Coronary artery stents: influence of adaptive statistical iterative reconstruction on image quality using 64-HDCT

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Objective The assessment of coronary stents with present-generation 64-detector row computed tomography (HDCT) scanners is limited by image noise and blooming artefacts. We evaluated the performance of adaptive statistical iterative reconstruction (ASIR) for noise reduction in coronary stent imaging with HDCT.

Methods and results In 50 stents of 28 patients (mean age 64 ± 10 years) undergoing coronary CT angiography (CCTA) on an HDCT scanner the mean in-stent luminal diameter, stent length, image quality, in-stent contrast attenuation, and image noise were assessed. Studies were reconstructed using filtered back projection (FBP) and ASIR–FBP composites. ASIR resulted in reduced image noise vs. FBP (P < 0.0001). Two readers graded the CCTA stent image quality on a 4-point Likert scale and determined the proportion of interpretable stent segments. The best image quality for all clinical images was obtained with 40 and 60% ASIR with significantly larger luminal area visualization compared with FBP (+42.1 ± 5.4% with 100% ASIR vs. FBP alone; P < 0.0001) while the stent length was decreased (−4.7 ± 0.9%, <P = 0.002) and volume measurements were unaffected.

Conclusion Reconstruction of CCTA from HDCT using 40 and 60% ASIR incrementally improves intra-stent luminal area, diameter visualization, and image quality compared with FBP reconstruction.

Keywords Adaptive statistical iterative reconstruction • Coronary artery stent • Coronary CT angiography

Introduction

The foremost concern with the increasing use of computed tomography (CT) technology is the associated dose of ionizing radiation and the potential risk of cancer development later in life. Since radiation-induced carcinogenesis is a stochastic effect, its probability declines with a decrease in the radiation dose. However, dose reduction in CT is hindered by increased image noise in lower radiation doses, especially in challenging situations such as coronary artery stent evaluation. Here, the diagnostic performance of the high-definition 64-slice CT scanner (HDCT) is compromised because of beam hardening causing ‘blooming’ artefacts which arise from metallic stent struts, excessive image noise, and limited temporal resolution.1 Accordingly, two recent pooled analyses have reported low overall sensitivity of in-stent restenosis detection with uninterpretability in up to 13% of cases.2–4

Recently, an HDCT scanner with improved in-plane spatial resolution of 230 µm and the ability to reconstruct images with the use of a novel adaptive statistical iterative reconstruction (ASIR) algorithm has been introduced. This scanner is able to correct image data using a system of models to improve image noise.5 Unlike filtered back projection (FBP), iterative reconstruction entails fewer assumptions regarding noise distribution within an image and operates with an iterative process of mathematical and statistical...
modelling to identify and selectively reduce noise.\textsuperscript{6,7} ASIR is a modified iterative reconstruction algorithm which models the photon statistics in X-ray attenuation, resulting in significant noise reduction. By particular correction for the fluctuations in projection measurement due to limited photon statistics, ASIR allows the reduction of pixel variance that is statistically unlikely to represent anatomical structures without trade-off in spatial resolution. This process improves the noise properties within the reconstructed images and maintains spatial resolution and image quality.\textsuperscript{6} In clinical practice, variably blended images created with FBP and ASIR to produce different levels of ASIR can be obtained and the image reconstruction process on ASIR-capable scanners allows a mixture of FBP and ASIR images with adjustable increments ranging 0–100%. Images with 0% ASIR represent reconstruction with FBP only, images with 1–99% ASIR represent a composite of ASIR with the inverse proportion of FBP, and 100% ASIR represents reconstruction with ASIR only.

Although ASIR has been shown to reduce noise and improve image quality permitting reduction in the radiation dose in cardiac CT,\textsuperscript{9} it has not been evaluated in coronary stent assessment in vivo in low-dose protocol examinations. Thus, the purpose of this study was to evaluate the impact of ASIR on both quantitative measures and image quality evaluation in coronary stents using an ASIR-equipped HDCT scanner. Because image reconstruction can be performed using both FBP and ASIR, we additionally sought to determine the optimal combination of ASIR and FBP for coronary stent assessment.

