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# Non-invasive 16-row multislice CT coronary angiography: usefulness of saline chaser

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**Abstract** The aim of this study was to investigate the usefulness of saline chaser in 16-row multislice CT (16-MSCT) coronary angiography. Forty-two patients were divided into two groups for contrast material (CM) administration: group 1 (140 ml at 4 ml/s) and group 2 (100 ml at 4 ml/s followed by 40 ml of saline chaser at 4 ml/s). All patients underwent retrospectively ECG-gated 16-MSCT coronary angiography. The attenuation at the origin coronary vessels was assessed. Three regions of interest (ROIs) were drawn throughout the data set: (a) ascending aorta (ROI 1); (b) descending aorta (ROI 2); and (c) pulmonary artery (ROI 3). The attenuation in the superior vena cava was recorded (ROI 4). The average attenuation and the slope were calculated in each ROI and differences were assessed with a Student's *t* test. The average attenuation in the coronary vessels was not significantly different in the two groups. The average attenuations in ROI 1 were 325 and 327 HU, in ROI 2 were 328 and 329 HU and in ROI 3 were 357 and 320 HU, for groups 1 and 2, respectively ($p>0.05$). The slopes in ROI 1 were −0.2 and 1.1, in ROI 2 were 2.8 and 2.1 ($p>0.05$) and in ROI3 were 3.9 and −9.0 ($p<0.05$), for groups 1 and 2, respectively. The average attenuations in ROI 4 were 927 and 643 HU ($p<0.05$), for groups 1 and 2, respectively. One hundred milliliters of CM with 40 ml of saline chaser provides the same attenuation as 140 ml of CM (35% less) with decreased hyper-attenuation in the superior vena cava.

**Keywords** 16-row multislice CT · Bolus chaser · Coronary angiography · Contrast material

## Introduction

Multislice-CT scanners with 16 rows of detectors (16-row MSCT) and increased spatial and temporal resolution have been introduced [1, 2, 3]. The increased number of detector rows and gantry rotation speed reduce the time needed to scan the coronary arteries to <20 s [3]. Early experiences reported improved results in the visualisation of coronary arteries and in the detection of coronary artery disease [3, 4, 5, 6].

The shorter scan time, provided by 16-row MSCT, allows to decrease the volume of contrast material (CM) needed for CT coronary angiography (CTA) [7]. Moreover, bolus-tracking technique can be easily applied which allows a better synchronisation of the CTA scan with contrast material passage [4, 7, 8, 9, 10, 11, 12].

The use of a saline solution injected intravenously immediately after the CM main bolus, also known as bolus chaser, has been reported to allow a significant reduction of CM volume with vascular attenuation comparable with the one obtained with larger volumes of CM [13, 14, 15]. It is expected that the use of bolus chaser also allows CM volume reduction in MSCT coronary angiography [16, 17, 18].

The aim of this study was the comparison of a "conventional" CM protocol without bolus chaser with a "low-volume" protocol with bolus chaser in non-invasive 16-row MSCT coronary angiography.

