

All scans were successfully completed in all of the 80 enrolled patients. Patient characteristics are shown in table 1. In 40 patients, 407 segments out of 80 bypass grafts from the 270-group were present, whereas, 383 segments out of 74 grafts were present in 40 patients from the 350-group. As shown in table1, no significant difference was identified between the two groups for the demographic characteristics.

Baseline characteristics of the two groups during CCTA examinations are shown in table 2. There was no significant difference between the two groups in terms of the contrast volume used for CCTA ($p=0.57$). The iodine content in the 270-group was 178.94 ± 32.40 mg, while in 350-group was 224.61 ± 29.31 mg, with 20.33% reduction of iodine content in the 270-group ($p < 0.001$). No significant difference was reached between the two groups with respect to CTDI, DLP, ED, scan time, and scan length (Table2).

Subjective evaluation of graft vessels

The overall inter-observer agreement for image quality scoring was moderate ($k = 0.71$). Two segments (0.491%) in the 270-group were non-diagnostic and 1 (0.261%) segment of the 350-group was non-diagnostic. There was no significant difference between two groups ($p=0.60$). The non-diagnostic segments in the 270-group were due to noise-related blurring and the reason for the non-diagnostic segment in the 350-group was caused by marked motion artefacts. The average image quality was 1.11 (270-group) and 1.22 (350-group), with significant difference ($p=0.026$) (Table3), indicating that the image quality of 270-group was significantly better than the 350-group.

Regarding the assessment of arterial and the venous grafts separately, there was obvious difference between the two types of grafts. For the arterial graft vessel, the average image quality of the 270-group is 1.24, which was better than 1.32 of the 350-group ($p=0.027$). For the venous graft vessel, there was no significant difference between the two groups ($p=0.377$). (Fig.2)

Objective evaluation of graft vessels

The mean CT attenuation values was 409.69 ± 98.27 in the 270-group, which was lower than 475.14 ± 104.75 in the 350-group. There was significant difference between the two groups ($p=0.04$). However, no significant difference was observed in the SD of the ascending aorta (SDao), SNR, and CNR between the two groups (Table 4).

Discussion

This study has two important findings, which are considered valuable from clinical perspectives: Firstly, we found that low concentration iso-osmolar Iodixanol 270 is feasible for CCTA in patients with prior CABG. This protocol effectively reduced iodine load, while maintaining image quality in comparison to Iohexol 350. Secondly, our results indicated that the image quality for 270-protocol was superior to 350-protocol in the arterial graft vessels, due to the fact that high concentration posed more beam hardening artefacts with presence of more metal clips in the arterial graft vessel.

CCTA is becoming a regular examination for follow-up of CABG as conventional coronary angiography is an invasive procedure. The diagnostic performance of the CCTA after CABG has been confirmed by clinical trials¹⁴⁻¹⁷. The prognostic value of CCTA in coronary bypass patients also has been studied¹⁸. CCTA is considered a promising tool for risk stratification in CABG patients. Despite promising results of CCTA in the follow-up of CABG patients, CCTA involves much higher radiation exposure and contrast dose, due to the extended scan length. Over the past few years, great efforts have been made to reduce radiation dose during CCTA. Some dose-reduction techniques such as prospective ECG-gating, iterative reconstruction algorithm as used in this study has been developed and proven to be effective. With the use of new CT scanners, the effective dose has been dramatically reduced^{10,16,19}. While the contrast does used in the CCTA examination in CABG patients is still high, it is well known, the application of low concentration

contrast media is feasible with the use of low tube voltage, because reducing the tube voltage increases the attenuation of iodinated contrast media. The image noise caused by low tube voltage can be improved by the use of iterative reconstruction algorithm. SCCT guidelines recommend the routine use of low tube voltage of 100-kV in patients weighing ≤ 90 kg or with a BMI ≤ 30 kg/m² ¹³. Our study protocol was consistent with the guideline. A recent study which enrolled 5,006 patients in emergency department demonstrated that the incidence of CIN was 7% after contrast-enhanced CT ²⁰. It is widely acknowledged that the iodine load is the crucial parameter for the nephrotoxicity of contrast medium. The updated ESUR contrast media safety committee guidelines indicated the importance of using the minimal dose of low- or iso-osmolar contrast medium for a diagnostic examination ²¹.

It has been reported that in procedures with higher volumes of iodinated contrast, patients with moderate-severe chronic kidney disease undergoing coronary angiography are accompanied by an increased, contrast-volume dependent risk of CIN ²². It is well known that the major effective content of the contrast-volume is iodine. Administration of contrast medium with low iodine concentration has the potential to decrease nephrotoxicity ²³. In this study, although there was no significant difference in the contrast volume between the 270-group and 350-group, the iodine content in 270-group is 20.33% lower than in 350-group.