**Methods**

**Patients**

We included 28 patients with previous coronary stent implantation, undergoing clinically indicated CCTA. The need to obtain written informed consent was waived because of the nature of the study, which included solely clinical data collection. Exclusion criteria for CCTA examination were renal failure (glomerular filtration rate <30 mL/min), known allergy to iodine contrast material, severe claustrophobia, pregnancy, and high heart rate in the presence of contraindications to beta-blockade.

**Coronary CT acquisition**

Patients received oral or IV \(\beta\)-blockers if needed to achieve a heart rate <65 bpm, and were given 0.4 mg sublingual nitroglycerine immediately before the study, assuming no contraindications. All examinations were performed using a 64-HDCT scanner (Discovery HD 750, GE Healthcare). All scans were performed in the cranio-caudal direction during inspiratory breath-hold with prospective electrocardiogram-triggering\textsuperscript{9–11} and a body surface area (BSA) adapted contrast media bolus as previously established.\textsuperscript{12} The radiation dose was quantified with a dose-length product conversion factor of 0.014 mSv/mGy/cm as previously described.\textsuperscript{12} Studies were acquired in high resolution, which was 230 μm. The scanning parameters included 64 × 0.625 mm collimation, a rotation time of 0.35 s, tube voltage of 100–120 kV, and a tube current of 450–700 mA. Tube current and voltage were adjusted on the basis of the BMI.\textsuperscript{13} All studies were reconstructed using the ASIR-assisted high-definition kernel with a display field of view of 25 cm, using FBP (0% ASIR) and increasing ASIR blending factors, i.e. 20, 40, 60, 80, and 100% (the latter uses no FBP).

**CCTA analysis**

Reconstructed data were transferred to workstations (Advantage AW 4.4, GE Healthcare) for analysis. The mean signal value in Hounsfield units (HU) and SD (noise) were measured in the aortic root and in the stent lumen without touching the lumen walls using a region of interest area (ROI), respectively. The ROI was chosen as large as possible and placed in the centre of the visible stent lumen, avoiding the inclusion of the stent struts or streak artefacts. An automated tool was used to ensure that all measurements were performed in precisely the same location for all of the reconstructions (Compare Viewer, GE Healthcare, Milwaukee, WI, USA). For each image series, the stent volume was determined using a semi-automatic volume analysis tool (GE Healthcare, Milwaukee, WI, USA). Coronary artery calcifications and stents were colour marked automatically by drawing ROIs around these structures. Voxels within these ROIs with attenuation values in the range of contrast medium were automatically excluded from the segmentation. Thus, we measured the maximum contrast attenuation in HU within the descending aorta and added 20% to this value to define the minimum attenuation level of voxels to be included in the volumetric analysis. Between the different reconstruction techniques of individual stents this level was kept constant. Dimensions of all stents are indicated as the diameter or the length in millimetres. Luminal diameter and area measurements were performed with a zoomed display field of view of 3.0 cm by using electronic calipers.

Luminal diameter was measured at the minimal and maximal intracoronary stent lumen. Length measurements were averaged for each stent. To standardize the analysis, images were displayed with a fixed window level at 240 HU and a window width at 1200 HU. Figure 1 shows an example of diameter and length measurements in a left circumflex (LCX) coronary artery.