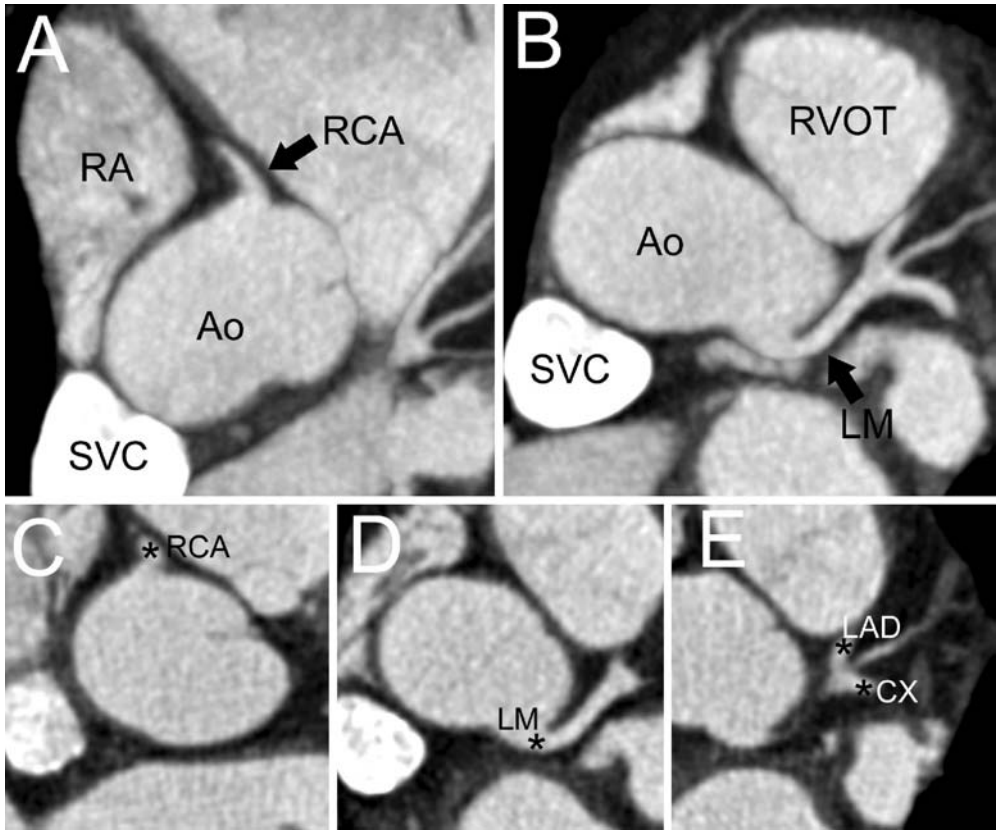



**Fig. 1A–E** Assessment of attenuation at the origin of coronary vessels. In **A** and **B** two oblique para-axial maximum intensity projection reconstructions show the ascending aorta (*Ao*), the origin of the right coronary artery (*RCA*; *arrow*) and left main coronary artery (*LM*; *arrow*). The superior vena cava (*SVC*) is also shown with very high attenuation. The assessments of attenuation at the origin of the main coronary arteries are performed for RCA (*asterisk*), for LM (*asterisk*), for the left anterior descending (*LAD*; *asterisk*) and for the circumflex (*CX*; *asterisk*) as shown in **C**, **D** and **E**, respectively. *RA* right atrium, *RVOT* right ventricle outflow tract

## Materials and methods

### Patient population

In November and December 2002, 42 patients (30 men and 12 women; mean age 59 years, age range 34–79 years), undergoing non-invasive MSCT coronary angiography for suspected coronary artery disease were prospectively enrolled in the study. Exclusion criteria for coronary CTA were irregular heart rates, previous allergic reaction to iodine contrast media, renal insufficiency (serum creatinine >120 mmol/l), pregnancy, respiratory impairment, unstable clinical status, or marked heart failure. The Institutional Review Board approved the study and patients gave informed consent.

After enrollment, patients were randomly divided into two groups with different protocols for intravenous contrast material (Visipaque 320 mg I/ml, Amersham Health, Little Chalfont, UK) administration: group 1 (conventional) 140 ml administered at 4 ml/s and group 2 (low-volume) 100 ml at 4 ml/s followed by 40 ml of saline at 4 ml/s. In each patient, age, body weight and heart rate were recorded.

### Multislice-CT scan

Prior to the examination, the patients' heart rate (HR) was measured. Patients with a pre-scan HR ≥65 bpm were given 100 mg of metoprolol per os 1 h before the scan.

The scan parameters for MSCT coronary angiography (Sensation 16, Siemens, Forchheim, Germany) were: number of detectors 12; individual detector width 0.75 mm; gantry rotation time 420 ms; 120 kV; 400–500 mAs; feed/rotation 2.8 mm; and scan direction cranio-caudal. The heart rate during the scan was also recorded.

### Contrast material administration and synchronisation protocols

The iodinated CM was administered intravenously using a prototype of double-head power injector (Stellant, MedRAD, Pittsburgh, Pa.) through an 18-G venflon in the antecubital vein. Two different injection protocols were applied.

Synchronisation between the passage of CM and data acquisition was achieved with real-time bolus tracking (CARE bolus, Siemens, Forchheim, Germany) using an ROI in the ascending aorta for monitoring a threshold of +100 HU above the baseline attenuation to trigger the scan.

