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Initial Evaluation of Coronary CT Angiography Image Quality on the Revolution CT System

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INITIAL EVALUATION OF CORONARY CT ANGIOGRAPHY IMAGE QUALITY ON THE REVOLUTION CT SYSTEM

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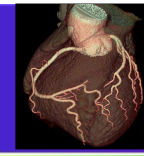

INTRODUCTION

- **BACKGROUND:** CT Perfusion allows for the evaluation of myocardium in particular for the detection of ischemia and infarction. Previous studies have, however, described beam hardening artifacts within the myocardium, which may have an effect on identifying true perfusion defects. Larger or volume detector CT scanners have shown promise in reducing myocardial heterogeneity but have been limited by cone beam artifacts and lower gantry rotation speeds. We sought to evaluate the performance of a new volume CT scanner (Revolution CT, GE Healthcare) enabled with novel wide cone reconstruction software (Volume HD reconstruction) and improved temporal resolution with regards to image quality and signal homogeneity.

METHODS

DESIGN AND SETTING

- Study Groups Prospective enrollment of 24 subjects was performed from May 2013 to November 2013. This study was approved by IRB. All 24 patients provided informed consent. Inclusion criteria were: 18 years or older not requiring acute care, without allergies to iodinated contrast media, and without renal insufficiency. Women less than 60 years of age were confirmed to be nonpregnant.
- All 24 patients had both a volumetric CCTA study (Revolution CT scanner) for research purposes after having undergone a prior clinical 64-slice CCTA (64- Slice CT scanner). The 64-slice CCTA scan may have been performed at a prior time point within a few weeks or months. This made for an in person comparison of 24 subjects which formed our analysis.

CCTA SCAN PROTOCOLS AND IMAGE RECONSTRUCTION

- The CT images from the large detector scanner were acquired in one heart cycle with a volumetric coverage of 16 cm (256 slice CT x 0.625mm) (Revolution CT, GE Healthcare) and a gantry rotation speed of 0.28 sec/rotation. Images were reconstructed with Volume HD reconstruction and next generation iterative reconstruction technology, (ASIR-V Adaptive Statistical Iterative Reconstruction, GE Healthcare, Milwaukee, WI) (Table 1). Compared to past generations of iterative reconstruction, the version being validated in our analysis includes more advanced noise and object modeling.
- All CT acquisitions with the Volumetric CT scan were axial prospectively triggered CCTA with different acquisition windows dependent heart rate. Motion correction software (SnapShot Freeze, GE Healthcare) was selectively applied only if motion was present.
- Patients were given an injection of 60 cc of contrast in the first phase, followed by 20 cc of contrast and 30 cc of saline in the second phase and completed by 50 cc of saline. Effective radiation dose was calculated by multiplying dose-length product with the conversion factor for Cardiac CT examinations (0.014 mSv/mGy•cm)5.

QUANTITATIVE ANALYSIS (SIGNAL INTENSITY, NOISE AND CONTRAST)

- The post-processing analyses were performed on an offline three-dimensional workstation. Multiplanar reconstructions of the left ventricular chamber at 5 mm thickness were created. Quantitative measures of image quality were performed in the myocardium, blood pool and aorta. Six Region of Interest (ROI) measurements were made across the myocardium in each of the Volume CT image sets as well as in the 64-slice CT image sets (Figure 1).
- An ROI of the myocardial wall was obtained, which ranged between 0.1cm2 and 0.2cm2. These measurements were made in the following regions: base-anterior, base-inferior, mid-anterior, mid-inferior, apex-anterior, apex-inferior. The same technique was used to assess blood pool with three ROI measurements made in the left ventricular chamber at the base, mid and apex of the heart in each of the Volume CT as well as the 64-slice CT image sets.
- Unlike the smaller ROI in the myocardial wall, a larger maximum ROI ranging between 1cm2 and 4cm2 was utilized to assess the most possible blood pool. ROI measurements ranging between 1cm2 and 2 cm2 were made in the aorta in each of the Volume CT image sets as well as the 64-slice CT image sets.
- These measurements were obtained in one session by a single radiologist (RR, 3 years of post-fellowship experience) manually placing a circular region of interest at each anatomic site mentioned above. For a given ROI, signal-to-noise ratio (SNR) was calculated by dividing the mean CT number within the ROI divided by the standard deviation from the mean value within the ROI.
- The variation in mean values across multiple ROI was quantified by the Coefficient of Variation (CV). This value is calculated by dividing the standard deviation of the mean CT numbers across multiple ROI by the mean of the mean CT numbers. The CV metric normalizes relative contrast volume and opacification differences from patient to patient, which do not reflect the performance of the scanner itself.