In addition to high doses of contrast agents, the risk factors for CIN development, which is related to the contrast agents established by Contrast Media Safety Committee of the ESUR include high osmolality and viscosity ²⁴. Iodixanol 270 and iodixanol 320 are iso-osmolality contrast media ²⁵. The advantage of using of contrast media with a lower iodine concentration is the lower viscosity than those of high iodine-concentration contrast media. The viscosity of the Iohexol 350 is 10.6 Pa·s at 37°C, which is much higher than the Iodixanol 270 of 5.8 Pa·s at 37°C (data from GE Healthcare). We believe that patients would benefit from using low concentration Iodixanol 270 during CTA examination as shown in this study.

Contrast enhancement in CCTA is affected not only by the total volume and concentration of the contrast medium used but also by the injection rate and duration of injection. A previous study showed that the use of 300 mg I/mL contrast medium results in better contrast enhancement than that of 370 mg I/mL contrast medium in CT of the chest including aorta if

equivalent iodine delivery rate was given. Viscosity was thought to be a possible explanation for the higher mean attenuation with contrast media at low iodine concentration in the early phase of CT ²⁶. In contrary to the study design of high concentration contrast medium protocol with high tube voltage and filtered back projection reconstruction versus low concentration contrast protocol with low tube voltage and iterative reconstruction, the tube voltage, contrast volume, and the injection rate in our study were routinely used and identical for the two protocols for direct comparison. The total iodine load is lower in Iodixanol 270 protocol.

According to our results, the CT value at the ascending aorta was higher for the 350 mg I/mL protocol than for the 270 mg I/mL protocol. The contrast material that drains into the coronary arteries as well as the graft vessel can be represented by the enhancement of the ascending aorta. An optimal CT density in the coronary arteries is considered to be from 250 to 350 HU ²⁷⁻²⁹. Thus the mean attenuation of 410HU in ascending aorta for Iodixanol 270 protocol is still sufficient to evaluate the graft vessel with high image quality scores.

Subjective assessment of the image quality for the Iodixanol 270 group was better than the Iohexol 350 group, especially for the arterial grafts. This is due to the difficulty in identifying mental clips in the arterial graft vessel in a high attenuation 350-group. This is consistent with a recently published study comparing low iodine concentration iomeprol-320 with high iodine iomeprol-400 for the coronary stent evaluation ³⁰. Our results indicated that the image quality of CCTA using Iodixanol 270 is adequate for CABG evaluation compared with Iohexol 350 protocol.

There are limitations in this study that should be noted. Firstly, the safety profile (vital signs and adverse events) of both contrast agents was not recorded, and follow-up was not performed for side effects. Secondly, we did not study the diagnostic performance using conventional angiography as the reference standard as the focus of this study is to determine the image quality of CCTA follow-up of CABG patients. Thirdly, the Iodixanol 270 was only used in 100 kVp and 80 kVp protocol and only in patients with BMI less than 30 kg/m². The feasibility of Iodixanol 270 in 120 kVp protocol or in larger patients was not tested and may offer challenges for proper enhancement in coronary arteries. Finally, the use of conversion coefficient factor of 0.014 mSv·mGy⁻¹·cm⁻¹ could underestimate the effective dose as the latest conversion coefficient factor of 0.026 mSv·mGy⁻¹·cm⁻¹ was recommended in the literature since this value was likely to be

more accurate for estimation of radiation dose associated with cardiac CT compared to the chest CT³¹. Moreover, the tissue weighting factor in the breast has been reported in ICRP-103 and it changed significantly from 0.05 to 0.12. Thus, it is of paramount importance to apply the timely relevant factor according to the latest publication of the ICRP tissue weighting factor³¹⁻³³.

Conclusion

Our study indicates that low concentration iso-osmolar Iodixanol 270 is feasible for CCTA study in patients with prior CABG, as the protocol can reduce iodine load while maintaining image quality compared with Iohexol 350. Our results are considered to be beneficial for these patients (BMI<30) to undergo repeat CCTA follow up examinations for graft patency.

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Table 1

Patients' characteristics between the 270 and 350-groups

	Iodixanol 270-group	Iohexol 350-group	<i>P</i>
Gender (Male)	72.5%	87.5%	0.09
Age (Y)	63.48±9.27	65.30±11.17	0.41
Weight (kg)	70.19±9.76	70.51±9.80	0.88
Height (cm)	167.03±6.12	168.28±7.35	0.30
BMI (kg/m ²)	25.16±2.72	24.90±3.19	0.69

Mean heart rate (bpm)	67.80±11.98	66.34±11.42	0.58
Hypertension ^a	26	26	1.00
Diabetes ^b	17	12	0.25
Hyperlipidemia ^c	24	25	0.82
Current smoker	15	14	0.82
Previous MI	12	11	0.81