### Data collection

Two data sets were reconstructed using retrospective ECG gating with time window starting 400 ms before the next R wave. The first data set was reconstructed for the purpose of coronary artery attenuation assessment with effective slice width 1 mm, reconstruction interval 0.5 mm, field of view (FOV) 160 mm and convolution filter medium smooth. The second data set was reconstructed for the purpose of great thoracic vessel assessment with effective slice width 3 mm, reconstruction interval 3 mm, FOV 200 mm and convolution filter medium smooth.

### Coronary artery attenuation

Axial slices in the data set were scrolled to find the best location to measure the attenuation at the origin of the main coronary arteries (Fig. 1): left main coronary artery; left anterior descending; circumflex artery; and right coronary artery (RCA). The ROI was

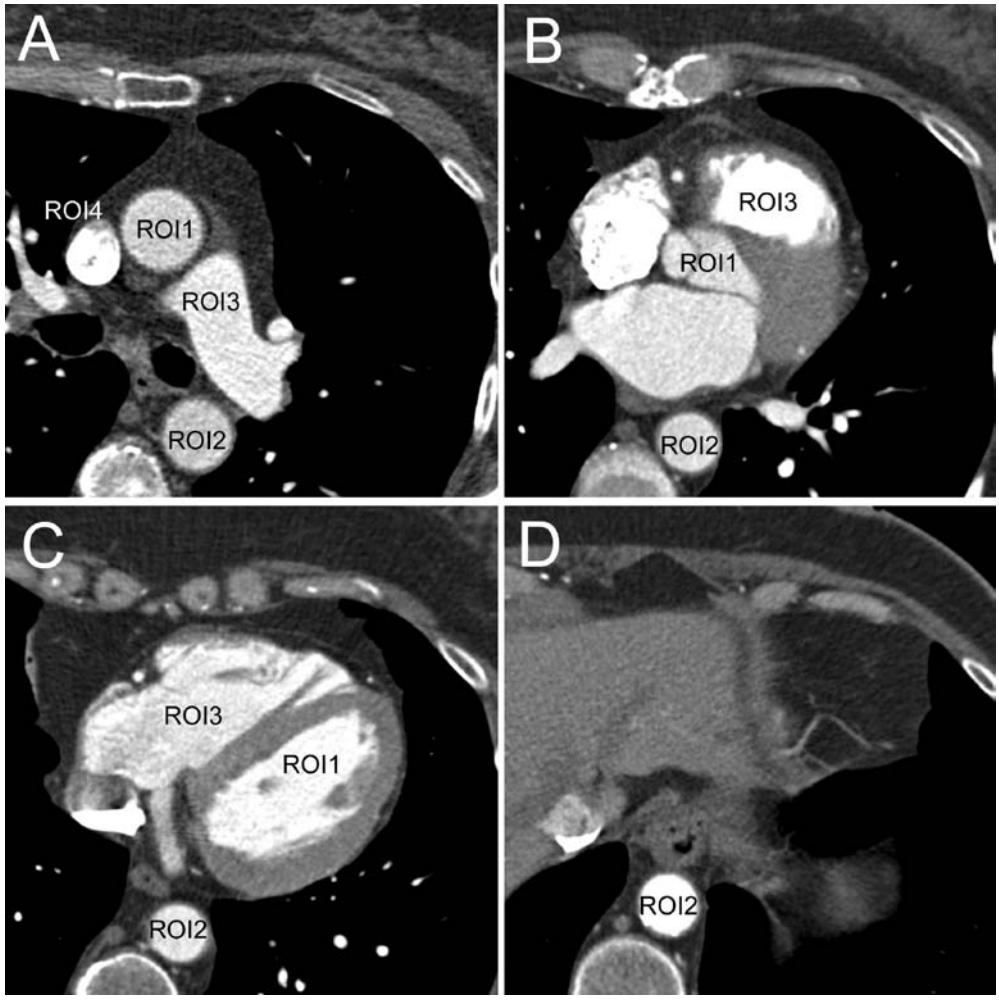



**Fig. 2A–D** Assessment of bolus geometry through the data set. The assessment of bolus geometry in the great vessels of the thorax have been performed using four regions of interest (ROIs). **A, B** The first (*ROI1*) is located in the ascending aorta at the beginning of the scan, whereas **C** the second part follows the path of the contrast material into the left ventricle. **A–D** The second ROI (*ROI2*) is located in the descending aorta all through the data set. **A** The third ROI (*ROI3*) is located in the pulmonary artery at the beginning of the scan, and then **B** follows into the right ventricle outflow tract and **C** into the right ventricle. The fourth ROI (*ROI4*) is plotted into the superior vena cava at the beginning of the scan

drawn as large as possible and calcifications, plaques and stenosis were carefully avoided.