Qualitative image analysis was performed by two independent, blinded, and experienced coronary CCTA readers. The six image sets, obtained with FBP and ASIR for each stent, were displayed side by side at a pre-set soft tissue window (window width, 240 HU; window level, 1200 HU) (Figure 2). The original transaxial slices were visually examined assisted by oblique and curved multiplanar reconstructions. After review of all of the data sets, each reader then assigned a 4-point Likert score for each stent on the basis of preferred...
image quality, with the focus on image noise, coronary wall definition, structure visibility, lumen interpretability, and image conspicuity. In addition, study interpretability was assessed. The Likert scale was defined as 1: excellent attenuation of the vessel lumen and clear delineation of the vessel walls, excellent enhancement of small structure visibility, limited perceived image noise, no artefacts; 2: good, impact of image noise, limitations of low contrast resolution and vessel margin definition are minimal, minor artefacts not interfering with diagnostic decision-making; 3: adequate, reduced image quality with poor vessel wall definition or excessive image noise, limitations in low contrast resolution remain evident, major artefacts affecting visualization of major structures; and 4: poor, impaired image quality limited by excessive noise or poor vessel wall definition, artefacts affecting diagnosis. The following artefacts were assessed: streak artefacts due to metals and leads, blotchy pixilated, blooming artefacts, and attenuation artefacts. Subsequently, each stent was evaluated for patency which was visually graded according to the proportion of the stent lumen that showed no contrast enhancement: grade 1 = homogeneous enhancement with no lumen narrowing, indicating a patent stent; grade 2 = eccentric or concentric non-enhanced area between the stent and the contrast-enhanced lumen with a lumen decrease ≤50%—indicating a non-significant in-stent restenosis; grade 3 = non-enhanced area

Figure 2 Oblique CT image reconstruction of a left circumflex artery stent at incremental ASIR% [(A) 0%, (B) 20%, (C) 40%, (D) 60%, (E) 80%, (F) 100%].
within the stent leading to a reduction of the contrast-enhanced lumen >50%—indicating a significant in-stent restenosis; and grade 4 = no contrast enhancement within the stent, indicating stent occlusion.

**Statistical analysis**
Quantitative variables were expressed as mean ± SEM or mean ± SD, as appropriate, and categorical variables as frequencies or percentages. Normally distributed data were identified using the Shapiro–Wilk test. Comparisons between groups were performed using ANOVA for continuous variables with normal distributions and the Mann–Whitney U test for continuous variables with non-normal distributions. The Wilcoxon signed-rank test was used to analyse subjective image quality. A two-tailed P-value < 0.05 was deemed significant. All analyses were performed with statistics software (SPSS version 20.0 for Microsoft Windows). For every stent the mean stent volume, the signal and noise and SEM were calculated for all image reconstruction intervals separately.

**Results**

**Study population and radiation dose**
The study population consisted of 28 patients with a total of 50 stents (range: 1–4), including 3 women, with a mean age of 64 ± 10 years, a mean body mass index (BMI) of 26.9 ± 2.5 kg/m² (range 22–32 kg/m²), and a mean heart rate of 57.7 ± 6.9 bpm. The patient baseline characteristics are listed in Table 1. Clinical indications for a CCTA referral are summarized in Table 2. The mean interval between coronary stent implantation and CCTA was 3.4 ± 0.6 years. The effective radiation dose was 1.7 ± 0.6 mSv (range 1.1–3.4 mSv).