METHODS (CONT'D)

QUALITATIVE ANALYSIS

- All Volumetric and 64-Slice CCTA scans were subjectively evaluated by one experienced Level 3 CCTA reader (DM) with 3 years of post-fellowship experience, on an offline workstation (AW 4.3–4.4 Advantage Workstations; GE Healthcare). The CT reader was blinded to the image acquisition protocols. All scans were graded using a modified Likert scale.
- An overall image quality score was assigned to each coronary CTA, which takes into account the degree of contrast enhancement in the coronary arteries and the presence of image noise and motion artifact.
- A separate image quality score was assigned to the coronary arteries on a per-segment basis. Dichotomization of the five-point Likert Scoring system was performed by grouping scores of 1 and 2 into the "non-diagnostic" category and scores of 3, 4, and 5 into the "diagnostic" category. A Likert score of 1 was non-diagnostic with impaired image quality that precluded appropriate evaluation of the coronary arteries due to severe image noise, or poor signal or had severe motion artifact.

STATISTICAL ANALYSIS

- Analyses were performed using statistical software (SAS version 9.1; SAS Institute, Cary, NC, USA). A statistically significant difference was defined as a p value (two-tailed) less than 0.05.
- Continuous variables were expressed as median ± standard deviation, or quartile ranges. In the quantitative analyses, the median coefficient of variance (CV) and standard deviation of the CV were calculated across all Volume CT images and all 64-slice CT images.
- The difference in the median CV in the blood pool, myocardium, and aorta respectively in the Volume CT and 64-slice CT images was tested utilizing Mann-Whitney test. Similarly, the median, SI, Noise and SNR in each region of the myocardium and blood pool was calculated.
- Differences in quantitative measures of image quality (Signal Intensity, Noise and SNR) were tested between the Volume and 64-Slice CT image sets.
- A two-sided t-test was applied when the distribution of data from the Volume and 64-Slice CT image sets were of equal variance, and Welch–Satterthwaite Students t test was used when unequal variance was found.

RESULTS

- Heart Rate The median heart rate of patients undergoing the Volume CT was 60 bpm ± 10 SD (range=49-86). The median heart rate for patients undergoing 64-Slice CT was 57 bpm ± 6 SD (range=44-65). There was a significant difference in heart rate between the Volume and 64-slice CCTA (p=0.036). Motion correction algorithm was applied at the time of the scan acquisition in 11 of 24 subjects. Radiation Dose Median effective dose for the Volume CT studies was 2.06 mSv ± 0.87 (median ± SD) and for the 64-Slice CT images was 3.79 mSv ± 5.76.
- On the 64 slice platform, 8 patients had retrospectively gated scans and 16 had prospectively triggered CCTA. Median dose for the retrospectively gated CCTA was 11.46 ± 5.74 (median ± stdev) and median dose for the prospectively triggered CCTA was 4.74 ± 1.26. As expected, there was a significant difference in the radiation dose between those who had retrospectively gated scans from prospectively triggered CCTA (p=0.002)

- Quantitative Analysis The distributions between the CV in the Volume and 64-Slice CCTA were significantly different in each of the myocardium (0.097, 0.080-0.125 vs 0.138, 0.116-0.183, p=0.0012), blood pool (0.016, 0.009-0.024 vs 0.058, 0.047-0.075, p<0.001) and aorta (0.013, 0.008-0.019 vs 0.049, 0.033-0.077, p<0.001)
- Measurements of Signal Intensity were not statistically significant in the 64-slice CCTA and Volume CCTA at all the measured region of interest at the anterior and inferior wall at the base, mid and apical portion of the left ventricular chamber. Measurements of noise were statistically significant at all the abovementioned region of interest (Table 4). Improvement of SNR is statistically significant at all the measured ROI at the anterior and inferior wall of the left ventricular wall at the base, mid and apex of the heart within the Volume scans compared with the prior 64-slice CCTA (Table 5).