### Bolus geometry of great vessels

The attenuation in Hounsfield units was measured in three arteries drawing a ROI in consecutive slices (at intervals of ~1 s.) through the data set (Fig. 2): (a) the ascending aorta–left ventricle (ROI 1); (b) the descending aorta (ROI 2); and (c) the pulmonary artery–right ventricle (ROI 3). In addition, the attenuation inside the superior vena cava (ROI 4) at the beginning of the scan (e.g. first slice of the data set) was recorded. Time-related contrast measurements for each vessel, which were available in all patients, were included in the study to maintain homogeneous results.

### Data analysis

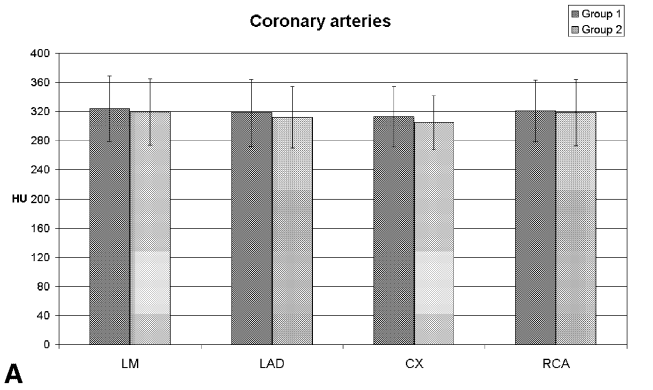
The attenuation values obtained from the three ROIs in each patient were averaged at each time point to generate the average time/density curves. Bolus geometry was described by two parameters, which represented quantitatively, the amount of CM present in the vessel during the scan (average attenuation) and the pattern of enhancement in the vessel (slope of attenuation). Three additional parameters were considered descriptive of bolus geometry: the attenuation value at the beginning of the scan (time 0), the maximum enhancement value (MEV; the peak of attenuation) and the time to reach the MEV (tMEV). Significant differences between the two groups were assessed using Student's *t* test. A $p$ value $<0.05$ was considered significant.

## Results

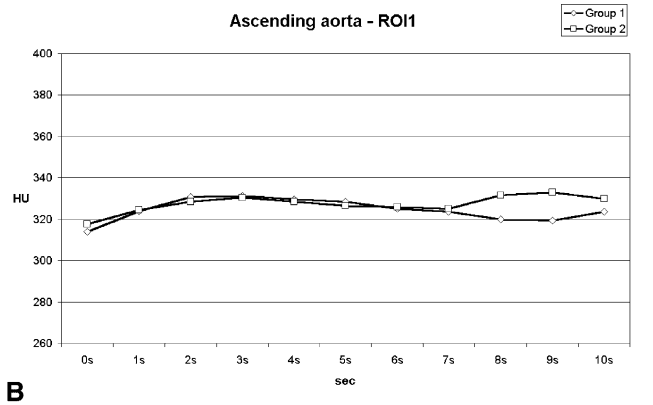
Scans and bolus timing procedures were successfully completed in all patients. No significant adverse reactions to CM were observed. Age, weight, mean heart rate during the scan, mean scan delay and mean scan time were not significantly different in the two groups (Table 1).

### Coronary artery attenuation

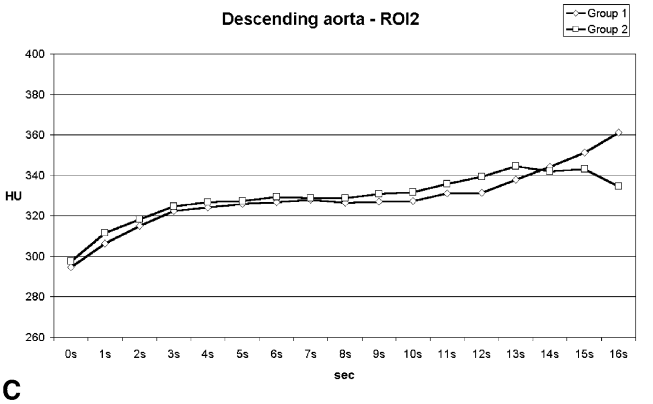
The attenuation at the origin of the four main coronary vessels was higher in group 1, but there was not a significant difference between the two groups (Fig. 3A; Table 2).