**Stent characteristics and location**
Fifty stents (42 drug-eluting stents (DESs) and 8 bare-metal stents (BMSs); 10 stents ≥ 3 mm diameter at implantation, 40 stents < 3 mm diameter at implantation) were analysed. Complete stent characteristics are shown in Table 2. Stents were located as follows: left main stem (n = 1), left anterior descending (LAD; n = 24), LCX (n = 8), in the right coronary (RCA; n = 11) artery, and in the side branches (n = 6; Table 2). The use of ASIR did not significantly change the coronary artery stent volume (P = NS, Figure 3B). In comparison with FBP, coronary artery stents showed both a larger maximal and minimal intraluminal diameter with ASIR. The maximal luminal diameter was (1.56 ± 0.6 mm at 0% ASIR, 1.63 ± 0.6 mm at 20% ASIR, 1.73 ± 0.6 mm at 40% ASIR, 1.74 ± 0.6 mm at 60% ASIR, 1.78 ± 0.6 mm at 80% ASIR, and 1.82 ± 0.6 mm at 100% ASIR; P < 0.05; Figure 6B and C, Table 3). Accordingly, the difference in the luminal diameter between stent implantation and the diameter measured by CCTA decreased with increasing proportions of ASIR (46 ± 14.9% at 0% ASIR, and 36.6 ± 16.0% at 100% ASIR; P = 0.005; Table 3). Similarly, with ASIR algorithms the stent length was decreased by 4.7 ± 0.9% compared with FBP algorithms (P = 0.002; Figure 6A). No significant difference was detected in the maximal luminal diameter of DESs compared with BMSs with increasing percentages of ASIR (data not shown). Further, at all levels of ASIR blending, no differences in the overall patency rate was noted when comparing DESs vs. BMSs (P = NS, Table 3). Significant in-stent stenosis (defined as luminal narrowing >50%) was detected in 42% of all stents analysed. In 50% of BMSs significant stenosis was detected and remained the same at all ASIR blending compared with 40.5% in DESs. However, in one DES, stenosis was interpreted to be non-significant at 80 and 100% ASIR by both readers, while at lower proportions of ASIR (0–60%) a significant in-stent stenosis was diagnosed (Table 3).

**Image noise**
Image noise was significantly reduced when the ASIR percentage increased (Figure 2). Noise measurements in a region of interest located in the ascending aorta and the stent lumen indicated a noise reduction from 49.7 ± 19.6 to 19.1 ± 11.1 HU and from 70.1 ± 27 to 47.4 ± 30 HU, respectively, between a standard FBP reconstruction (0% ASIR) and 100% ASIR (P < 0.001; Figure 4A) while the mean signal remained unchanged (P = NS, data not shown). There was a significant increase in the signal-to-noise ratio (SNR) with increased use of ASIR in both, descending aorta, and stent lumen (P < 0.001, Figure 4B). No differences were observed between DES and BMS for image noise and SNR (P = NS; data not shown).

**Image quality**
Image quality as assessed by the Likert scale showed a significant difference between groups, with the highest values noted for reconstructions using 40 and 60% ASIR (Figure 5). Thirty stents (60%) were of excellent and good image quality, 10 stents (20%) were of moderate image quality, and 10 stents (20%) were of poor image quality using FBP. The optimum structure visibility and, thus, the highest value of image quality were found with ASIR percentages of 40 and 60% when compared with the reference image (FBP only). The associated Likert scores were 1.82 (40% ASIR) and 1.8 (60% ASIR), while images reconstructed with 0, 20, and 100% ASIR were assigned to mean Likert scores of 2.56, 2.48, and 2.6, respectively. With ASIR percentages >80%, the visibility steadily decreased. Besides the severe noise-free effect present on all 80 and 100% ASIR images, anatomical details appeared to be affected by the formation of pixel clusters in these images (Figure 2). Also, structure outlines seemed to be less sharp than the reference images (0% ASIR) and images reconstructed with lower ASIR percentages. The overall image quality was classified to be good or excellent in 20/50 images using 20%
ASIR, 39/50 images using 40% ASIR, 39/50 images using 60% ASIR, 32/50 images using 80% ASIR, and 30/50 images using 100% ASIR (Figure 5). Calcifications were observed in 5/50 images (10%). The image quality was significantly ($P < 0.001$) worse if calcification was present, independent of the CT image reconstruction technique (data not shown). Most streak and high-density artefacts on FBP (ASIR 0%) were reduced on those with ASIR 40 and 60%, but were enhanced with ASIR 80 and 100% (Figure 2). Reasons for impaired image quality were partial volume artefacts in 81%, motion artefacts in 8%, and calcifications in 10%. Seventy-five per cent of patients with motion artefacts had heart rates $>65$ bpm (mean $57.7 \pm 6.9$ bpm). Lumen interpretability did not differ significantly from one stent location to another ($P = $ NS, data not shown).

When image quality was assessed vs. stent characteristics, no significant differences in image quality were detected between DESs and BMSs with increasing percentages of ASIR. Improved image quality was noted for stents with a diameter $\geq 3$ mm at implantation compared with stents $<3$ mm at implantation, however, this difference was not significant (Table 3).