The Volume CT scanner showed a higher SNR as compared to 64-slice CT scanner for all anatomical segments evaluated (p<0.001).

- Qualitative Analysis Improvement in image quality was observed at a per-patient as well as per segment level. Overall Likert score was 4.5±0.7 and 3.7±1.2 for Volume CT and 64-slice CCTA, respectively (p<0.001) Significant image quality improvement was observed in multiple segments; proximal Right Coronary Artery (pRCA), mid Right Coronary Artery (mRCA), mid Left Anterior Descending artery (mLAD), distal Left Anterior Descending artery (dLAD), first Obtuse Marginal branch (OM1), distal Circumflex artery (dCx), second Obtuse Marginal branch (OM2), p<0.05) (Table 6). In terms of image quality, 346 of the 432 segments (80.1%) were classified as having good image quality in the Volume CT image set, compared to 299 of the 432 segments (69.2%) for the 64-slice CCTA image set (p < 0.001).

RESULTS (CONT'D)

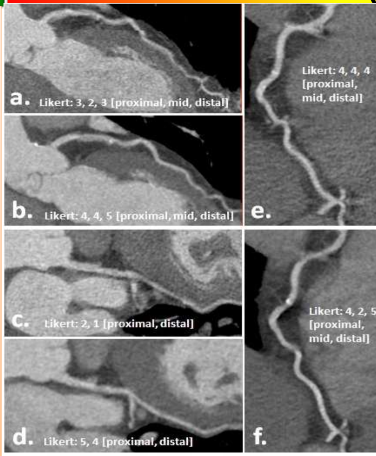

Figure 1

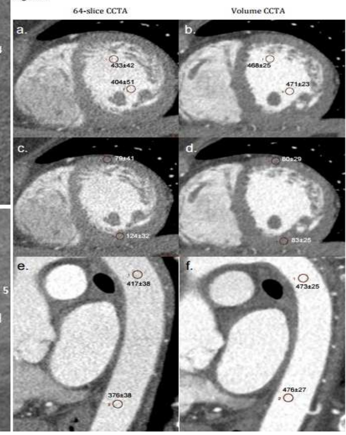

Table 5- Signal-Noise-Ratio (SNR) as a median +/- standard deviation at the base, mid and apex of the blood pool, and the base anterior, base inferior, mid anterior, mid inferior, apex anterior and apex inferior of the myocardium between Volume and 64 Slice CT. The p value has been calculated and is considered statistically significant if p < 0.05.

		Volume CT	64 Slice System	p*
		SNR (median ± stdev)	SNR (median ± stdev)	
Blood Pool n=24	Base	11.53 ± 2.59	6.68 ± 2.01	*p* < 0.001
	Mid	13.12 ± 3.73	7.00 ± 2.45	*p* < 0.001
	Apex	12.27 ± 4.13	7.90 ± 2.66	*p* < 0.001
Myocardium n=24	Base Anterior	3.062 ± 0.668	2.621 ± 0.470	p < 0.001
	Base Inferior	3.071 ± 0.889	2.0.49 ± 0.937	p = 0.003
	Mid Anterior	3.217 ± 0.691	2.217 ± 0.801	p < 0.001
	Mid Inferior	3.493 ± 0.972	2.339 ± 1.001	p = 0.006
	Apex Anterior	2.835 ± 0.901	1.926 ± 0.795	p < 0.001
	Apex Inferior	3.110 ± 1.313	2.339 ± 0.948	p = 0.002

*Welch's t-test

CONCLUSIONS

- CT Perfusion allows for the evaluation of myocardium in particular for the detection of ischemia and infarction. Previous studies have, however, described beam hardening artifacts within the myocardium, which may have an effect on identifying true perfusion defects. Larger or volume detector CT scanners have shown promise in reducing myocardial heterogeneity but have been limited by cone beam artifacts and lower gantry rotation speeds. We sought to evaluate the performance of a new volume CT scanner (Revolution CT, GE Healthcare) enabled with novel wide cone reconstruction software (Volume HD reconstruction) and improved temporal resolution with regards to image quality and signal homogeneity.