A




B

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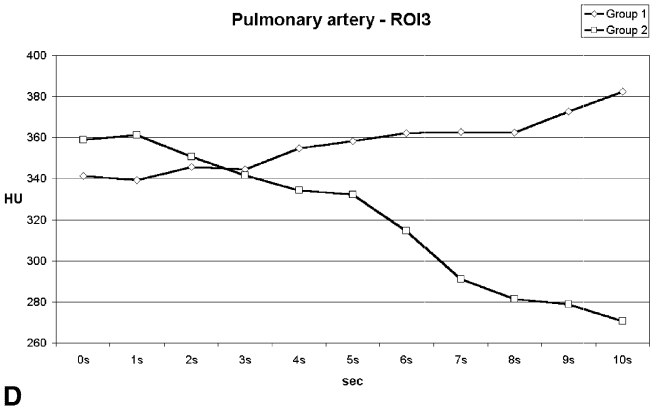


D

## Ascending aorta–left ventricle

The average attenuation and the slope were slightly higher in group 2 but not significantly different ($p>0.05$; Fig. 3B; Table 3). The attenuation values at time 0, the MEV and the tMEV were slightly higher in group 2 but not significantly different ($p>0.05$).

## Descending aorta

The average attenuation and the slope were slightly higher in group 2 but not significantly different ($p>0.05$; Fig. 3C; Table 3). The attenuation values at time 0 and the MEV were slightly higher in group 2 but not significantly different ($p>0.05$). The tMEV was significantly higher in group 1 ($p<0.05$).

**Table 1** Patient data

| | Group 1 | Group 2 |
|---|---|---|
| No. of patients | 21 | 21 |
| Male/female | 16/5 | 14/7 |
| Mean age (years)[a] | 59 (34–74) | 59 (39–79) |
| Mean weight (kg)[a] | 72 (53–90) | 74 (60–95) |
| Mean heart rate (bpm)[a] | 60 (48–72) | 60 (49–80) |
| Mean scan delay (s) | 21.5±1.7 | 20.9±2.3 |
| Mean scan time (s) | 17.9±0.9 | 18.2±1.6 |

No significant differences were detected between the two groups ($p>0.05$)
[a] Range in parentheses

**Table 2** Coronary vessel attenuation. *LM* left main, *LAD* left anterior descending, *CX* circumflex, *RCA* right coronary artery

| | Group 1 | Group 2 |
|---|---|---|
| LM | 324±45 | 319±46 |
| LAD | 318±46 | 312±42 |
| CX | 313±41 | 304±37 |
| RCA | 321±42 | 319±46 |

Measurements are in Hounsfield units
The mean density (±SD) at the origin of coronary vessels for group 1 (conventional 140-ml protocol) and group 2 (low-volume protocol with bolus chaser) shows no significant differences ($p>0.05$)

**Fig. 3A–D** Results of attenuation assessment of coronary arteries and great thoracic vessels. **A** The results of the attenuation assessment at the level of coronary arteries show slightly lower values for group 2 but not significantly different in all four sample regions. **B, C** The average time/density curves in the ascending aorta and descending aorta are almost identical for groups 1 and 2. **D** For the pulmonary artery, instead, group 1 shows more "pooling" of contrast material in the right chambers of the heart