Discussion

Evaluation of stent patency is important in the follow-up of patients after coronary artery stenting, as in-stent restenosis remains a dreaded complication.$^{14}$ However, the delineation of the coronary stent lumen by CCTA is challenging because of partial volume artefacts from the highly attenuated stent struts, which lead to artificial narrowing of the lumen.$^{15–17}$ Previous studies indicate that the intra-stent lumen cannot be interpreted in 7.3–42% of stents$^{2,18–22}$ due to severe blooming artefacts. A recent ex vivo study has reported that the ASIR image reconstruction techniques enhanced in-stent assessment while decreasing image noise.$^{23}$ An improvement of stent imaging with CCTA is of growing
importance due to its increasing use for this purpose. In fact, recent coronary revascularization guidelines specifically recommend a follow-up CCTA for patients with unprotected left main stenting.\textsuperscript{24}

Our results support that the use of ASIR substantially reduces image noise in vivo and improves stent diameter and area evaluation. Although the largest reduction in noise was observed with 100% ASIR, reconstruction with 40 and 60% ASIR appeared superior, which is reflected by the Likert value of 2.6 for FBP reconstructions improving to 1.82 for 40% ASIR and 1.8 for 60% ASIR. This is in line with previous reports from un-stented coronaries.\textsuperscript{25} Reconstructions with high proportions of ASIR were significantly different in appearance from traditional FBP, with a different noise texture, an artificial over-smoothing of the images and yielding a significantly ‘lower’ structure visibility than standard FBP. Accordingly, previous studies have raised concerns about the loss of anatomical details with 100% ASIR due to its aggressive noise reduction, the formation of pixel clusters and image over-smoothing.\textsuperscript{6} Moreover, it seemed that streak artefacts and high-density artefacts were more visible with 80 and 100% ASIR.

Coronary artery stents are difficult to image due to their high attenuation characteristics rendering stents susceptible to partial volume and beam-hardening artefacts.\textsuperscript{1,2,3} The present study suggests that these artefacts are diminished with 20, 40, and 60% ASIR compared with FBP offering best realistic appreciation of the true size and volumes of these high-density objects. In fact, measures of the luminal stent diameter and area increased by 42.1% with the use of 40% ASIR, whereas FBP reconstruction is more prone to blooming artefacts, which make the stent struts appear larger than they are in reality. As a consequence, artificial lumen narrowing is observed with standard FBP reconstruction, obscuring part of the stent lumen. ASIR reduces noise and allows the margin of the stent thrust to be seen more clearly. These effects appear to allow better delineation of the vessel lumen adjacent to high-density structures and result in an incremental improvement in the CT evaluation of heavily calcified coronary artery segments as well as of coronary artery stents. However, whether this may translate into higher accuracy in the assessment of in-stent restenosis or stenosis severity of calcified

\begin{table}
\centering
\caption{Stent characteristics}
\label{table:stent_characteristics}
\begin{tabular}{l|c}
\hline
Left main stem & 1 \\
LAD & 24 \\
CX & 8 \\
RCA & 11 \\
Diagonal branch & 5 \\
Intermedius branch & 1 \\
Model & \\
Resolute Integrity\textsuperscript{TM} & 11 \\
Cypher\textsuperscript{®} & 6 \\
Endeavour\textsuperscript{®} & 2 \\
Multilink VISION\textsuperscript{TM} & 2 \\
Nobori\textsuperscript{®} & 3 \\
XIENCE PRIME\textsuperscript{™} & 5 \\
Promus\textsuperscript{®} & 11 \\
PRO-Kinetic\textsuperscript{®} & 3 \\
BIOMATRIX\textsuperscript{TM} & 3 \\
Driver Sprint RX\textsuperscript{®} & 3 \\
Presillion\textsuperscript{TM} & 1 \\
DES (n) & 42 \\
BMS (n) & 8 \\
Mean diameter (mm) & 2.86 ± 0.5 \\
Diameter ≥3 mm & 10 \\
Diameter <3 mm & 40 \\
Mean strut thickness (mm) & 0.093 ± 0.003 \\
\hline
\end{tabular}
\end{table}