Abbreviations: Data are expressed as mean±SD. Y = years; kg = kilogram; BMI = body mass index;

bpm= beats per minute; MI= myocardial infarction

^a Defined as systolic blood pressure ≥ 140 mm Hg and/or diastolic blood pressure ≥ 90 mm Hg and/or the use of antihypertensive medication

^b Defined as fasting blood glucose of greater than or equal to 126 mg/dl and/or the use of antidiabetic medication

^c Defined as Serum total cholesterol ≥ 230 mg/dl and/or serum triglycerides ≥ 200 mg/dl or treatment with lipid lowering drugs

Table 2

Baseline characteristics of CCTA

	Iodixanol 270-group	Iohexol 350-group	<i>P</i>
Contrast volume (ml)	66.28±12.00	64.98±8.12	0.57
Iodine content (mg)	178.94±32.40	224.61±29.31	0.00
CTDIvol (mGy)	11.83±4.46	10.29±3.97	0.10
DLP (mGy)	233.67±93.73	215.04±84.30	0.35
Effective dose (mSv)	3.27±1.30	3.01±1.18	0.35

Scan time (s)	9.46±1.54	9.91±1.96	0.93
Scan length (cm)	19.74±2.17	20.51±1.45	0.06

Table 3

Subjective image quality

	Iodixanol 270-group				Iohexol 350-group				<i>p</i>
	1	2	3	4	1	2	3	4	
<hr/>									
Arterial graft vessel									
Proximal segment	31	2	0	0	26	5	0	0	
Middle segment	30	2	0	1	23	7	1	0	
Distal segment	27	5	1	0	21	9	1	0	
Anastomosis	25	6	2	0	24	5	2	0	

Distal run-off	24	4	4	1	17	13	0	1	
All arterial graft segments	137	19	7	2	111	39	4	1	0.03
Venous graft vessel									
Proximal segment	47	0	0	0	42	1	1	0	
Middle segment	43	1	3	0	42	1	1	0	
Distal segment	45	1	1	0	37	5	2	0	
Proximal anastomosis	41	2	1	0	40	3	0	0	
Distal anastomosis	10	2	1	0	11	0	0	0	
Distal runoff	33	9	2	0	27	14	1	0	
All venous graft segments	219	15	8	0	199	24	5	0	0.30
All segments	356	34	15	2	310	63	9	1	0.02

— The number in each column refers to the amount of the segments of the corresponding image quality. —

The definitions of image quality scores 1-4 were as follows:

1: Segments corresponded to excellent vessel opacification, absence of motion artefacts or noise-related blurring, and no structural discontinuity

2: Segments corresponded to good vessel opacification, minor motion artefacts or noise-related blurring, and minimal vessel discontinuity;

3: Segments corresponded to fair vessel opacification, some motion artefacts or noise-related blurring, or moderate structural discontinuity, but sufficiently delineation of the individual segments;

4: Segments that could not be evaluated (non-diagnostic), corresponding to poor vessel opacification, lack of vessel wall definition due to marked motion artefacts, severe image noise-related blurring, and prominent structural discontinuity.

Table 4

Objective evaluation of graft vessels

	Iodixanol 270-group	Iohexol 350-group	<i>P</i>
HU _{AO} ^a	414.72±101.47	478.85±108.73	0.01
SD _{AO} ^b	22.59±7.87	24.97±7.24	0.16
SNR ^c	19.89±6.76	18.96±7.22	0.55
CNR ^d	24.66±7.81	22.98±8.47.	0.36

^arefers to the CT attenuation values in the ascending aorta. ^brefers to the standard deviation of the mean CT attenuation values of the ascending aorta.

^crefers to contrast-to noise ratio of the ascending aorta. SNR was calculated as: $SNR = HU_{ao} / \text{image noise}$.

^drefers to signal-to-noise ratio of the ascending aorta. CNR was calculated for the ascending aorta (ao) as: $CNR = (HU_{ao} - HU_{fat}) / \text{image noise}$.

Figure Legend

Fig.1. Images showed examples of image quality. A, Excellent image quality (score 1). B, Good image quality (score 2). C, Fair image quality (score 3). D, Poor image quality (score 4).

Fig.2. A, B, C: A 66 year-old male patients with BMI: 27.34 kg/m^2 , images were acquired using Iodixanol 270, flow rate: 4.5 ml/s, contrast volume: 75 ml, scan length: 20.6 cm. Volume rendered image (A) and CPR images show good to excellent image quality of venous graft (B) and arterial graft (C).

D, E, F: A 61 year-old male patient with BMI: 27.33 kg/m^2 , images were acquired using Iohexol 350, flow rate: 4.5 ml/s, contrast volume: 75 ml, scan length: 20.6 cm. Volume rendered image (D) and CPR images show good to excellent image quality of venous graft (E) and arterial graft (F).