**Table 3** Bolus geometry in the great vessels of the thorax. *MEV* maximum enhancement value, *tMEV* time to reach the MEV

| | Ascending aorta | | | Descending aorta | | | Pulmonary artery | | | Superior vena cava | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Group 1 | Group 2 | *p* value | Group 1 | Group 2 | *p* value | Group 1 | Group 2 | *p* value | Group 1 | Group 2 | *p* value |
| Average (HU) | 325±39 | 327±48 | >0.05 | 328±49 | 329±55 | >0.05 | 357±73 | 320±81 | >0.05 | 927±89 | 643±170 | <0.05 |
| Slope | –0.2 | 1.1 | >0.05 | 2.8 | 2.1 | >0.05 | 3.9 | –9.0 | <0.05 | – | – | – |
| Time 0 (HU) | 314±36 | 318±48 | >0.05 | 295±32 | 298±44 | >0.05 | 341±62 | 359±67 | >0.05 | – | – | – |
| MEV (HU) | 350±40 | 356±56 | >0.05 | 373±64 | 374±79 | >0.05 | 422±74 | 409±88 | >0.05 | – | – | – |
| tMEV (s) | 4.2±1.7 | 5.4±3.1 | >0.05 | 14.0±3.0 | 10.7±4.4 | <0.05 | 6.4±3.5 | 2.8±3.0 | <0.05 | – | – | – |

The quantitative parameters of bolus geometry for the main vessels of the thorax are displayed for group 1 (conventional 140-ml protocol) and group 2 (low-volume protocol with bolus chaser)

Pulmonary artery–right ventricle

The average attenuation was higher in group 1 but not significantly different ($p>0.05$; Fig. 3D; Table 3). The slope, instead, was significantly higher in group 1 ($p<0.05$). The attenuation values at time 0 and the MEV were not significantly different between the two groups ($p>0.05$). The tMEV was significantly higher in group 1 ($p<0.05$).

Superior vena cava

The average attenuation was significantly higher in group 1 ($p>0.001$; Table 3).

## Discussion

With the new generation of MSCT scanners featuring 16 rows of detectors, the time needed to scan the heart for the purpose of coronary CTA has been reduced to ~20 s [1, 2, 3, 4, 5]; yet, no studies have been performed on the optimisation of CM administration in non-invasive coronary imaging with MSCT.

We compared a conventional CM protocol for non-invasive MSCT with a low-volume protocol adding the pushing and washout effects of a bolus chaser. The two protocols showed comparable attenuation values at the level of coronary arteries and similar bolus geometry in the ascending and descending aorta. A significant difference was observed at the level of pulmonary artery where more "pooling" of CM was present for the conventional protocol. This observation is confirmed by the significantly lower attenuation observed in the superior vena cava for the low-volume protocol and supports the conclusion that 100 ml of CM pushed by 40 ml of saline provide optimal coronary artery enhancement with less attenuation in the right cavities of the heart. This result can be beneficial for a better visualisation of the mid-tract (segment 2) of RCA that may suffer from beam-hardening artefacts when highly concentrated CM is present in the right atrium and right ventricle. This effect can be a drawback when cardiac masses need to be studied. In this case a conventional CM protocol must be used.

The attenuation at time 0 and the MEV were not significantly different between the two protocols. The tMEV, instead, was significantly longer in the descending aorta (~3.2 s) and significantly shorter in the pulmonary artery (~3.6 s), for the conventional protocol. We have no clear explanation for the differences detected at this level.

Previous experiences with bolus chaser support the evidence that the same results, in terms of vascular and parenchymal attenuation, can be achieved using less CM volume (up to 20–40% less) and with a concomitant reduction of the artefacts at the level of superior vena cava [13, 14, 15, 19].

The explanation may be that a saline chaser pushes the injected CM through the veins of the forearm which will give the same result as the injection of a larger contrast volume, and that the saline chaser prevents the decrease of the contrast material flow in the arm veins which may normally cause an increase in the CM concentration after the end of the contrast injection [7].

A limitation of this study is that the evaluation of coronary vessels could have been completed by the assessment of the length of coronary artery visualisation and/or the number of side branches visualised. We did not perform this evaluation because of the variable diameter of coronary arteries, heart rate and the degree of vessels with atherosclerotic disease (soft and calcified lesions, vessel stenosis and vessel occlusions). These parameters severely affect the capability of visualisation of the vessel regardless of the performance of the protocol for CM administration (e.g. the attenuation inside the vessel), and the number of patients enrolled in our study was not large enough to account for these variables.

## Conclusion

In conclusion, the integration of bolus chaser in the CM administration protocol for non-invasive coronary artery angiography with 16-row MSCT allows to preserve the optimal intra-vascular attenuation, decreasing the volume of CM (35%) and the hyper-attenuating superior vena cava and right heart, with resulting cost savings and decreased risk of CM nephropathy.

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