\begin{table}
\centering
\caption{Comparative performance for stent assessment}
\label{table:stent_assessment}
\begin{tabular}{l|c|c|c|c|c|c|c}
\hline
 & \textbf{At implantation} & \textbf{0\%} & \textbf{20\%} & \textbf{40\%} & \textbf{60\%} & \textbf{80\%} & \textbf{100\%} \\
\hline
Maximal diameter (mm) & 2.86 ± 0.5 & 1.56 ± 0.6 & 1.63 ± 0.6 & 1.73 ± 0.6 & 1.74 ± 0.6 & 1.74 ± 0.6 & 1.82 ± 0.6 \\
% change & 46 ± 14.9 & 43.2 ± 15.4 & 39.9 ± 15.8 & 39.6 ± 15.3 & 37.7 ± 15.8\textsuperscript{a} & 36.6 ± 16.0\textsuperscript{a} & \\
Patency (total) & 2.28 ± 1.0 & 2.26 ± 1.1 & 2.24 ± 1.1 & 2.24 ± 1.0 & 2.24 ± 1.0 & 2.24 ± 1.0 & 2.24 ± 1.0 \\
BMS (n = 8) & 2.5 ± 1.4 & 2.5 ± 1.4 & 2.5 ± 1.4 & 2.5 ± 1.4 & 2.63 ± 1.3 & 2.63 ± 1.3 & 2.63 ± 1.3 \\
DES (n = 42) & 2.24 ± 1.0 & 2.2 ± 1.0 & 2.2 ± 1.0 & 2.2 ± 1.0 & 2.17 ± 1.0 & 2.17 ± 1.0 & 2.17 ± 1.0 \\
Significant stenosis (>50\%) (%) & 42 & 42 & 42 & 42 & 40 & 40 \\
DES (n = 42) (%) & 40.5 & 40.50 & 40.50 & 40.50 & 38 & 38 \\
BMS (n = 8) (%) & 50 & 50 & 50 & 50 & 50 & 50 & 50 \\
Image quality & \\
Stent ≥3 mm (n = 10) & 2.53 ± 0.8 & 2.45 ± 1.0 & 1.78 ± 1.0 & 1.75 ± 1.0 & 2.33 ± 0.8 & 2.58 ± 0.9 & \\
Stent <3 mm (n = 40) & 2.7 ± 0.8 & 2.6 ± 1.0 & 2.0 ± 1.25 & 2.0 ± 1.1 & 2.3 ± 1.1 & 2.8 ± 1.0 & 2.8 ± 1.0 \\
DES (n = 42) & 2.5 ± 0.8 & 2.5 ± 0.8 & 1.75 ± 1.0 & 1.75 ± 0.7 & 2.38 ± 0.5 & 2.68 ± 0.6 & 2.68 ± 0.6 \\
BMS (n = 8) & 2.57 ± 0.9 & 2.48 ± 1.0 & 1.83 ± 1.0 & 1.81 ± 1.0 & 2.31 ± 0.9 & 2.55 ± 0.9 & 2.55 ± 0.9 \\
\hline
\textsuperscript{a}P < 0.05 vs. diameter at implantation.
\end{tabular}
\end{table}
lesions remains to be evaluated. Moreover, it is important to note that, although iterative reconstruction on an HDCT scanner provides improved stent visualization, this technique substantially underestimates actual stent sizes. Potential reasons include incomplete inflation during deployment, strut thickness, and stent angulation during CT measurement.

In our study, ASIR in combination with a high-definition acquisition protocol provided superior image quality and reduced noise in the setting of relatively low-dose and low tube current examinations. Similarly, previous normal or even high-dose studies performed with ASIR allowed image noise reduction and improved image quality, not otherwise possible with FBP reconstruction algorithms. Moreover, preliminary phantom and patient study indicated that dose reductions of up to 65% without a significant loss in image quality were possible using ASIR. Thus, ASIR not only reduces noise and improves image quality for standard or high-dose CT protocols, it also allows even more aggressive dose reduction with low-dose techniques. Thus, the use of ASIR protocols can efficiently work to improve image quality by reducing image noise and may ultimately permit further reduction in the current radiation dose in challenging scenarios such as the evaluation of stents.

Our study has several limitations, which have to be considered. All images were post-processed on the same workstation/software from one vendor to minimize the potential impact of different workstations/softwares on image quality. It has recently been shown that differences in reconstruction algorithms may introduce more variability than different scanners. Therefore, the applicability of these findings to scans obtained in other types of scanners from different vendors may be limited. A general, inherent limitation of all studies that compare iterative reconstruction with traditional FBP is that observers cannot be effectively blinded to the reconstruction technique because of the distinct differences in image characteristics between the two approaches. However, although 80 and 100% ASIR were associated with a Likert score indicating lower structure visibility, and thus lower image conspicuity
and quality, it was not possible in the present analysis to accurately determine whether this reconstruction could affect diagnostic confidence since no comparison with invasive coronary angiography, which serves as the standard reference, was conducted. Moreover, due to the lack of a reference standard, conclusion regarding the evaluation of the actual stent size and in-stent stenosis with the use of ASIR cannot be drawn from this study. Instead, we chose to evaluate the luminal area and diameter by ASIR to determine a proof of concept that enhanced spatial resolution and did indeed result in higher stent diameter and area visualization without increasing image noise. Future studies should evaluate the diagnostic accuracy of detecting in-stent restenosis with the use of ASIR. Finally, ASIR provided superior image quality in the present study; however, this was in the setting of relatively low-dose and low tube current examinations in a slightly overweight population with low heart rates. The applicability of these findings for patients with coronary artery stents who would otherwise have significant noise, such as severely obese patients or patients with high heart rates is uncertain and additional work is needed to evaluate the diagnostic performance of ASIR in these subpopulations.

In summary, our findings suggest that ASIR may be useful in CCTA evaluation of patients who underwent coronary artery stenting. ASIR 40 and 60% provides the best image quality, while higher percentages of ASIR blending are associated with more visible artefacts and lower image quality due to its aggressive noise reduction resulting in excessive blurring of anatomical structure outlines.

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**References**


![Figure 6](image-url)
A 60-year-old asymptomatic patient with a previous history of arterial hypertension and hyperlipidaemia presented in our centre for routine cardiology check-up. Transthoracic echocardiography revealed the presence of a large echoluent structure at the level of the right ventricle (RV), but suboptimal window made more detailed imaging of the structure difficult. For further evaluation of this finding, we performed transoesophageal echocardiography. This nicely depicted a giant aneurysm at the level of the right sinus of Valsalva with maximum diameter (aortic root excluded) $\approx 5$ cm (Panels A and B showing short-axis and long-axis views, respectively, An, aneurysm and Ao, aorta). The RV itself appeared dilated and hypokinetic. Moreover, the turbulent flow at the level of the right ventricular outflow tract (RVOT) during systole was detected with colour Doppler, clearly suggesting RVOT obstruction (arrow in Panel C). Continuous wave Doppler interrogation at the site of the obstruction revealed an RVOT gradient of 25–30 mmHg, whereas through the tricuspid regurgitation Doppler signal the RV systolic pressure was estimated 45–50 mmHg. Subsequently, contrast-enhanced computed tomography of the aortic root was performed using a 64-slice scanner. This confirmed the presence of the aneurysm of the right sinus of Valsalva, demonstrating the protrusion of the aneurysm towards the RV and the narrowing of the RVOT (arrow in Panel D; An, aneurysm and Ao, aorta). The right coronary artery was patent and originated just above the aneurysm. The patient opted for elective aneurysm repair.